THE CLINICAL ASSESSMENT OF SYSTEMIC HYPERTENSION IN OPTOMETRIC PRACTICE

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Doctor of Philosophy

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THESIS SUMMARY

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This thesis sets out to examine in detail the condition of systemic hypertension (high Blood Pressure) in relation to optometric practice in the United Kingdom. Systemic hypertension, which is asymptomatic in the early stages, is diagnosed from the Blood Pressure (BP) measurement recorded by a sphygmomanometer and/or from the complications that have developed in target organs.

Optometric practice based surveys revealed that diagnosed systemic hypertension was the most prevalent cardiovascular medical condition (20.5%). Measurement of BP of patients in this sample revealed that if an optometrist included sphygmomanometry into the sight examination then at least one patient each day would be referred for suspect systemic hypertension.

Optometric opinion felt that the measurement of BP in optometric practice would advance the profession, being appreciated by both patients and GPs, but was felt to be an unnecessary routine procedure. The present sight examination for the systemic hypertensive is similar to that of the normotensive patient, but may involve an altered fundus examination and a visual field test. The GPs were in favour of optometric BP measurement and a future role in the shared care management of the systemic hypertensive.

The application of a new pictorial grading scale for the grading of vascular changes associated with pre-malignant systemic hypertension was found to be both accurate and reliable. Clinical trial of the grading scale in optometric practice found positive correlations between BP and increasing severity of the retinal vascular features.

The subtle pre-malignant vascular changes require reliable accurate detection and analysis to assist in the management of the systemic hypertensive patient. Vessel width was shown to decrease with increasing age. Image analysis of the A/V ratio, arteriolar tortuosity and focal calibre changes revealed a positive correlation to the patient's BP ($p<0.001$). The retinal vasculature is relatively stable longitudinally with only minor changes in response to early disease states. Age and elevated BP increased a patient's risk of developing systemic medical conditions over a two-year period.

The application of the pictorial grading scale to optometric practice and training the optometrist in the use of sphygmomanometry would improve the management of the systemic hypertensive patient in optometric practice. Future advances in image analysis hold substantial benefits for the detection and monitoring of subtle vascular changes associated with systemic hypertension.

Key Words: High Blood Pressure, Sphygmomanometry, Pictorial Grading Scale, Image Analysis.

To Mum and Dad.

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"There is a time for everything"

Ecclesiastes 3 v.1

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CHAPTER 1 - REVIEW OF SYSTEMIC HYPERTENSION AND THE EYE

1.10 - Introduction

Systemic hypertension (high blood pressure) is a silent killer that may have very few warning signs. It is asymptomatic until the complications in the target organs develop (Martin, 1994). The diagnosis is based upon a measurement that is influenced by factors such as time of day, stress, exercise, diet, age, and gender (Hayreh, 1996; Marshall and Malinovsky, 1998; Black *et al.*, 1999; Moore *et al.*, 1999). Although blood pressure (BP) can be easily measured indirectly by sphygmomanometry (Grundy, 1990) this reading does not indicate the degree of arterial wall degeneration and end organ damage (Black *et al.*, 1999). Hypotension (low BP) can also be damaging to the body (e.g. increased cardiovascular complications) and may be implicated in ocular disease such as low-tension glaucoma (Goldberg *et al.*, 1981; Farnett *et al.*, 1991).

The BP is affected by cardiac output, blood volume and peripheral resistance (Tortora and Anagnostakos, 1987) Systemic hypertension is the persistent elevation of the arterial blood against the wall of the blood vessel. This rise in BP is in response to an increase in peripheral vascular resistance due to a constriction of the arteriolar bed throughout the body (Terry, 1976). Systemic hypertension can be classified as either primary/essential (90-95%), which has no known cause, or secondary (5-10%) where the causative factor is known, eg: renal disease, toxaemia of pregnancy, endocrine or coarctation of the aorta (North, 1999). Arterial BP measurement is traditionally recorded as the systolic blood pressure (SBP) and diastolic blood pressure (DBP), as shown in Table 1.01.

The diagnosis of cardiovascular disease is complicated compared to a conventional illness for the dividing line between its presence and absence is determined by an arbitrary figure. The Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure has classified BP into groups according to measures of systolic BP and diastolic BP to aid its management (Table 1.02; J.N.C., 1997). Systolic BP is now thought to be a better diagnostic indicator of coronary heart disease, cardiovascular disease, heart failure, stroke and renal disease than is diastolic BP (Marshall and Malinovsky 1998; Black *et al.*, 1999). The BP level at which management is instigated may differ between patients, as treatment is dependent upon the patient's co-existing cardiovascular risk factors (Aylett *et al.*, 1999).

Systolic Blood Pressure: The pressure in the arteries when the contraction of the heart forces blood into them (at the height of pulsation). In a young adult it is approximately 120mmHg.

Diastolic Blood Pressure: The pressure in the arteries, maintained by the elastic recoil of the large arteries during cardiac relaxation. In a young adult it is approximately 80mmHg.

Pulse Pressure (PP): The difference between SBP and DBP.
PP is related to anatomical and functional changes occurring in the larger arteries (eg stiffening of the aorta, systemic hypertension), and may be a primary indicator of cardiac risk (Black *et al.*, 1999).

Mean Arterial Blood Pressure (MABP): The force against the blood vessel wall due to cardiac output and peripheral vascular resistance.
MABP = 1/3 PP + DBP.

Perfusion Pressure: The relative pressure gradient at the retinal blood vessel wall. MABP - IOP (Intra Ocular Pressure).

Table 1.01: Blood pressure terminology. (from Marshall and Malinovsky, 1998).

	Blood Pressure (mmHg)			
Category	**Systolic**		**Diastolic**	**Recommended Follow up**
Optimal	<120	and	<80	
Normal	<130	and	<85	Recheck in two years
High normal	130 – 139	and	85 – 89	Recheck in 1 year/provide lifestyle advice
Hypertension				
Stage 1	140 – 159	or	90 – 99	Confirm within 2 months/lifestyle advice
Stage 2	160 – 179	or	100 – 109	Evaluate/refer to care within 1 month
Stage 3	≥ 180	or	≥ 110	Evaluate/refer depending on clinical situation

Table 1.02: Blood pressure classification and management for adults (≥18 years): The 6th report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure (1997).

1.11 - Prevalence

The occurrence of high BP increases with age and its prevalence over the age of 40 years (taken as >160/90mmHg) in the United Kingdom is 10-15% of the population (Grundy, 1990). The prevalence is greater (~21%) in Afro-Caribbeans (Sharp *et al.*, 1995). The age related elevation of BP assists the involutionary sclerotic circulation system in maintaining an adequate peripheral circulation (Leishman, 1957). Malignant hypertension (>260/140mmHg) constitutes 5% of all systemic hypertensive cases (Grundy, 1990). Systemic hypertension in children is rare, (1-2%) and the health care practitioner is unlikely to measure the BP of a child with blurred vision and headaches (Logan *et al.*, 1992). Patients whose BP is in the high normal range in their twenties tend to go on to develop systemic hypertension by middle age. (Goldring and Chasis, 1944). In the diabetic population, 40% of type II diabetics are systemic hypertensive, rising to 60% by the age of 75 (UK Prospective Diabetes Study Group, 1998). The World Health Organization (WHO) have proposed that there are presently 600 million systemic hypertensives in the world, of which three million die annually as a direct result of systemic hypertension (World Health Organization, 1999). These individuals are more at risk from cardiovascular diseases, myocardial insufficiency, left ventricular hypertrophy, blood vessel damage resulting in arteriosclerosis, stroke and renal disease.

1.12 - Morbidity

The major risk factors for developing systemic hypertension are: hereditary factors, organic diseases, medicines and lifestyle (weight, diet, smoking, stress, emotional strain, alcohol consumption, and exercise). High BP is a major risk factor for cardiovascular disease and stroke, which are among the chief causes of death in developed countries (Marshall and Malinovsky, 1998). The mortality rates for systemic hypertensive patients compared to normotensives are increased in conditions such as: stroke (x7), heart attack (x4), coronary artery disease (x3) and peripheral arterial disease (x2; Kannel and Sorlie, 1975). Two thirds of systemic hypertensive patients will die of heart disease (Chasis, 1974). It is estimated that around 20% of mortality in the western world is due to cardiovascular disease associated with diastolic BP of 90-100mmHg (Hickey and Graham, 1988). Mortality (incidence of death) and morbidity (incidence of disease) can be reduced by early diagnosis and management of the systemic hypertensive patient for the remainder of their lives (Harris *et al.*, 1994). The longest life expectancy is associated with a BP of 100/60mmHg and decreases with increasing BP (Davis *et al.*, 1977). A 1mmHg rise in systolic BP is associated with a 1% rise in all causes of mortality (Silagy and McNeil, 1992).

1.20 - Treatment

The present treatment of mild-moderate systemic hypertension (Stage 1 – 2; Table 1.02) is initiated after a review of the patient's BP and associated medical history as opposed to the retinal lesions present (Dodson *et al.*, 1996). Treatment involves life long concordance between patient and doctor. With 90-95% of systemic hypertension being essential (idiopathic), treatment is empiric and mainly non-specific, aimed at reducing the pressure load of the heart (Hurst, 1978). Treatment can be: non-pharmacological, surgical and/or pharmacological.

1.21 - Non-Pharmacological Treatment

Non-pharmacological management of the mild hypertensive patient includes: career change (reducing stress levels / emotional tension), relaxation, weight reduction, reduction in alcohol consumption (although alcohol is a vasodilator and is encouraged in small amounts), regular mild exercise, change in diet (reduction in salt and saturated fat) and cessation of smoking (North, 1999).

1.22 - Sympathectomy

Sympathectomy (surgical division of sympathetic nerve fibres) lowers BP by denervating large areas of the vascular bed (e.g. splanchnic nerves), which reduces vasoconstriction and in turn vascular resistance. Patients considered for sympathectomy tend to be younger (<50 years), have a satisfactory renal function, are unable to take adequate medication (i.e. are allergic to the drugs or have failed to respond to the non-pharmacological therapy; Hurst, 1978). Pharmacological treatment following sympathectomy has a greater influence on BP. Advances in the pharmacological treatment of systemic hypertension has meant sympathectomy is now rarely performed.

1.23 - Pharmacological Treatment

Non-specific pharmacological management lowers a patient's BP, but neglects to treat the primary cause of systemic hypertension (Goldring and Chasis, 1944). There are six main classes of hypertensive drugs: diuretics, beta-blockers, angiotensin converting enzyme inhibitors, calcium antagonists, alpha-adrenergic receptor blockers and angiotensin II antagonists, Table 1.03. The prescribed drug will depend upon the co-existing medical conditions of the individual (e.g. glaucoma, asthma, pregnancy and diabetes mellitus) and previous toxicity to medications. The initial treatment of the asymptomatic hypertensive may, however, produce more symptoms than the disease itself (Davis *et al.*, 1977). A combination of two or more low dose anti-hypertensive medications can be more effective than monotherapy for reaching the target BP and has a lower risk of side effects (Black *et al.*, 1999).

1.24 - Treatment Outcome

The recurrence of strokes is not significantly reduced with anti-hypertensive therapy, so early diagnosis of systemic hypertension and preventative treatment is necessary (Hypertension Drug Co-operation Study Group, 1974). More aggressive regimes are applied if target organ damage is present (Dodson and Kritzinger, 1997). The target BP is lower in patients with diabetes mellitus (systemic hypertension accelerates the development of diabetic retinopathy) or renal disease with proteinuria. Reduction of BP to <140/90mmHg is only achieved in a quarter of hypertensive patients (J.N.C., 1997). Approximately three-quarters of hypertensives are at or below this diastolic level, but only one third are below the systolic level (Lapuerta and L'Italien, 1999). It is unusual for the cessation of all medication without the return of high BP (Hurst, 1978).

The therapeutic reduction of BP, which is associated with a reduced incidence of retinopathy, does not produce an immediate regression of retinopathy (Rutstein *et al.*, 1978; Klein *et al.*, 1997). Even with intense treatment a patient may experience intermittent hours of high BP, which may maintain or progress vascular lesions (Scarpelli *et al.*, 1977). The lowering of BP too drastically can be detrimental, inducing a rise in mortality and morbidity (J-shaped curve phenomenon; Fletcher and Bulpitt, 1992). A reduction of diastolic BP from 85mmHg to 75mmHg is associated with a doubling in the prevalence of cardiac events (Farnett *et al.*, 1991). A sudden and large reduction in the BP of a hypertensive, dropping the BP out of the autoregulation range, may induce vascular accidents, e.g. non-arteritic ischaemic optic neuropathy, which can cause complete blindness (Hayreh, 1986; 1996).

Despite long-term treatment of patients (<65 years old) with systemic hypertension resulting in a 40% drop in strokes and 14% drop in coronary heart disease rate (Collins, 1994), there is still a need for improved drug treatments to reduce systolic BP more effectively (Messerli *et al.*, 1997).

Hypertensive Drug	Site/Mode of Action
Diuretics	Increase in urination, which lowers salt and water retention, drop in circulating fluid volume reduces BP. Thiazides and related diuretics - sodium reabsorption inhibited in the initial distal convoluted tubule. Loop diuretics – reabsorption (active chloride transport) inhibited in the ascending limb of the loop of Henlé. Potassium sparing diuretics – retention of potassium, ammonium and tritratable acid and an increase in excretion of sodium chloride.
Beta-Adrenoceptor Blockers Adrenergic Inhibitors or sympathetic agents	Block the beta-adrenoreceptors in the heart and peripheral vasculature. Cardiac output is lowered by 18% and heart rate slowed. Baroceptor reflex sensitivity is altered.
Angiotensin Converting Enzyme Inhibitors Selective Antagonists	Inhibition of the chloride dependent converting enzyme essential for the conversion of angiotensin I to angiotensin II. Blood vessels relax.
Calcium Channel Blockers Calcium Antagonists, Adrenergic Inhibitors or sympathetic agents	Interfere with the entry of calcium ions through the slow channels of active cell membranes. Reduce myocardial (smooth muscle) contractility. Reduce peripheral vascular resistance through vasodilation.
Alpha Adrenergic Receptor Blockers Adrenergic Inhibitors or sympathetic agents	Block the action of circulating adrenergic constricting hormones (epinephrine and norepinephrine). Sympathetic nervous stimulation at peripheral receptor areas. No control of supine BP and may cause postural hypotension.
Angiotensin II Antagonists Selective Antagonists	Blocks angiotensin II (a vasoconstrictor). Blood vessels relax.

Table 1.03: Systemic hypertensive medication (Hurst, 1978; B.N.F., 2000).

1.30 - Ocular Anatomy

The structures of the vessels that carry the blood away from the heart are illustrated in Figure 1.01. The artery has three coats or tunica: interna (1) media (2) and externa (3). The contraction (vasoconstriction) of the vessel is due to the smooth muscle, which is innervated by the sympathetic branches of the autonomic nervous system. An increase in the number of sympathetic impulses induces vasoconstriction and a reduction in sympathetic impulses vasodilation. The anatomical change from an artery to an arteriole includes the gradual loss of the tunica externa, elastic fibres and a reduction in the amount of the smooth muscle. The vast majority of the arteries in the fundus are arterioles with a maximum diameter of 100μm. The few scattered smooth muscle cells on the arteriole permit regulation of the blood from the arteries to the capillaries.

Alterations in intraluminal blood flow (as found in systemic hypertension) have a greater effect on the arterioles as all the layers of the vessel wall depend on the diffusion of plasma constituents for nutrition (Davis *et al.*, 1977). The retinal vessels and optic nerve head lack sympathetic innervation, but possess autoregulation – a vessel's ability to maintain a constant blood flow and meet tissues' metabolic requirements under varying perfusion pressures (Chen *et al.*, 1994; Hayreh, 1996). The terminal arterioles, in response to a change in BP and perfusion pressure, constrict or dilate, to alter their vascular resistance and maintain a constant blood flow (Ramalho and Dollery, 1968; Hayreh, 1996). The diameter of the choroidal vessels is controlled by the sympathetic nervous system (Schmidt and Löffler, 1993).

The blood-retinal barrier (tight cell junction) stops the leakage of macromolecules from the retinal vessels (retinal endothelial cells) and from the blood vessels of the optic nerve head towards the interstitial space (Hayreh *et al.*, 1986). The Retinal Pigment Epithelium (RPE) cells stop the leakage of choroidal fluid into the retina. There is no blood-ocular barrier in the choroid or between the choroid and optic nerve head; therefore, fluid is able to leak freely from the choroid into the optic nerve head.

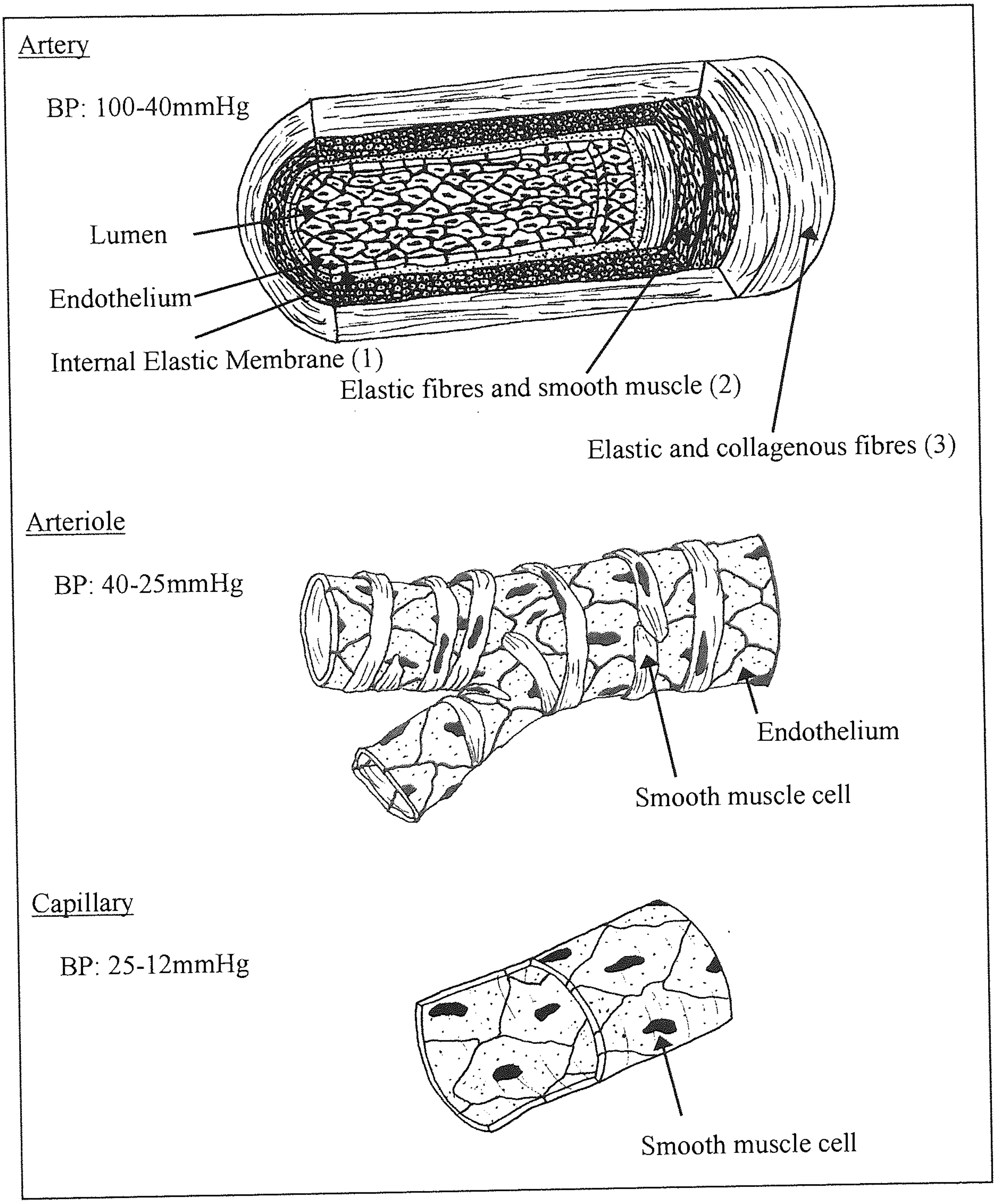


Figure 1.01: Structure of artery, arteriole and capillary.

(redrawn from Tortora and Anagnostakos, 1987).

1.31 - Autoregulation

Adapting to chronic malignant hypertension the range over which autoregulation operates will shift upward, offering improved protection at higher perfusion pressures, but less so for low BP, Figure 1.02 (Hayreh, 1989; 1996). Autoregulation becomes ineffective and breaks down when BP moves outside the critical range over which it operates (22-50% above the resting values; Davies *et al.*, 1991). Beyond the range of autoregulation, the arteriole cannot constrict any more and necrosis of the muscle wall results. There is also endothelial cell loss, dilation of arterioles resulting in a drop in arteriolar resistance, increase in blood flow and a focal disruption of the endothelium resulting in a breakdown of the blood retinal barrier (Hayreh *et al.*, 1985; Logan *et al.*, 1992). The increased pathological permeability of the blood retinal barrier in moderate systemic hypertension, which leads to the development of systemic hypertensive retinopathy, is reversible when the BP is controlled with medical treatment, but may be irreversible in long standing systemic hypertension (Ramalho and Dollery, 1968; Krogsaa *et al.*, 1983).

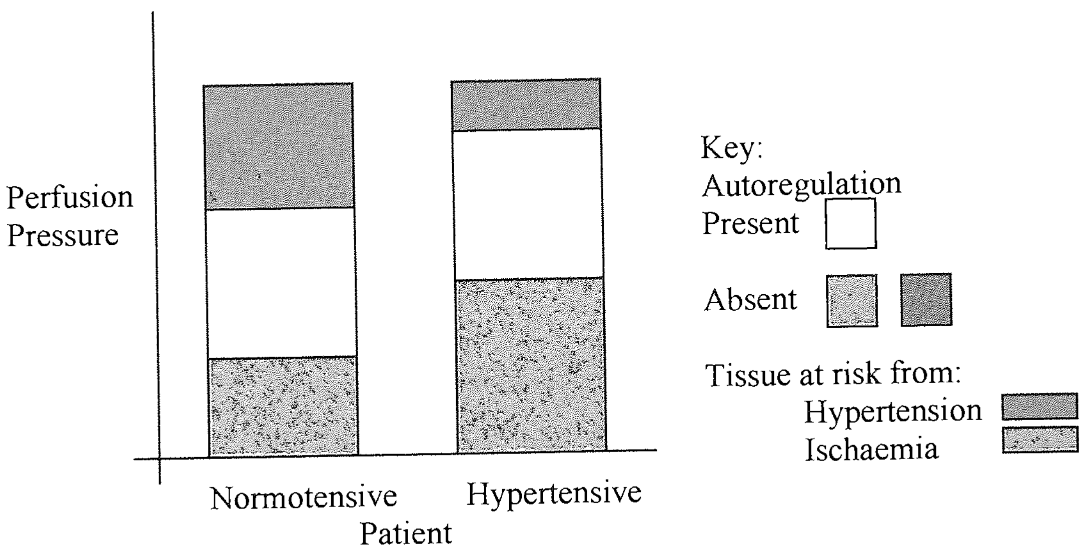


Figure 1.02: Schematic diagram of autoregulation in a normotensive and systemic hypertensive patient (redrawn from Hayreh, 1996).

1.32 - Ocular Conditions Associated with Systemic Hypertension

Vascular accidents are more common in the systemic hypertensive than the general population (Goldring and Chasis, 1944). The most common forms of retinovascular disease are retinal vein occlusion, retinal artery occlusion and non-arteritic anterior ischaemic optic neuropathy (Figure 1.03; Dodson and Kritzinger, 1997). The central retinal artery and vein occlusions are in response to turbulent blood flow at or posterior to the lamina cribosa and arteriosclerosis in the adjacent vessel, damaging the vessel endothelium and exposing the collagen which initiates platelet aggregation and an eventual thrombosis (Elton, 2000). A patient with a single retinal vein occlusion has a 10-15% chance of it occurring in the fellow eye (Dodson and Kritzinger, 1987; Hayreh *et al.*, 1994). It is uncommon for patients to have a retinal artery occlusion recur, but these patients show a significant mortality rate for myocardial infarction (Hankey *et al.*, 1991). With increasingly effective anti-hypertensive medication there has been a rise in visual disorders, such as optic nerve head ischaemia and vascular occlusive disorders in response to arterial hypotension particularily nocturnal hypotension (a drop in BP of ~10-20% during sleep; Hayreh, 1996; Marshall and Malinovsky, 1998). The retinal circulation is particularly at risk from hypotension due to its high tissue pressure (~20mmHg), with glaucomatous patients being at greater risk (Cogan, 1974). Patients with glaucoma and low BP show an increased deterioration rate in their visual fields compared to those with normal or high BP. An elevated systolic BP may offer some protection against glaucoma and, therefore, the treatment of systemic hypertension in a glaucomatous patient may accelerate visual field loss (Drance, 1997; Tielsch *et al.*, 1995).

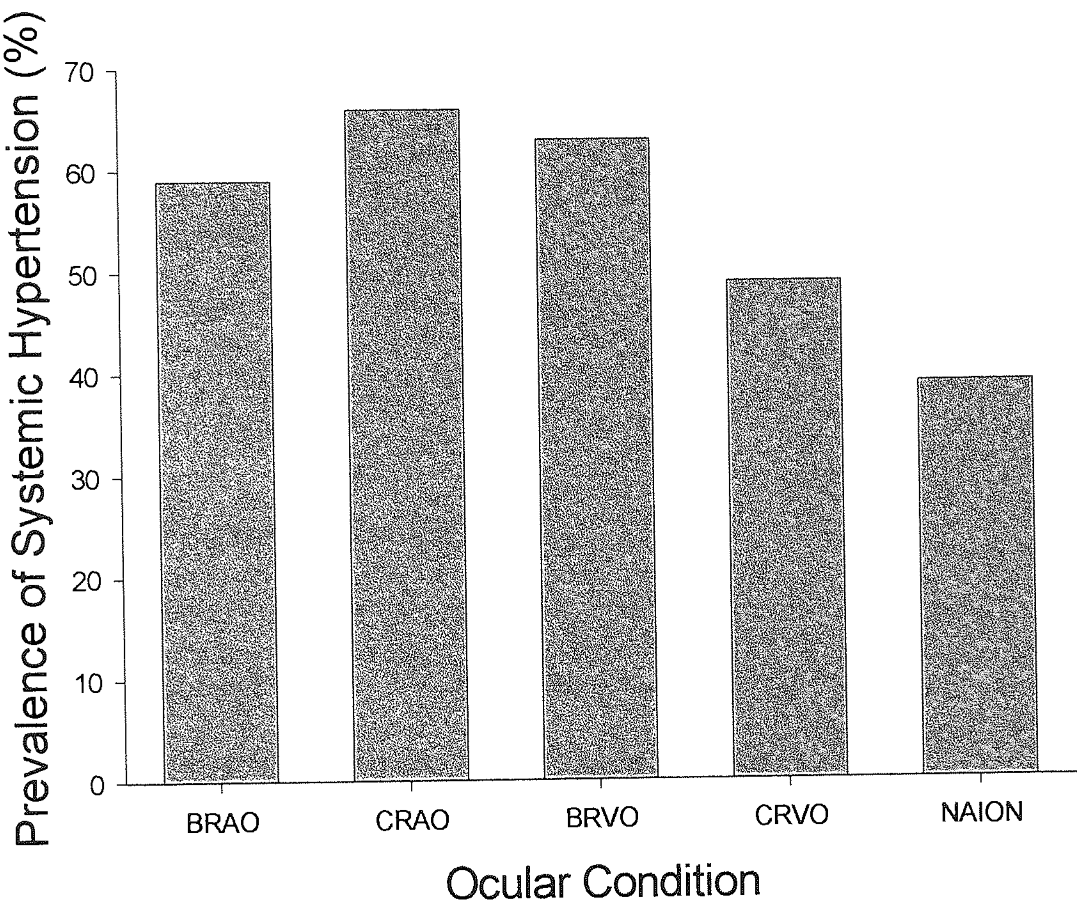


Figure 1.03: Prevalence rate of systemic hypertension in patients with retinovascular disease (redrawn from Dodson and Kritzinger, 1997).

Key: BRAO - Branch Retinal Artery Occlusion;

CRAO - Central Retinal Artery Occlusion;

BRVO - Branch Retinal Vein Occlusion;

CRVO - Central Retinal Vein Occlusion;

NAION - Non-Arteritic Anterior Ischaemic Optic Neuropathy.

1.40 - Detection of Systemic Hypertension

1.41 - Symptoms

Symptoms are rare with systemic hypertension until complications in target organs develop. Headaches are the most consistent symptom directly associated with systemic hypertension, in particular when the diastolic BP is above 100mmHg. These headaches tend to be occipital in location and are present on awaking, disappearing after several hours (Terry and Schoessler, 1976).

1.42 - Blood Pressure Measurement

The measurement of BP can be performed directly (intra-arterial) or indirectly (sphygmomanometer; Terry, 1976). Sphygmomanometry involves the rapid inflation of an arm cuff, level with the heart, which collapses the brachial artery (no sound is heard, phase 1). Non-rapid inflation will collapse the vein prior to the artery and trap blood in the forearm. The cuff is then deflated at a constant rate and the sounds (known as Korotkoff noises) from the artery as the blood distends the wall and surges past the cuff are monitored. These sounds can be classified into five phases, Figure 1.04 (McCutcheon and Rushmer, 1967; Terry, 1976). As the air is gradually released from the cuff (2-3mmHg/sec), taping sounds occur (phase 2 – SBP). Initially the taping sounds gradually increase in intensity, as the cuff pressure falls (phase 3). As the cuff pressure drops further, the Korotkoff noises gradually lessen in intensity, changing from loud thumping to soft, dull sounds, and finally muffled beats, the initial muffling being taken as the DBP (phase 4). Prior to a repeat measurement two minutes should elapse, allowing free blood flow in the brachial artery. Additional measurements are required if the readings vary by more than 5mmHg (J.N.C. Report, 1997). Elevated readings on at least two occasions would indicate the diagnosis of systemic hypertension (Augsburger and Good, 1986). Sphygmomanometry can give a measure of high BP, but not the extent and duration of degeneration of arterial walls and end organ damage in response to it (Black *et al.*, 1999).

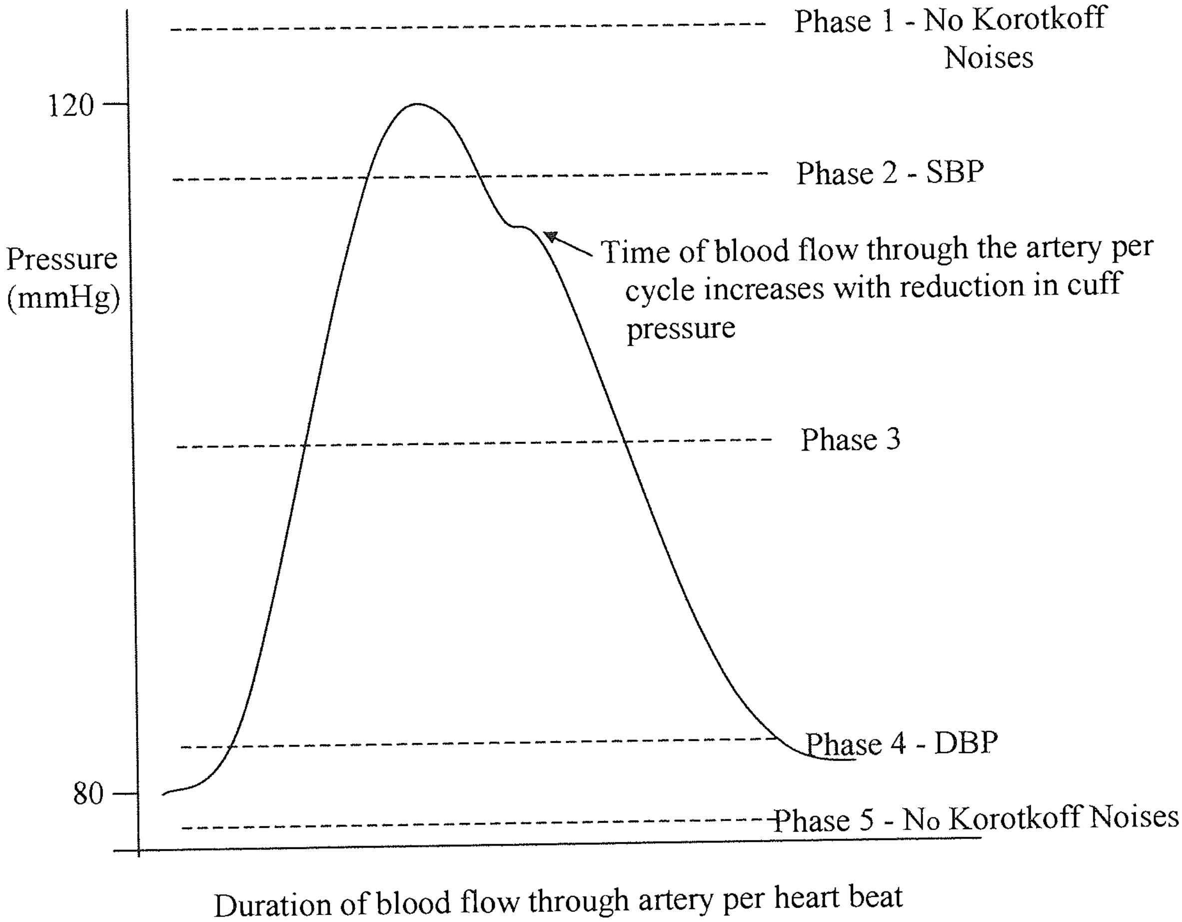


Figure 1.04: Cuff pressures during sphygmomanometry (redrawn from Terry, 1976).

Key: Phase 1: No sound.

Cuff has collapsed the brachial artery and stopped the blood flow.

Phase 2: Appearance of taping sounds (gradually increase in intensity).

Systolic Blood Pressure.

Phase 3: Sounds become louder with dropping cuff pressure.

Phase 4: Sudden muffling of sounds.

Diastolic Blood Pressure.

Phase 5: All sounds disappear.

Artery no longer occluded, normal blood flow re-established.

The main types of manometer are:

Mercury Sphygmomanometer;

- Korotkoff noises are subjectively monitored using a stethoscope.
- Advantages: accurate, inexpensive and maintainable by user.

Aneroid gauge;

- Korotkoff noises subjectively monitored using a stethoscope.
- Advantage: portable.

Automatic;

- Objective monitoring of Korotkoff noises.
- Advantages: requires no expertise to use and rate of in/deflation of cuff standardised.
- Accuracy is determined against the Association for the Advancement of Medical Instrumentation's recommendations (Anwar *et al.*, 1998).

The reliability and repeatability of the measurement depends upon several factors:

1) The appropriate cuff size for the individual.

   Width 40-50% of the circumference of the patient's upper arm (Geddes and Whistler, 1978; Good and Augsburger, 1989).

   Long enough to encircle the arm, approximately one and a half times otherwise BP will be over-estimated and vice versa (Terry, 1976; Nielson *et al.*, 1983).

2) Measurement is to be taken half an hour after drinking coffee, smoking, exercise and exposure to cold (Terry, 1976; Augsburger and Good, 1986).

3) BP measurement should be taken at a constant room temperature.

4) The patient should be relaxed. BP can be stabilised with 5-6 minutes of gentle breathing before the measurement.

1.43 - White Coat Hypertension

Measurement of BP in a clinical setting may elevate a patient's BP (possibly due to anxiety), known as White Coat Hypertension (WCH). WCH has been quantified as ~15mmHg (systolic BP) and ~10mmHg (diastolic BP; Mancia *et al.*, 1983) and is of concern in the measurement of borderline systemic hypertensives (Pickering *et al.*, 1982). The reliability of BP measurement is improved by increasing the number of readings taken at each appointment and the number of appointments (Pickering, 1994). BP has also been found to decrease over time with repeat measurements, known as the Hawthorn Effect (Pickering *et al.*, 1988).

1.44 - Diurnal Variation

BP varies diurnally (Figure 1.05), so as with the measurement of IOP, the time the readings were recorded needs to be noted (Hayreh, 1996). BP is at its highest approximately between 06.00 and 12.00 hours, the time span associated with an increased prevalence of cardiovascular morbid events (Pickering, 1994).

Ambulatory BP monitoring, which removes the effects of WCH, has a closer relationship to the target organ damage in systemic hypertensives than clinic measurements (Dodson and Kritzinger, 1997). However, the variation in BP with stress, such as that found in WCH, is a useful indicator of BP fluctuations experienced by the individual's lifestyle (Pickering *et al.*, 1989). Exaggerated fluctuations of BP are an early indicator of an individual's predisposition to systemic hypertension in later life (Goldring and Chasis, 1944). Therefore, a satisfactory clinic BP indicates good ambulatory control of BP (Mancia *et al.*, 1997).

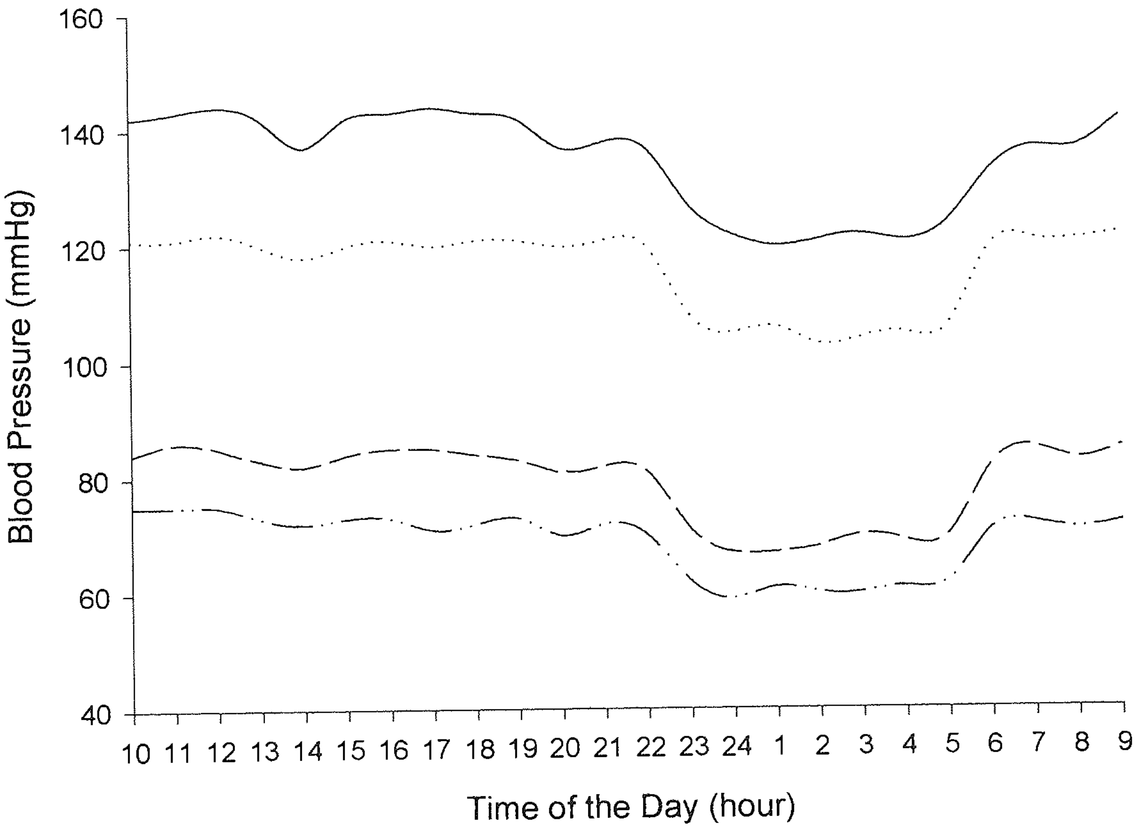


Figure 1.05: Mean systolic and diastolic blood pressures over 24 hours.

(redrawn from Hayreh, 1996).

Key: ——— Systolic BP - Systemic hypertensive

.... Normotensive

- - - - - Diastolic BP - Systemic hypertensive

—··—·· Normotensive

1.45 - Ocular Signs of Systemic Hypertension

The blood vessels are the primary tissue to respond to an acute rise in BP (Hayreh, 1989). In a similar manner to diabetes, there are changes in the pericytes in the retinal capillary walls (Wallow *et al.*, 1993). Systemic hypertension affects the retina, choroid and optic nerve head, sparing the iris and ciliary body (Ashton, 1972). There are many retinal changes associated with severe systemic hypertension, which have been well documented (e.g. Scheie, 1953; Hayreh, 1989, 1996). Retinopathy can also occur with other conditions; such as haemorrhages and inner retinal ischaemia spots with diabetes mellitus (Klein *et al.*, 1993, 1997), arteriolar narrowing and reflex changes with ageing (Salus, 1958; Klein *et al.*, 1994) and retinitis pigmentosa (Cogan, 1974). Retinopathy has also been found to occur idiopathically in a significant percentage (6.3%) of the non-diabetic population who do not have systemic hypertension (Klein *et al.*, 1993, 1994). The frequency of systemic hypertensive retinopathy increases with BP (both systolic BP and diastolic BP) and the duration of known systemic hypertension (Fuchs *et al.*, 1995). Retinopathy is 2.4 times more prevalent in uncontrolled systemic hypertensives than normotensives (Klein *et al.*, 1997).

For the purpose of this review, ocular signs of systemic hypertension are divided into those considered to be indicators of:

(i) Malignancy, such as haemorrhages, hard exudates and cotton wool spots.

(ii) Pre-malignancy, such as arteriolar narrowing and focal constriction.

Hypertensive retinopathy is also separated from choroidal and hypertensive optic neuropathy, acknowledging the different anatomical and physiological properties (Hayreh *et al.*, 1986).

1.50 - Malignant Hypertensive Retinopathy

The fundus appearance of a patient with malignant hypertensive retinopathy is illustrated in Figure 1.06. Hypertensive retinopathy is the second most common retinal vascular disease after diabetic retinopathy (Marshall and Malinovsky, 1998). In animal trials hypertensive retinopathy has been found to appear earlier than choroidopathy or optic neuropathy (Hayreh *et al.*, 1986).

Lipid Deposits (also known as Hard Exudates)

The breakdown of the blood retinal barrier in the deep capillary bed results in lipid deposits (Marshall and Malinovsky, 1998). Oedema in the macular area will follow the outer and relatively loose layers of the Henle's fibres, which radiate out from the fovea, resulting in a macular star (Ashton, 1972). These deposits are yellowish white in colour with well-defined sharp borders (Grundy, 1990). Hyperlipidaemia increases their presence (Hayreh, 1996). In youthful vessels they appear when the diastolic BP is above 130mmHg and in fibrotic cases are associated with the late stage of the illness (Leishman, 1957). They are usually indicative of subsiding malignant systemic hypertension and their resolution takes over a year (Stokoe, 1975; Hayreh, 1996).

Cotton Wool Spots (CWS)

Hayreh and colleagues (1989) have put forward the concept that CWS are in fact two separate entities: Inner Retinal Ischaemia Spots and Focal Intraretinal Periarteriole Transudates. They differ in their appearance, location, life cycle and resolution pattern.

i) Inner Retinal Ischaemia Spots

Occlusion of the fine terminal retinal arterioles causes an area of acute focal ischaemia of the inner retinal layer, leading to swelling of axonal fibres, and nerve fibre loss (Hodge and Dollery, 1964; Hayreh *et al.*, 1989). They are initially fluffy white (turning dull white) polymorphous feathery edged lesions and situated along the radial peripapillary retinal capillaries within a few disc diameters of the optic disc (Grundy, 1990; Hayreh, 1996). They lie superficially in the retinal nerve fibre layer obscuring the blood vessels (Hayreh *et al.*, 1989). They are proportional in number to haemorrhages (Cogan, 1974). Inner Retinal Ischaemia Spots are an early retinal lesion observed during acute phases of severe systemic hypertension (diastolic BP >130mmHg) and resolve rapidly, often disappearing without ophthalmoscopic trace in 6 to 12 weeks (Leishman, 1957; Hayreh *et al.*, 1989). Permanent obliteration of the retinal capillaries (indicated by fundus fluorescein angiography; FFA) is responsible for the development of intra retinal microvascular abnormalities (Hayreh, 1989).

ii) Focal Intraretinal Periarteriole Transudates (FIPTs)

Dilation and the breakdown of the blood retinal barrier in the precapillary retinal arterioles (in response to a severe rise in BP) leads to an accumulation of plasma macromolecules in the deep retinal layers along the major retinal arterioles and their main branches. FIPTs are round or oval dull white lesions varying in size from a pinpoint to a quarter of the disc diameter, but may fuse together to form a larger lesion. They differ from inner retinal ischaemia spots in their retinal layer location, life span (2-3 weeks) and on resolution leave no trace, unlike inner retinal ischaemia spots which leave an area of focal retinal capillary non-perfusion visible on FFA (Hayreh *et al.*, 1989). FIPTs are thought to be an early and specific sign of malignant systemic hypertension (Hayreh *et al.*, 1985).

Intra Retinal Microvascular Abnormalities (IRMAs)

Occlusion of the retinal capillaries may cause IRMAs, such as; microaneurysms, arteriovenous shunts, looped convoluted vessels and venous collaterals.

Retinal Haemorrhages

Extreme arteriolar narrowing impairs blood flow. The resulting nutritional damage to vessel walls and retinal tissues results in haemorrhages (Scheie, 1953; Dodson *et al.*, 1986). Haemorrhages most commonly associated with systemic hypertension are flame shaped, as they lie in the nerve fibre layer and are situated around the disc along the temporal and nasal vessels (Cogan, 1974; Marshall and Malinovsky 1998). Increases in the frequency and number of haemorrhages generally indicate a more serious systemic hypertensive state (Becker, 1981). On average, few haemorrhages are evident in the pre-malignancy stage of systemic hypertension and as 6.3% of the population has non-hypertensive or diabetic related retinopathy, they are not a diagnostic factor (Klein, 1993, 1994; Hayreh, 1989).

Retinal and Macular Oedema

Retinal oedema may be in response to autoregulatory failure, ischaemia or a breakdown in the blood retinal barrier in the RPE resulting in leakage of sub retinal fluid into the retinal tissue (Hayreh, 1996). Macular oedema is the most frequent hypertensive retinopathy in children (Logan *et al.*, 1992).

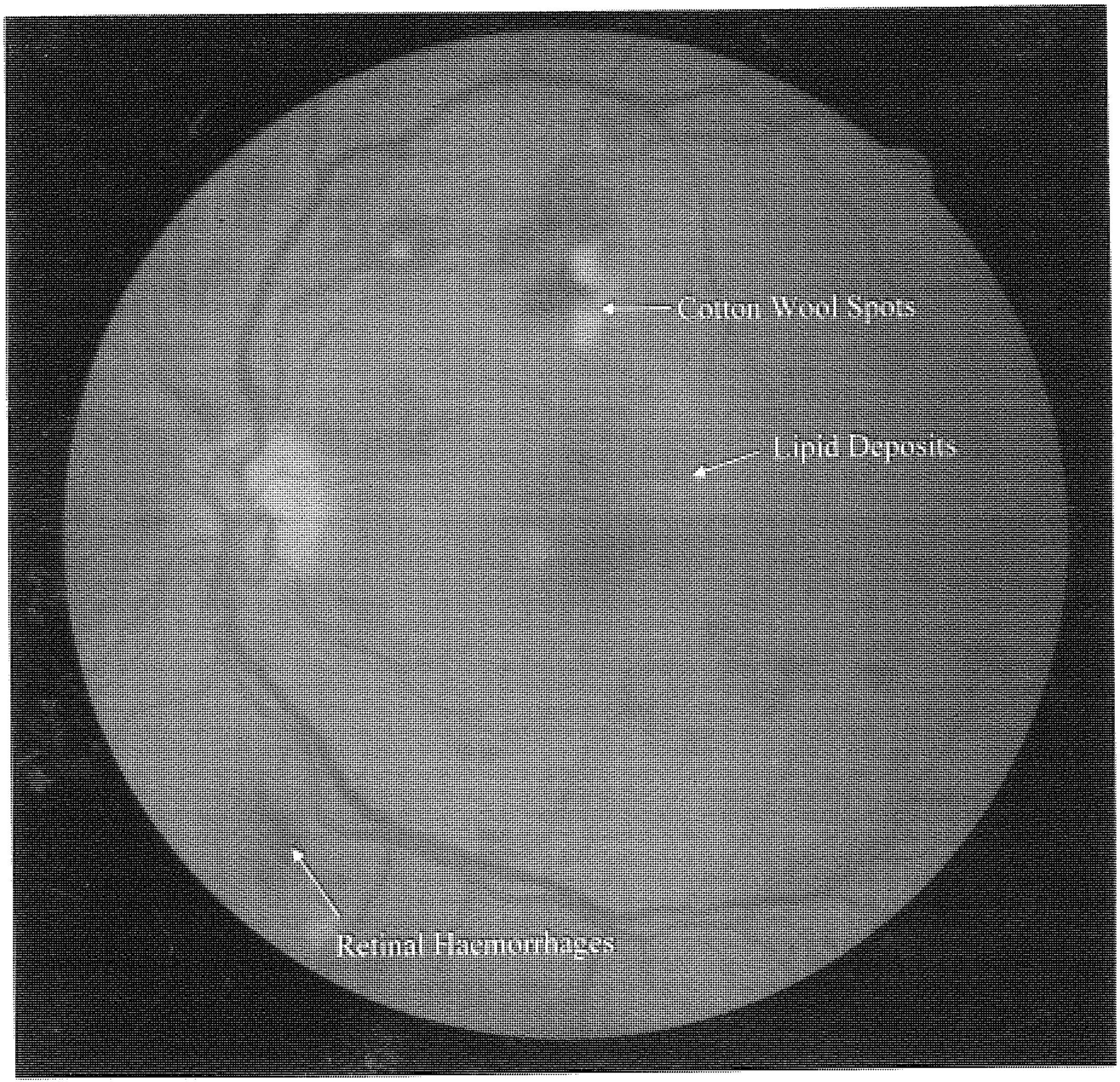


Figure 1.06: Malignant hypertensive fundus.

1.51 - Retinopathy Studies

The Beaver Dam Eye Study has provided a wealth of information on the prevalence of malignant retinopathy in the population over the age of 40 years (Klein, 1992; Klein *et al.*, 1993; Klein *et al.*, 1994; Klein, Klein and Moss, 1997). One third of this population (n = 4,541) had systemic hypertension. Malignant retinopathy was present in 7.8% of the non-diabetic population and >10% in the diabetic population (reaching 67% in juvenile-onset insulin dependent diabetics; Klein, 1992). The frequency of retinopathy in the general non-diabetic population, over the age of 40 years, was 10.7% in those with high BP (classified as systolic BP >160mmHg and/or diastolic BP >95mmHg) and 6.3% in normotensives. Under the age of 65 years, there was little difference in the prevalence of malignant retinopathy between people with or without systemic hypertension (Klein *et al.*, 1993; Klein *et al.*, 1994).

The frequency of systemic hypertension increased with age (Klein *et al.*, 1993; Klein, Klein and Moss, 1997) from about 20% in the 4th decade of life to 40-60% in those over the age of 75 years. The frequency of hypertensive retinopathy also increased with age, from about 5.5% in the 4th decade of life to 10.0% in those over the age of 75 years. The frequency of retinal lesions increased with increased systolic BP, but not so reliably with diastolic BP. In a five-year follow up, 6.0% of the population developed malignant retinopathy, 9.9% arterial narrowing and 6.5% arterial nipping (Klein, Klein and Moss, 1997). The Blue Mountains Eye Study in Australia confirmed these findings, with retinopathy present in 9.8% of a slightly older population (Yu *et al.*, 1998). Both these studies found a considerably higher prevalence of retinopathy in the population than had been previously reported, such as 0.8% in the Framingham Eye Study (Leibowitz *et al.*, 1980) and 0.1% in a population of middle-aged Swedish men (Aurell and Tibblin, 1965; Svardsudd *et al.*, 1978), presumed by them to be due to the increased sensitivity of multiple retinal photography.

1.52 - Hypertensive Choroidopathy

Choroidal changes are present in both pre- and malignant systemic hypertension, but to a greater extent in the malignant phase. The pre-malignant changes are masked by an intact RPE and concomitant overlying retinal changes, but are of significant prognostic value when found (McMahon and Maino, 1982; Kishi *et al.*, 1985). The choroidal vessels are amongst the most vulnerable to systemic hypertension due to their short course, limited branching and less effective regulatory mechanisms compared to the retina (Ashton, 1972; de Venecia and Jampol, 1984). Hypertensive choroidopathy tends to occur with acute rises in BP in young patients with severe malignant hypertension (de Venecia and Jampol, 1984; Hayreh *et al.*, 1986; Hayreh, 1996).

Pre-malignant choroidopathy is associated with localized variations in vessel calibre (aneurysmal dilations and focal narrowing; Friedman *et al.*, 1964). The malignant changes, in addition to the pre-malignant changes, are hyaline arteriole changes and various stages of vessel necrosis and retinal detachment (Friedman *et al.*, 1964). In malignant hypertension, endogenous vasoconstrictor agents leak freely from the choriocapillaries into the choroid interstitial fluid, which causes choroid vasoconstriction and ischaemia.

Filling Defects in the Choroidal Vascular Bed

One of the earliest signs of hypertensive choroidopathy is patchy, delayed filling of the choroidal vessels, more prominent in the macular/foveal region (Hayreh and Servais, 1986).

Retinal Pigment Epithelium Lesions

Necrosis of the choroidal vessel endothelial cells and the hypertensive involvement of the RPE result in acute focal RPE lesions (Elschnig spots; de Venezia and Jampol, 1984). These are pale or white, round, pinhead sized sub-retinal lesions, usually present in groups situated in the macular region. The choroidal capillary bed accounts for the scattered distribution of Elschnig spots (Schmidt and Löffler, 1993). All patients with acute Elschnig's spots have malignant hypertension and fundus changes (de Venezia and Jampol, 1984). Acute focal RPE lesions progress into RPE degenerative lesions and are associated with delayed and patchy choroidal vascular bed filling. Elschnig's spots are an adverse prognostic sign and are associated with acute episodes, which affect specific target organs (Klein 1968; Schmidt and Löffler, 1993). Chains of pigment spots along the course of sclerosed choroidal vessels are known as Siegrist's streaks. These streaks are indicative of a more generalized sclerotic change to the organs and a poorer prognosis for life (Klein, 1968).

Early RPE degenerative lesions have a similar ophthalmoscopic appearance to acute focal RPE lesions, either merging together (becoming ill defined) or maintaining their margins. They are more numerous than acute focal RPE lesions. Late RPE degenerative lesions are scattered over the fundus, the temporal periphery and fovea being more involved. The areas of RPE atrophy are of various shapes and the pigmentary changes correspond to chronic occlusive changes of the choroidal vessels. Changes present in the macula can resemble age-related macular degeneration, whereas widespread changes resemble "Birdshot Retinopathy" (Hayreh, 1996).

Serous Retinal Detachment (SRD)

Ischaemia of the RPE leads to a breakdown of the blood retinal barrier, allowing fluid to diffuse into the sub-retinal space causing a retinal detachment, principally in the macular region. A peripheral (bullous) retinal detachment may extend 360° and if extensive choroidal changes are present, can produce a total retinal detachment (McMahon and Maino, 1982; de Venezia and Jampol, 1984; Hayreh, 1996). The sub-retinal fluid will move with head movements. A SRD usually resolves in response to medical intervention of the BP or spontaneously (de Venezia and Jampol, 1984; Hayreh, 1996).

1.53 - Hypertensive Optic Neuropathy

Swelling of the ganglion cell axons, in response to ischaemia, causes the optic nerve head to swell. The appearance of the optic nerve head may resemble that found in raised intracranial pressure or hypertensive encephalopathy. Initially the disc will appear slightly elevated with blurred margins and there will be overfilling of the veins with a lack of venous pulsation. The elevated disc will eventually be surrounded by flame shaped haemorrhages, exudates and CWS. Ischaemia of the optic nerve head and the inner retinal layer causes retinal nerve fibre loss (Hayreh *et al.*, 1986). An abrupt drop in BP in patients with hypertensive optic neuropathy may lead to complete permanent blindness (Hayreh, 1986). Papilloedema present in a patient who already has bilateral retinal haemorrhages and exudates will not adversely affect their prognosis (McGregor, 1986).

1.54 - Pre-Malignant Retinal Signs

Pre-malignant retinal changes are more subtle than the malignant changes and similar observations may be physiological in origin or can occur with increasing age (Salus, 1958). The fundus appearance of a patient with pre-malignant hypertensive retinopathy is illustrated in Figure 1.07. Improvements in the detection of pre-malignant retinal signs of systemic hypertension could provide for better screening, monitoring and management of systemic hypertensive patients in the future.

Arteriolar Narrowing – Arterio / Venous (A/V) Ratio Changes

The extent of arteriole narrowing is dependent upon the level of pre-existing involutional sclerosis (replacement fibrosis). In young individuals with little involutional sclerosis hypertensive narrowing will be more evident than in an elderly patient whose vessels are more rigid due to involutional sclerosis (Cogan, 1974; Kanski, 1992). Arteriolar narrowing is associated with prolonged high BP, particularly diastolic BP. The extent of arteriolar narrowing is proportional to the BP elevation (Bechgaard *et al.*, 1950; Scheie, 1953; Breslin *et al.*, 1966) and age (arteriosclerosis; Svardsudd *et al.*, 1978; Fuchs *et al.*, 1995). The prevalence of diffuse arteriolar narrowing in males aged 40-60 years is 6.2% in normotensives, 15.8% in mild-moderate hypertensives, and 30.0% in severe hypertensives (Van Buchem *et al.*, 1964). A 10mmHg increase in MABP is associated with a decrease in the A/V ratio of only 0.02 (Hubbard *et al.*, 1999). Therefore, arteriolar narrowing, unless extreme, is hard to detect with an ophthalmoscope (Stokoe and Turner 1966; Stokoe, 1975).

Examination of the degree of arteriolar narrowing is best established beyond the second branch of the central retinal vessel or around the fovea (Salus, 1953, 1958). The A/V ratio must be assessed at a comparable branching of the arteriole and venule (Stokoe and Turner 1966; Michaelson *et al.*, 1967). However, the selection of two such vessels is difficult, time consuming and often impossible by casual ophthalmoscopy. It is first observed in the nasal branches of the retinal vasculature and most pronounced in the foveal arterioles (Cogan, 1974). The diameter of venules is relatively constant but can vary in conditions such as raised intra-cranial pressure or central retinal venous obstruction (Stokoe and Turner 1966). There is wide spread opinion on the A/V ratio of healthy individuals: 2/3 – 3/4 (Wagener *et al.*, 1947); 2/3 (Duke Elder, 1976). 3/5 – 5/5 (Nicholls *et al.*, 1956) and 5/6 (Majewska *et al.*, 1976).

Intensity of Arteriolar Reflex

The normal arteriolar light reflex, present on medium and large vessels, originates from the surface of the erythrocytes. The intensity of the arterial reflex is related to age (arteriosclerosis; Brinchmann-Hansen and Heier, 1986). and systolic BP (Bechgaard *et al.*, 1950; Salus, 1958). In systemic hypertension the vessel wall is thickened (increase in refractive index makes the vessel wall less transparent) and a change in the intravenous pressure (affecting the refractive index of the erythrocytes and plasma) gives an increased reflex intensity (copper and silver wiring; Brinchmann-Hansen *et al.*, 1987, Kanski, 1995). The intensity is significantly reduced by moderate reduction of systolic BP and to a lesser extent diastolic BP (Brinchmann-Hansen *et al.*, 1990). The arteriolar reflex is present in 46% of the hypertensive population and 10-33% of a general population (Bechgaard *et al.*, 1950; Aurell and Tibblin, 1965). The change in intensity of the arteriolar reflex is considered to be the first change of arteriolosclerosis retinopathy and reflects the state of general arteriolar circulation throughout the rest of the body (Marshall and Malinovsky, 1998). The presence of copper and silver wiring in non-malignant hypertensives is rare (Bechgaard *et al.*, 1950).

Arteriolar Tortuosity

With the vessels geometrically fixed in the retinal tissue, their response to an increase in size (in response to an increase in intraluminal volume and pressure) is tortuosity (longitudinal stretching; Bartlett and Price, 1983). Congenital tortuosity is thought to be uniform throughout the fundus, whereas segmental arterial tortuosity is reported to be always abnormal (Walsh, 1982). The association of tortuosity with BP is less marked than other observed vasculature changes, being present in 22% of systemic hypertensives (Bechgaard *et al.*, 1950). Tortuous vessels are first observed in the nasal (to the disc) branches of the retinal vasculature (Cogan, 1974). There is considerable variation in the tortuosity of vessels in the healthy population (Crombie and Button, 1995). Clinical observation performed by Salus (1958) stated that arteriolar tortuosity was not diagnostic of systemic hypertension. Arteriolar tortuosity has been reported to decrease (Leishman, 1957; Michaelson *et al.*, 1967), increase (Elwyn, 1954) and remain unaltered (Bechgaard, 1950) with ageing.

Focal Arteriolar Calibre Changes

The extent of autoregulatory arteriole narrowing is determined by the BP and the capacity of the vessel to react (influenced by age and duration of systemic hypertension; Ramalho and Dollery, 1968). Focal arteriolar calibre changes were originally thought to reflect arteriolosclerosis (Bechgaard *et al.*, 1950; Salus, 1958), but have been found to be highly related to high systolic BP (Dimmitt *et al.*, 1989; Klein *et al.*, 1993, 1997) and are an indicator of long-term systemic hypertension (North, 1999). MABP has been found to be ~8mmHg higher in subjects with focal narrowing (Hubbard *et al.*, 1999). Its presence has been shown to be an important prognostic retinal indicator for mortality, stroke and death from malignancy in a $12^1/_2$ year follow up period (Svardsudd *et al.*, 1978). There is an increase in prevalence with increasing diastolic BP (17% when <100mmHg rising to 99% when >140mmHg; Breslin *et al.*, 1966) and age (~10% in the 4th decade to over 30% in those over the age of 75 years; Svardsudd *et al.*, 1978). Arteriolar narrowing as viewed by ophthalmoscopy may be an artefact caused by retinal oedema partially masking the arteriole from both sides (Hayreh, 1996).

Arteriovenous (A/V) Crossing Changes

Arteriovenous crossing changes in the form of arching of the vein passing under an artery and nicking (nipping) have long been recognised as a sign of systemic hypertension (Salus, 1958). Higher PP, secondary to an increase in systolic BP and a thickening of the arterial wall causes a deflection and venous compression of the underlying vein. There is an impedance of retinal blood flow, with the vein distal to the disc darker, larger (swollen) and more tortuous than the proximal segment (Walsh, 1982). Their prevalence is 37% in a systemic hypertensive population (Bechgaard *et al.*,

1950) and less than 10% in a general population (Aurell and Tibblin, 1965; Svardsudd *et al.*, 1978). The frequency of arteriovenous crossing changes increases with increased systolic BP, but not so reliably with diastolic BP and age (from 0.8% in the 4th decade to 5.0% in those over the age of 75 years; Klein *et al.*, 1993, 1997; Fuchs *et al.*, 1995). The crossing changes remain even after high BP is reduced. The degree of A/V crossing changes is more severe with systemic hypertension than with involutionary sclerosis or ageing (Stokoe, 1975). However, arteriovenous crossing changes were found to be the least important prognostic retinal indicator for mortality, stroke and death from malignancy over a $12^1/_2$ year follow up period (Aurell and Tibblin, 1965; Svardsudd *et al.*, 1978).

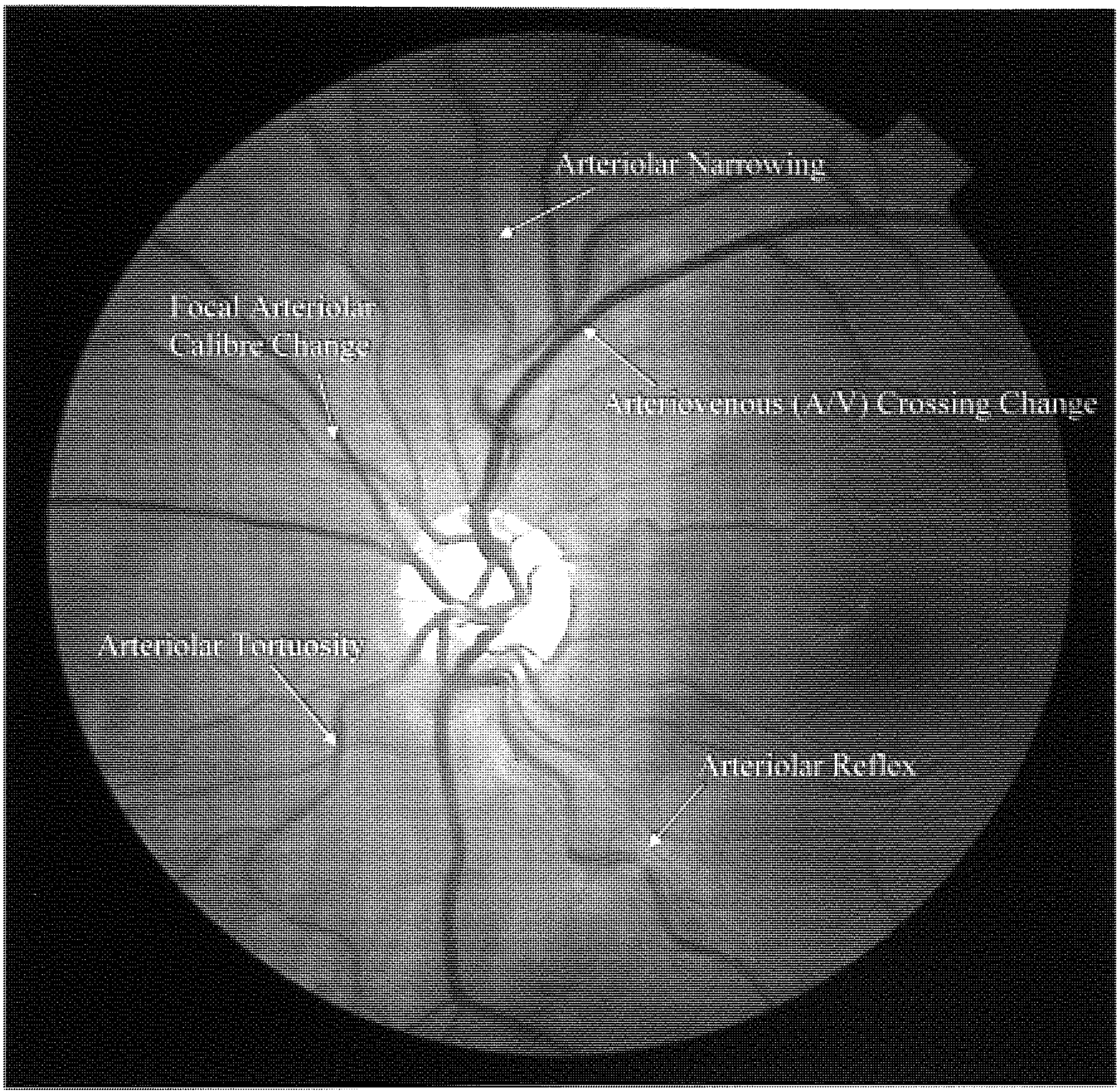


Figure 1.07: Pre-malignant hypertensive fundus.

1.60 - Assessment of the Signs of Systemic Hypertension

1.61 - Subjective Grading (Grading Scales)

The retinal circulation has two main features that make it an important prognostic indicator for assessing the vascular state of the whole body. Firstly, it is an end arteriolar system and as such is particularly vulnerable to the effects of high arterial BP and secondly it is easily observable with simple non-invasive techniques (such as ophthalmoscopy). Grading scales for examining the retinal vasculature have been in use since the late 1930's and assist in evaluating progression of a lesion and predicting the prognosis for survival within groups (Wagener *et al.*, 1947; Walsh, 1982). The most commonly used grading scale of the retinal vasculature is the Keith, Wagener and Barker system (Keith *et al.*, 1939; Wagener *et al.*, 1947).

<u>Keith, Wagener & Barker - 1939</u>

The Keith, Wagener & Barker scale grades arterial characteristics and retinopathy, observed with an ophthalmoscope, into four groups (Table 1.04). The non-malignant signs (A/V ratio, general vessel narrowing, and focal vessel narrowing) are graded compared to what the examiner considers to be normal. Additional malignant signs of haemorrhages, exudates and papilloedema are graded as to their presence or absence. As the group number increases (in Table 1.04), the prognosis for the individual worsens. The prognosis for a patient with untreated malignant hypertension (grade IV) was found to be poor with 90% mortality rate in the first year (Keith *et al.*, 1939). Several fundus examinations may be required before assigning a patient to a group to take account of the fact that some lesions (such as exudates) are only visible temporarily (Keith *et al.*, 1939).

RETINAL ARTERIOLES						
Grade	**A/V Ratio**	**General Narrowing**	**Focal Narrowing**	**Haemorrhage**	**Exudates**	**Papilloedema**
I	1/2	Mild	Mild	Absent	Absent	Absent
II	1/3	Moderate - Marked	Moderate - Marked	Possible	Absent	Absent
III	1/4	Marked	Marked	Possible	Possible	Absent
IV	<1/5	Marked	Marked	Possible	Possible	Present

Table 1.04: Summary of the Keith, Wagener and Barker (1939) grading scale.

Despite the longevity of utilisation of this scale, it suffers from a number of major problems with respect to the early detection and monitoring of systemic hypertension:

- The scale was based mainly on malignant systemic hypertension (67% of subjects were in grade IV), which makes up the minority of clinical cases and appears to have little prognostic value in those with less severe systemic hypertension (Bechgaard *et al.*, 1950; Aurell and Tibblin, 1965; Fuchs *et al.*, 1995). With improved systemic hypertensive medication giving an improved prognosis for patients, some consider the scale to be obsolete (North, 1999).
- Groups 1 and 2 only differ on the degree of sclerosis, making the allocation of a patient between the groups very subjective (Stokoe and Turner 1966; Hayreh 1989).
- Groups 3 and 4 only differ on the presence of papilloedema, which does not influence the prognosis of a patient who already has bilateral retinal haemorrhages and exudates when effective treatment is available (McGregor *et al*, 1986).
- Not all cases fall into just one group (Keith, Wagener and Barker, 1939).
- Vascular changes, which are due to arteriolar sclerosis from ageing (irrespective of BP) are not distinguished and are, therefore, recorded as systemic hypertensive in origin (Breslin *et al.*, 1966; Dodson *et al.*, 1986; Hayreh, 1989).

Wagener, Clay and Gipner – 1947

Wagener, Clay and Gipner (1947) took the rise in BP as central to the production of the arteriolar changes (generalized narrowing, focal constriction and sclerosis) and retinal lesions and classified the hypertensive retinopathy into six different categories. Retinopathy of: acute hypertension (angiospastic hypertension); chronic progressive hypertension; terminal malignant hypertension; acute hypertension in glomerulonephritis; chronic progressive hypertension in glomerulonephritis; and terminal malignant hypertension in glomerulonephritis. The scale records the severity of the arteriole constriction and the number of constrictions present (Wagener *et al.,* 1947). This grading scale is complex and some categories cannot be distinguished clinically, so the scale is not appropriate to clinical practice (Hayreh 1989).

Scheie – 1953

This grading system, based on the Keith, Wagener and Barker scale, distinguishes systemic hypertensive changes (arteriolar narrowing, focal constriction and retinopathy; Table 1.05) from arteriolar sclerosis (arterial light reflex and arteriovenous crossing changes). Systemic hypertensive changes will relate to the measured BP whereas the extent of sclerosis is hard to determine. Any degree of arteriosclerosis might conceivably occur with any degree of systemic hypertensive change (Scheie, 1953). However, Scheie assumed that arteriolar sclerosis was due only to systemic hypertension and ignored the influence of age (Dodson *et al.,* 1996). Scheie (1953) claimed good inter-clinician repeatability for the grading system, but its subjective nature has limited its clinical application (Hayreh, 1989).

Grade	Severity Of HYPERTENSION				ARTERIOLOSCLEROSIS Organic damage to arterioles due to Systemic Hypertension	
	A/V Ratio	Haemorrhages	Exudates	Papilloedema	Light Reflex	Vessel Crossings
Normal	3/4 - 3/5	Absent	Absent	Absent	Fine line	None
I	1/2	Absent	Absent	Absent	Increased	Mild compression
II	1/3	Absent	Absent	Absent	Marked	Greater compression
III	1/4	Present	Present	Absent	Copper Wire	Angular deviation
IV	<1/5	Present	Macula Star	Present	Silver Wire	Distal congestion

Table 1.05: Summary of the Scheie grading scale (1953).

Leishman - 1957

Leishman's scale recognised that arteriolar sclerosis increased with age and established a seven-part classification of hypertensive retinal changes according to the presumed evolution of the hypertensive arteriolar changes in vessels of differing age. The grades were: Aged vessels: involutionary sclerosis; involutionary sclerosis with hypertension; advanced involutionary sclerosis with hypertension. Youthful vessels: normal fundus; early hypertension; fulminating hypertension; and severe hypertension with reactive sclerosis. This classification of hypertensive changes is complicated and its clinical use has been limited (Hayreh, 1989).

Evelyn, Nicholls and Turnbull - 1958

A grading and semi-quantitative recording system of all the retinal hypertensive changes present in an individual (Evelyn *et al.*, 1958). The system, based on the Keith Wagener and Barker scale, allows lesions to be graded and recorded to follow the progression of the fundus changes. Each lesion is recorded by its frequency and location on the fundus (Figure 1.08). The findings of the examination are recorded in abbreviated form on the record sheet and these have been shown to be reproducible between observers (Evelyn *et al.*, 1958). This is a detailed recording system taking approximately 20 minutes per fundus, which is its limitation to widespread clinical use.

Upper T				Lower T				Lower N				Upper N				Haemorrhages
1				1	1	1		0				0				Number
1/2				1/10	1/8	1/8										Size
L				*L*	*L*	*R*										Type
11				6	7	7'										Bearing
1/8				1/16	0	1/8										DD-D

Figure 1.08: A sample record sheet for the recording of haemorrhages in the right eye of a patient using the hypertensive grading scale suggested by Evelyn, Nicholls and Turnbull (1958).

Key: Size = Maximum dimension

- expressed as a fraction of a disc diameter

Type = *L* = linear *F* = flame shaped *R* = round;

Bearing = Clock face: 7 = 7 o'clock, 7' = 7.30;

DD-D = Distance from disc margin measured in disc diameters.

Cogan - 1974

This scale has four grades from mild (grade 1) to severe (grade 4) narrowing. The grade of the arteriole can be accompanied by any degree of hypertensive change (be they retinopathy, choroidopathy or optic neuropathy). Cogan (1974) stated it was likely that with an increase in grade there would be an increase in the severity of the accompanying hypertensive changes. Cogan (1974) assumes the degree of arteriolar narrowing is the only important sign of hypertensive retinopathy, which is not borne out by research (Hayreh, 1989). Cogan also points out that over interpretation of arterial narrowing in the fundus is a common problem and that when a practitioner is aware a patient has systemic hypertension, they may attach more significance to questionable changes.

Tso and Jampol - 1982

The Tso and Jampol classification system separates hypertensive retinopathy into four phases: vasoconstrictive phase; exudative phase; sclerotic phase; and complications of the sclerotic phase. The criticism of this scale is that the retinal arteriolar vasoconstriction viewed on ophthalmoscopy may be an artifact and the phases do not maintain their separate entities in practice (Dodson *et al.*, 1996).

Dodson, Lip, Eames, Gibson and Beevers - 1996

Dodson and colleagues suggested a simplified grading scale, which categorizes systemic hypertensive retinal fundus changes into two categories: non-malignant hypertension and malignant hypertension (Table 1.06). Just recording whether a patient has either non-malignant or malignant hypertension by this scale could result in a loss of important clinical information, therefore, all abnormalities should be recorded by the examiner (Dodson *et al.*, 1996).

Grade	Non-Malignant	Malignant
Retinal Changes	General arteriolar Narrowing Focal constriction (not A/V nicking)	Haemorrhages Hard exudates CWSs ± Optic disc swelling Retinovascular damage
Hypertensive Category	Established hypertension	Malignant hypertension Retinovascular damage
Prognosis	Depends on BP, age and other concomitant cardio-vascular factors	Untreated – Survival <2 years Treated – Survival ≈ 12 years

Table 1.06: Hypertensive retinopathy grading scale.

(summarized from Dodson *et al.*, 1996).

This scale, like most of the subjective grading scales of systemic hypertensive retinal vasculature changes, aims to group patients in terms of their prognosis. It does not assist practitioners in their ability to quickly and comprehensively describe the state of the retinal vasculature to assist in the monitoring and early detection of possible systemic hypertensive damage to the body's vasculature. If referral is made on the presence of malignant hypertensive retinopathy, irreparable damage to the vasculature system of the body as a whole may have occurred and treatment may be less beneficial than if started years before (Terry and Schoessler, 1976; Augsburger and Good, 1986).

It has been suggested that classification groups (with a grade allocated arbitrarily) for hypertensive retinopathy are inadequate and result in the loss of clinical information (Svardsudd *et al.*, 1978; Hayreh, 1989). A detailed description of fundus features is more informative for assessing the current vascular status and for follow-up of any changes.

1.62 - Objective Grading (Image Analysis)

Advances in video imaging of the ocular fundus offers the opportunity for objective grading of fundus features and an improved sensitivity compared to observational (subjective) grading (see chapter 5).

1.70 - Optometrist's Role

Part of the function of the optometrist is to detect ocular disease and systemic disease with ocular manifestations. Systemic hypertension is both an ocular and systemic disease. Many patients with high BP are asymptomatic, unaware of their condition and may not attend their GP on a regular basis. These people may visit an optometrist every one to two years and, therefore, optometrists can play an important public health screening role for systemic hypertension providing: ocular fundus examination; measuring BP; feedback to the patients; emphasizing the importance of regular GP appointments (particularly to the elderly patient); and referring suspect patients to their GP for appropriate investigation and management (Terry, 1976; Augsburger and Good, 1986; Klein *et al.*, 1993).

With systemic hypertension being a contributing factor to many systemic conditions, it is important that the optometrist's records are detailed in the area of the patient's BP (Good and Augsburger, 1989). A family history of systemic hypertension related mortality increases the relative's mortality risk three fold (Grundy, 1990). However, it should be noted that patients' reporting of systemic hypertensive history can be unreliable (Scheie, 1953; Linton *et al.*, 1991; Wolffsohn *et al.*, 2001). Even a patient's ability to accurately record BP in a logbook has been found to be poor (Mengden *et al.*, 1999).

1.71 - Ophthalmoscopy versus Sphygmomanometry

BP measurement is a more specific and reliable predictor of acute cardiovascular disease than ophthalmoscopy (Good and Augsburger, 1989; Schubert, 1998). However, examination of the retinal vasculature is important as the fundus appearance is a useful prognostic indicator of the general state of the body's vascular network via a non-invasive technique (Scheie, 1953). The degree of sclerosis also serves as an excellent index of the duration of systemic hypertension and hence prognosis (Scheie, 1953). Therefore, retinal vasculature characteristics may be a clinical sign of greater value to the General Practitioner (GP) in the management of these patients than hypertensive retinopathy or BP measurement in some instances (e.g. patients with chronic disease).

Automatic BP measurement, a relatively simple procedure, like tonometry and field screening, can be delegated to a trained colleague as part of the pre-screening battery of tests. The benefits of such will be to reduce the influence of WCH (Pickering *et al.*, 1985) and not encroach on the optometrist's time. With BP having an inverse relationship with visual field loss in glaucoma, the measurement of BP is of benefit in the determination of the speed of referral and if a glaucoma suspect should be referred (Terry and Schoessler, 1976; Crombie and Button, 1995).

1.72 - Possible Future Optometric Role

If optometrists are to take a more active role in minimising morbidity and mortality due to systemic hypertension, it is important to have the support of the patient's GP and to ascertain appropriate referral criteria. Wesloski (1999) stated few doctors would object to optometrists measuring BP in the USA, but this is yet untested in countries such as the United Kingdom where BP measurement is not a common part of everyday optometric practice. With systemic hypertension being a major contributing factor to the leading killers in the developed world (cardiovascular disease and stroke), there is a need for optometrists to improve their interaction with GPs in the life long management of these patients.

1.80 - Aim of Thesis

This thesis sets out to examine in detail the condition of systemic hypertension in relation to optometric practice in the United Kingdom (UK). The areas examined are:

1) The UK optometrists' views on their role (present and future) in the detection and monitoring of systemic hypertension.
2) Objective examination of the retinal vasculature through computer assisted image analysis of retinal photographs to detect pre-malignant hypertensive retinopathy.
3) The prevalence of systemic hypertension and associated medical conditions in UK optometric practice.
4) The General Practitioners' opinion on the role of optometrist in the management of the systemic hypertensive patient.
5) The subjective grading of hypertensive retinopathy through the application of a recently devised pictorial grading scale.

CHAPTER 2 - CURRENT OPTOMETRIC OPINION ON BLOOD PRESSURE MEASUREMENT

2.10 - Introduction

There is little research into the detection and management of patients with cardiovascular disease by optometrists in the United Kingdom. Optometrists are trained to detect ocular and systemic disease through examination of the retinal fundus, rather than general medical techniques such as sphygmomanometry. The terms of practice, as laid out in the Opticians Act 1989, state that it is the duty of the examiner to perform an examination of the eye for the purpose of detecting injury, disease or abnormality in the eye or elsewhere. The equipment specified for the examination of the internal eye is that of an ophthalmoscope or other means appropriate (General Optical Council, 2002). As has been discussed in chapter 1, the ocular vascular system is particularly vulnerable to cardiovascular disease, due to its end arteriolar nature, and permits the only opportunity for the blood vessels to be examined non-invasively. There have been few studies examining the relationship between cardiovascular disease and the condition of the eye's vascular system in optometric practice. Research examining the specific retinal vasculature features, has shown limited ability for the observed findings to predict BP.

With the optometrist being situated in the community and seeing patients on a regular basis, various authors have proposed an argument for routine optometric BP monitoring (e.g. Daubs, 1974; Terry, 1976; Terry and Schoessler, 1976; Augsburger and Good, 1986; Port and Pope, 1988; Barnard *et al.*, 1991). Daubs (1974) estimated that an optometrist performing sphygmomanometry could detect one undiagnosed hypertensive patient for every fourteen adults tested. For example, Barnard and co-workers (1991) found that referrals of patients for systemic hypertension on the presence of fundus lesions and other information obtained from the eye examination without the use of BP monitoring equipment produced a 77.8% false positive referral rate. BP measurement on patients with normal fundi resulted in 9.1% of them being referred for systemic hypertension (referral criteria - 18 - 44 years 140/90mmHg; 45 - 64 years 150/90mmHg; >65 years 160/95mmHg).

BP, as with IOP, varies diurnally and is influenced by many factors such as diet, stress, age and exercise (e.g. Hayreh, 1996; Marshall and Malinovsky, 1998). Therefore, a single isolated measure of BP does not well describe the stress placed upon the vascular system by the pressure within the blood vessels. In addition, although the cause of vascular damage is of interest (i.e. the BP), it is essential that the actual extent of damage to the vascular system is monitored. For example, the effect of high BP on already damaged or aged blood vessels may be significantly different from its effect on a young individual with healthy vessels.

In the optometric profession, a survey of referrals (1986) of patients between 41 and 70 years found that 0.74% were referred for suspected vascular hypertension (Port and Pope, 1988). Referrals of patients to their GP for systemic hypertension following a routine eye examination accounted for 2.4% of all referrals, rising to 15.7% when BP readings were taken into account. Overall, 5% of referrals were systemic hypertensive / arteriosclerosis related compared to 12% for glaucoma. Given that systemic hypertension is ten times more prevalent in society than glaucoma, this could imply that the optometric profession is poor at detecting and / or appropriately managing possible systemic hypertension in their patients. Barnard and co-workers (1991) found that of the referrals to the GP by optometrists for systemic hypertension, 18% of these patients were already on medication for systemic hypertension and 31% presented with signs or symptoms warranting a review by their GP. Ignoring BP measurement and referring patients only after ophthalmological systemic hypertensive changes are present, may delay a patient's access to medical treatment, causing irreparable damage to other organ systems. With the vast majority of patients with grade I or II (using the Keith, Wagener and Barker scale, 1939), there is a need for more emphasis on the interpretation of early systemic hypertensive vascular changes.

This survey aimed to examine the nature and knowledge of detection of cardiovascular disease in a sample of the current optometric profession at the beginning of the 21st century.

2.20 - Method

A review of the literature revealed three questionnaires had been previously used to determine the use of sphygmomanometry in optometric practice and each of these studies were conducted in the USA (Eger, 1982; Kleinstein *et al.*, 1982; Good and Augsburger, 1989). The questions from these surveys were considered and expanded upon by a group of four research optometrists, all actively involved in optometric practice. An initial questionnaire was drafted to determine whether UK optometrists:

1. ask specific questions regarding BP and cardiovascular disease as part of their routine history and symptoms,
2. have access to a BP monitor in the practice(s) in which they work,
3. use a BP monitor on their patients in practice,
4. have set referral criteria for patients they suspect as having high BP / cardiovascular disease,
5. feel it is their role or future role to become more active in the detection and monitoring of BP and cardiovascular disease in optometric practice.

The initial questionnaire was sent to seven optometrists to determine how the questions were interpreted and whether any further amendments were appropriate (Table 2.01). This questionnaire was then merged with a colleague's questions on further investigative techniques to produce one questionnaire (Table 2.02). It was hoped the combined questionnaire would reduce the burden on the contacted optometrists (they only had one questionnaire to complete) and reduce production and mailing costs.

A trial run of the merged questionnaire was completed by a group of 67 optometrists attending a Continuing Education and Training (C.E.T.) day at Aston University in September 2000. The results (not shown) suggested that the questionnaire would be well received by the profession and that no misunderstanding of the questions had occurred. As the optometrists sampled were likely to be 'keener' members of the profession and naturally more likely to adopt less well used investigative techniques, the results were felt not to reflect the optometric profession as a whole and were not included in the final results.

The final questionnaire was sent out in December 2000 to 1402 optometrists (Table 2.02). The optometric sample was taken from databases of the optometric register and Dolland and Aitchison practices in the West Midlands area. The questionnaire results were double entered into an excel spreadsheet by P.H and A.M. and the results overlaid to eliminate data entry errors (0.12%) and corrected. The scoring sheet for the replies appears in appendix 1. All additional comments were entered into the computer, to avoid the loss of any information.

Management of the Hypertensive Patient

Practice type: Independent / Small Group / Franchise / Multiple*
(*circle as appropriate)
University Attended: Aston / Bradford / Cardiff / City / Glasgow / Ulster / UMIST*
Other:. . . . .
Years spent in Practice: 0- [ ] 5 - [ ] 10 - [ ] 15 - [ ] 20 - [ ] 25+ [ ]

1- When recording details on a patient's general health and medication, do you ask any of the following specific questions?

	No	Yes→Age of px	
a) Have you been diagnosed with High Blood Pressure?	[ ]	[ ]	. . . .
b) Do you take tablets for High Blood Pressure?	[ ]	[ ]	. . . .
c) When was the last time your GP checked your BP?	[ ]	[ ]	. . . .
d) Do you know what the last Blood Pressure reading was?	[ ]	[ ]	. . . .
e) Do you have any cardiovascular disease?	[ ]	[ ]	. . . .
f) Do you have raised cholesterol?	[ ]	[ ]	. . . .

2a - Would YOU adapt your routine on examination of a hypertensive patient?
No [ ]→ Q.2b
Yes [ ] → Please circle the following additional tests you would perform:
Direct Ophthalmoscopy with Green Filter — Dilation
Head Mounted BIO — Fundus Lens (eg Volk Lens)
Fundus Photographs — Visual Field Test
Other : . . . .

2b - Do you have blood pressure measuring equipment on the premises?
No [ ]→ Q3 Yes [ ] → Please circle the type of equipment you have:
Mercury Column / Aneroid / Automatic / Other:. . . . .→ Q2c

2c) How often do you use the equipment on: (*circle as appropriate)

All patients	Never / Sometimes / Always*
Hypertensives	Never / Sometimes / Always*
Suspect Hypertensives	Never / Sometimes / Always*
Patients with Headaches	Never / Sometimes / Always*
Other (please specify)	Never / Sometimes / Always*

3) To what importance would you grade the following criteria in influencing your referral of a patient to their General Practitioner for (suspect) systemic hypertension:

	Not Important			Moderately Important			Very Important
Symptoms	1	2	3	4	5	6	7
Haemorrhages	1	2	3	4	5	6	7
Elevated Blood Pressure	1	2	3	4	5	6	7
Tortuosity	1	2	3	4	5	6	7
A/V Crossings	1	2	3	4	5	6	7
Focal Arterial Constriction	1	2	3	4	5	6	7
A/V Ratio	1	2	3	4	5	6	7
Arterial Reflex	1	2	3	4	5	6	7

Table 2.01: Initial Blood Pressure questionnaire.

Further Investigative Techniques Questionnaire

Personal Details

University from which you graduated:

[ ] Aston [ ] Bradford [ ] Cardiff [ ] City [ ] Glasgow
[ ] Ulster [ ] UMIST [ ] Other ___________ (zero for no reply)

Gender: male (1) / female (2) ***Years qualified:*** ____ yrs

Your main form of employment:

(i) Location: [ ] Single practice
Practice with______ branches
[ ] Hospital
[ ] University
[ ] Other [ ] = Unknown... [ ] = 2 Places... [ ] = several Independent

(ii) Nature: [ ] Self-employed locum [ ] Employee [ ] Partner of practice / group
[ ] Owner of practice [ ] Other [ ] Combination

(iii) Mode: [ ] Full-time [ ] Part-time

Blood Pressure Measurement

The measurement of blood pressure is a good example of an additional procedure not currently part of a standard eye examination. This section allows you to express your opinions on its value in optometric practice.

1. For the following statements, please ring the number that best represents your opinion.

Blood pressure measurement in optometric practice	Agree			Neutral			Disagree
is appreciated by patients	1	2	3	4	5	6	7
is unnecessary	1	2	3	4	5	6	7
advances the profession	1	2	3	4	5	6	7
is not financially viable	1	2	3	4	5	6	7
should be measured on-indication	1	2	3	4	5	6	7
is treading on GP's toes	1	2	3	4	5	6	7
could be performed by an optometric assistant	1	2	3	4	5	6	7
is unpopular because of the extra chair time	1	2	3	4	5	6	7
should be measured routinely	1	2	3	4	5	6	7
would produce results I wouldn't know how to interpret	1	2	3	4	5	6	7

2. When recording details on a patient's general health and medication, do you usually ask any specific questions regarding their vascular health along the lines of:

	Never		Sometimes				Always	If >40yrs
"Have you been diagnosed with high BP?"	1	2	3	4	5	6	7	[ ]
"Do you take medication for high BP?"	1	2	3	4	5	6	7	[ ]
"When did your GP last check your BP?"	1	2	3	4	5	6	7	[ ]
"Do you know what the last BP reading was?"	1	2	3	4	5	6	7	[ ]
"Do you have any cardiovascular disease?"	1	2	3	4	5	6	7	[ ]
"Do you have raised cholesterol?"	1	2	3	4	5	6	7	[ ]
Other______________________________	1	2	3	4	5	6	7	[ ]

Table 2.02a: Final Questionnaire.

3. Would you adapt your routine when examining a hypertensive patient?

[ ] No [ ] Yes ⇒
- [ ] Direct ophthalmoscopy with a red-free filter
- [ ] Dilation
- [ ] Head mounted BIO
- [ ] Visual field test
- [ ] Fundus lens (e.g. Volk)
- [ ] Fundus photography
- [ ] Other ___________________

If yes, which additional procedures do you perform

4. Do you have access to a blood pressure monitor in your main place of practice?

[ ] No [ ] Yes ⇒
- [ ] Mercury column
- [ ] Aneroid
- [ ] Automated
- [ ] Other_______________

If yes, what type of instrument is it and

How often do you use it on the following patient groups:

	Never			Sometimes			Always
all patients	1	2	3	4	5	6	7
hypertensives	1	2	3	4	5	6	7
suspect hypertensives	1	2	3	4	5	6	7
patients with headaches	1	2	3	4	5	6	7
other ________________	1	2	3	4	5	6	7

5. How important are the following criteria in influencing your referral of a patient to their GP for suspected high blood pressure?

	Not at all			Relatively Important			Very Important
symptoms	1	2	3	4	5	6	7
haemorrhages	1	2	3	4	5	6	7
elevated BP	1	2	3	4	5	6	7
tortuosity	1	2	3	4	5	6	7
arterio-venous crossing changes	1	2	3	4	5	6	7
focal arteriolar constriction	1	2	3	4	5	6	7
arterio-venous ratio	1	2	3	4	5	6	7
arteriolar reflex	1	2	3	4	5	6	7

Routine pupil dilation

This section is designed to find out your opinion on the value of routine pupil dilation: note that for the purposes of this questionnaire, 'routine pupil dilation' can be defined as the use of mydriatic drops in the majority of adult patients' eye examinations.

6. For the following statements, please ring the number that best represents your opinion. Routine pupil dilation...

	Agree			Neutral			Disagree
is appreciated by patients	1	2	3	4	5	6	7
is unnecessary	1	2	3	4	5	6	7
advances the profession	1	2	3	4	5	6	7
is not financially viable	1	2	3	4	5	6	7
is unpopular due to light glare and drops stinging	1	2	3	4	5	6	7
is unpopular because of the extra chair time	1	2	3	4	5	6	7
protects against legal negligence claims	1	2	3	4	5	6	7
is unpopular because of the need to drive	1	2	3	4	5	6	7
improves the detection of retinal pathology	1	2	3	4	5	6	7
is dangerous due to inducing acute glaucoma	1	2	3	4	5	6	7

Table 2.02b: Final Questionnaire.

7. *In your estimate, what percentage of adult patients (including special groups such as those with diabetes) do you dilate?* _______%

Procedures that require topical anaesthesia

Many additional ophthalmic procedures require the use of anaesthetic eye drops and direct contact with the eye: for example, Perkins' tonometry or gonioscopy. This section is designed to find out your opinions on such procedures.

8. *For the following statements, please ring the number that best represents your opinion.*

Procedures that require topical anaesthesia

	Agree			Neutral			Disagree
are appreciated by patients	1	2	3	4	5	6	7
are unnecessary	1	2	3	4	5	6	7
advance the profession	1	2	3	4	5	6	7
are risky due to potential epithelial abrasions or melting	1	2	3	4	5	6	7
are not financially viable	1	2	3	4	5	6	7
should be performed <u>on-indication</u>	1	2	3	4	5	6	7
are unpopular due to the drops stinging	1	2	3	4	5	6	7
are unpopular because of the extra chair time	1	2	3	4	5	6	7
should be performed <u>routinely</u>	1	2	3	4	5	6	7
are risky due to potential cross-infection	1	2	3	4	5	6	7

9. *Do you use any of the following direct contact instruments in practice?*

	Yes	No
applanation tonometer (e.g. Goldmann / Perkins)	[ ]	[ ]
ocular blood flow tonometer	[ ]	[ ]
gonioscope	[ ]	[ ]
other:________________________________	[ ]	[ ]

Does or would the possibility of cross infection prevent you from using contact instruments that do not have disposable tips: for example, gonioscope lenses?

Yes [ ]   No [ ]

Thank you for your time and co-operation

If you have any further comments on the questionnaire or the issues it examines, please make them below:

Table 2.02c: Final Questionnaire.

2.30 - Results

Of the 1402 questionnaires mailed, 494 were returned completed. A further twenty were returned unanswered (optometrist moved, retired or deceased) and were not included in the analysis. The response rate was therefore 37.0%. The responses were calculated as percentages, and the number of subjects of those who had completed the question being analysed is included in the category given in brackets. For each of the numerically graded questions, the full range (-3 - +3 and 1 - 7) of responses were utilised denoting a high questionnaire sensitivity (Streiner and Norman, 1996).

2.31 - Demographics

Fifty four percent (269) of the optometrists were male and 45% (224) were female. The average length of career in optometric practice was 16.6 ± 10.6 years, covering the range from 0 years (pre-registration) to 57 years. Full time optometrists accounted for 73% (360) and part time 21% (103) of the sample. The university break down is shown in Figure 2.01.

Figure 2.02 illustrates the nature of optometric practice (i.e. Self Employed (SE) Locum, Employee, etc). Nature of employment classified as Combination 1% (Figure 2.02) included: SE Locum and Owner (2); SE Locum and Employee (1); Partner and Owner (1) and Owner and Employee (1). Other employment 0.04% (Figure 2.02) was stated as Director (1) and Franchisee (1). Fifty percent of those who responded stated they were an employee and 46% that they were working in a single practice.

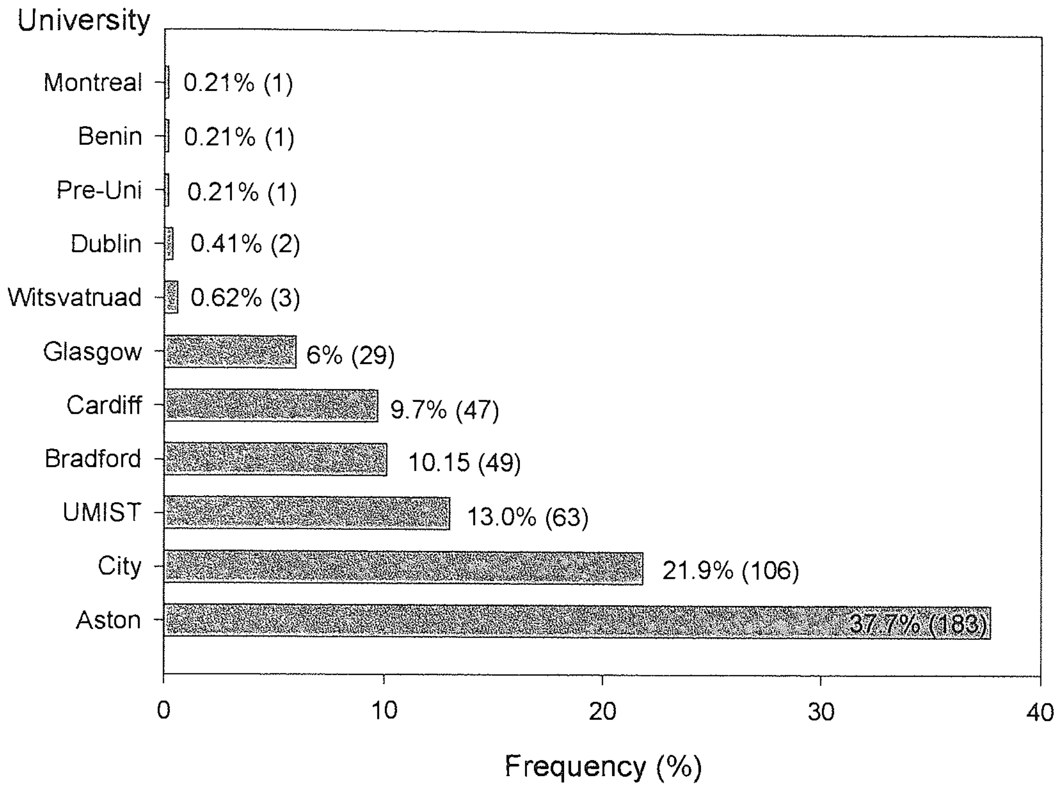


Figure 2.01: University attended (486 optometrists).

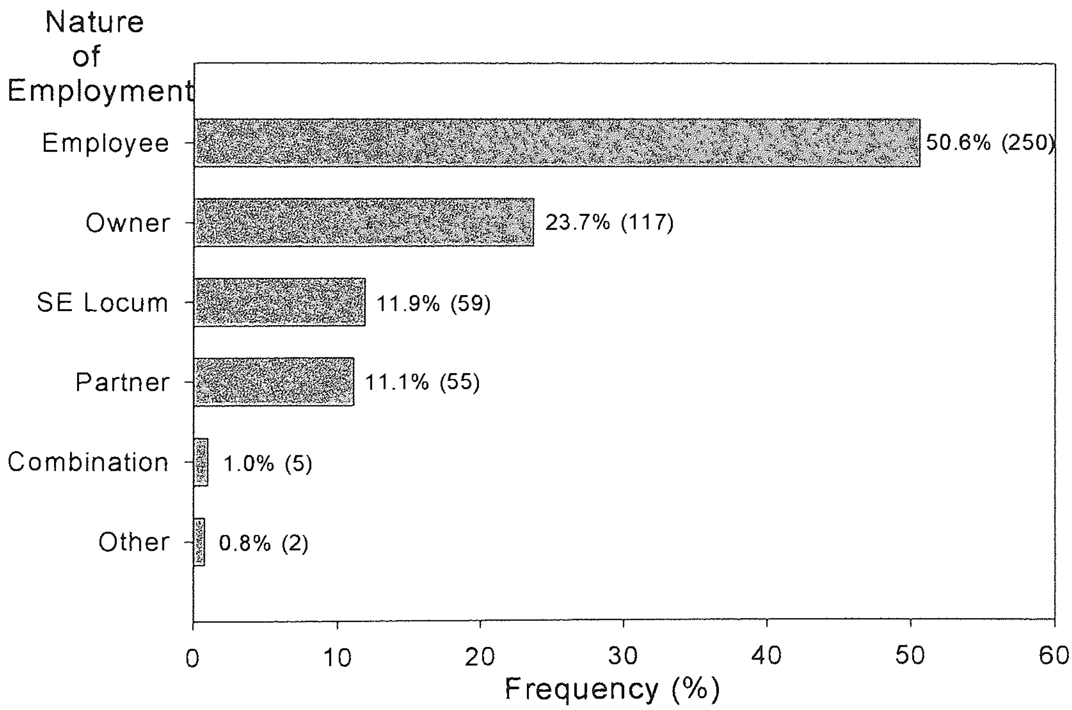


Figure 2.02: Nature of employment (490 optometrists).

2.32 - Blood Pressure Measurement in Optometric Practice

To assist in the interpretation of this question, the scoring system was constructed so that a neutral response to BP monitoring was scored as zero, a favourable response as a positive number and an unfavourable response as a negative number. The number increases with the magnitude of feeling, up to a score of ±3 (Table 2.03). The responses of the optometric profession are displayed in Figure 2.03. On average the response was neutral to slightly positive towards the use of BP monitors, but not on a routine basis. However, a great deal of variability between optometrists was highlighted as the full range of each scale was utilised. The breakdown of the profession into the four main categories of the respondents (SE locum, employee, partner and owner) is shown in Figure 2.04. The results indicate there is no clear differences in opinion on the use of BP monitoring in optometric practice with varying employment modalities.

Q1. For the following statements, please ring the number that best represents your opinion.

Blood pressure measurement in optometric practice...

	strongly disagree			neutral			strongly agree
a) Is appreciated by patients	-3	-2	-1	0	+1	+2	+3
b) Is necessary	-3	-2	-1	0	+1	+2	+3
c) Advances the profession	-3	-2	-1	0	+1	+2	+3
d) Is financially viable	-3	-2	-1	0	+1	+2	+3
e) Should be measured on <u>indication</u>	-3	-2	-1	0	+1	+2	+3
f) Does not encroach on the GP	-3	-2	-1	0	+1	+2	+3
g) Can be tested by an optical assistant	-3	-2	-1	0	+1	+2	+3
h) Chair time is not an issue	-3	-2	-1	0	+1	+2	+3
i) Should be measured routinely	-3	-2	-1	0	+1	+2	+3
j) I would be able to interpret the results	-3	-2	-1	0	+1	+2	+3

Table 2.03: Question 1 scoring system, enabling improved comparison of the statements on BP monitoring.

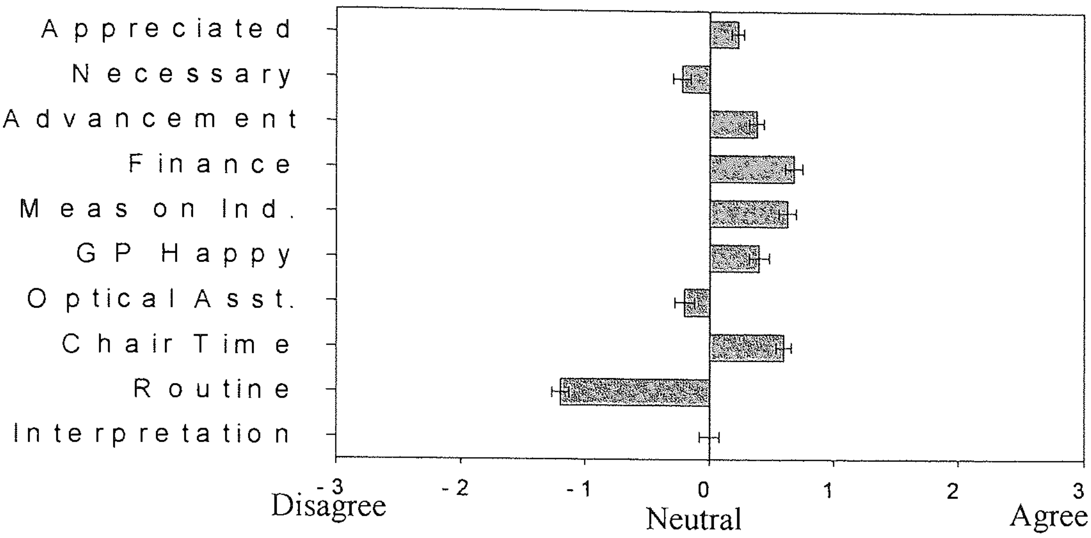


Figure 2.03: Optometric opinion on Blood Pressure measurement - whole profession (n=494; Error bars = 1 S.E.M.).

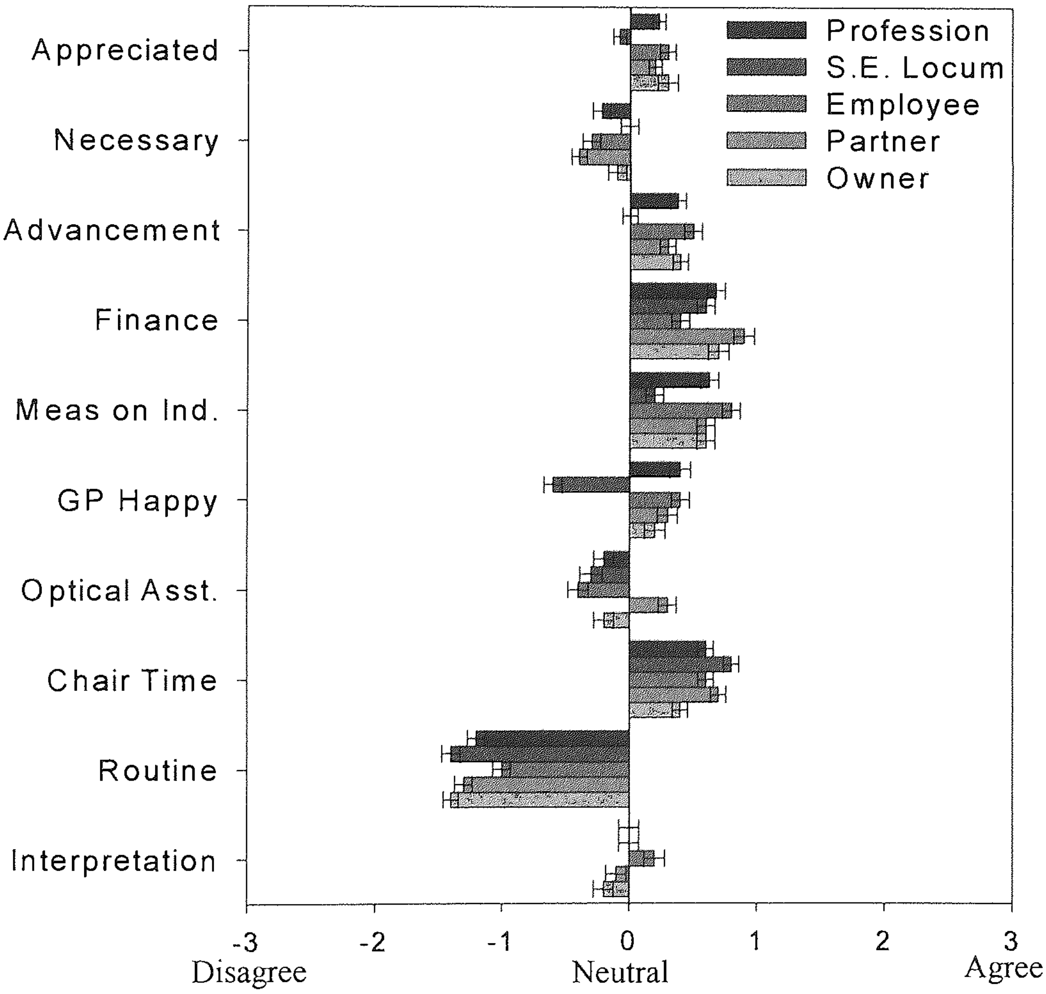


Figure 2.04: Optometric opinion (employment modality) on Blood Pressure measurement (n=494; Error bars = 1 S.E.M.).

2.33 - History & Symptoms

– Questions Concerning a Patient's Cardiovascular Status

The scoring system for history and symptoms is illustrated in Table 2.04 and the results in Figures 2.05 (whole profession) and 2.06 (response fragmented into various employment modalities). The history and symptoms taking of the whole profession mirrors that recorded by the various working practices. The most frequently asked question concerns the medication which the patient is presently taking and the least is on specifying what the last BP reading was. 100 optometrists stated that they asked additional questions concerning cardiovascular disease, of which 41 specified the actual question asked (Figure 2.07).

Q2. When recording details on a patient's general health and medication, do you usually ask any specific questions regarding their vascular health along the lines of:

	Never		Sometimes				Always
"Have you been diagnosed with high BP?" *HBP Diagnosed*	1	2	3	4	5	6	7
"Do you take medication for high BP?" *Medication*	1	2	3	4	5	6	7
"When did your GP last check your BP?" *Last BP Check*	1	2	3	4	5	6	7
"Do you know what the last BP reading was?" *BP Reading*	1	2	3	4	5	6	7
"Do you have any cardiovascular disease?" *Cardio. Dis.*	1	2	3	4	5	6	7
"Do you have raised cholesterol?" *Cholesterol*	1	2	3	4	5	6	7
Other *Other*	1	2	3	4	5	6	7

Table 2.04: Scoring system for question 2.

Words in Italics represent the labelling for Figures 2.05 and 2.06.

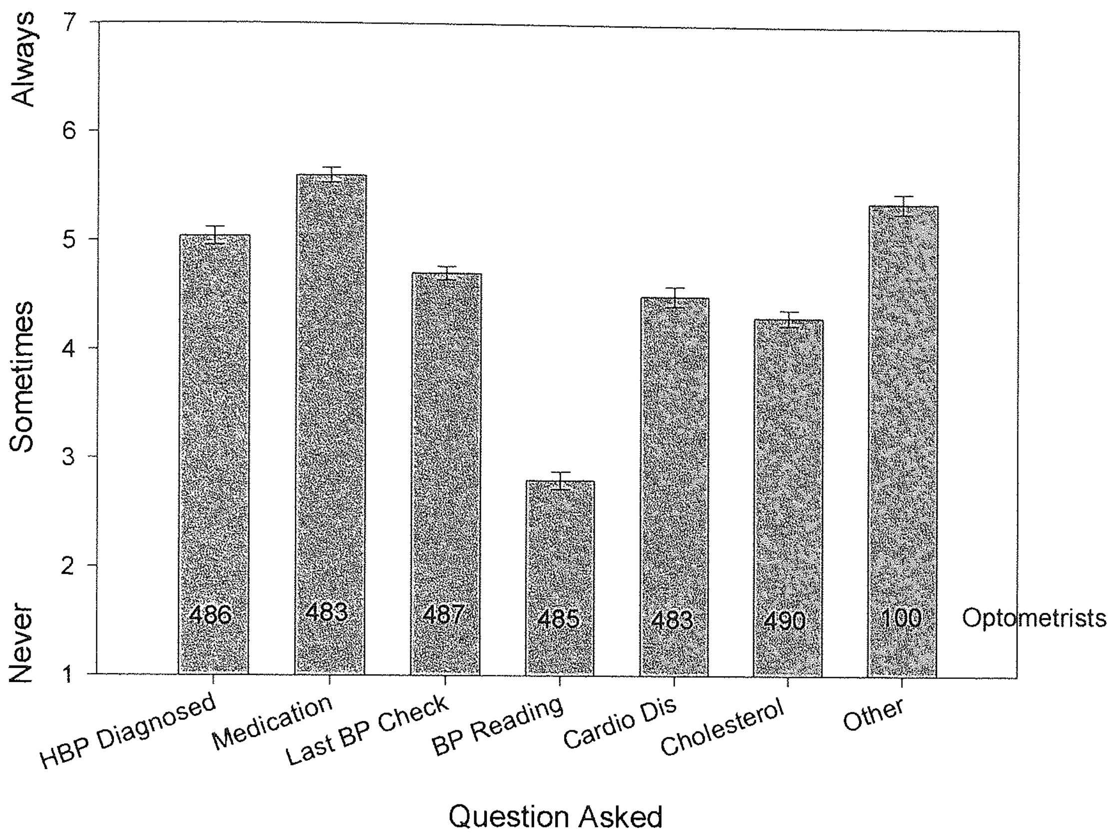


Figure 2.05: History and symptoms.

Questions concerning cardiovascular disease – whole profession.

(Error bars = 1 S.E.M.)

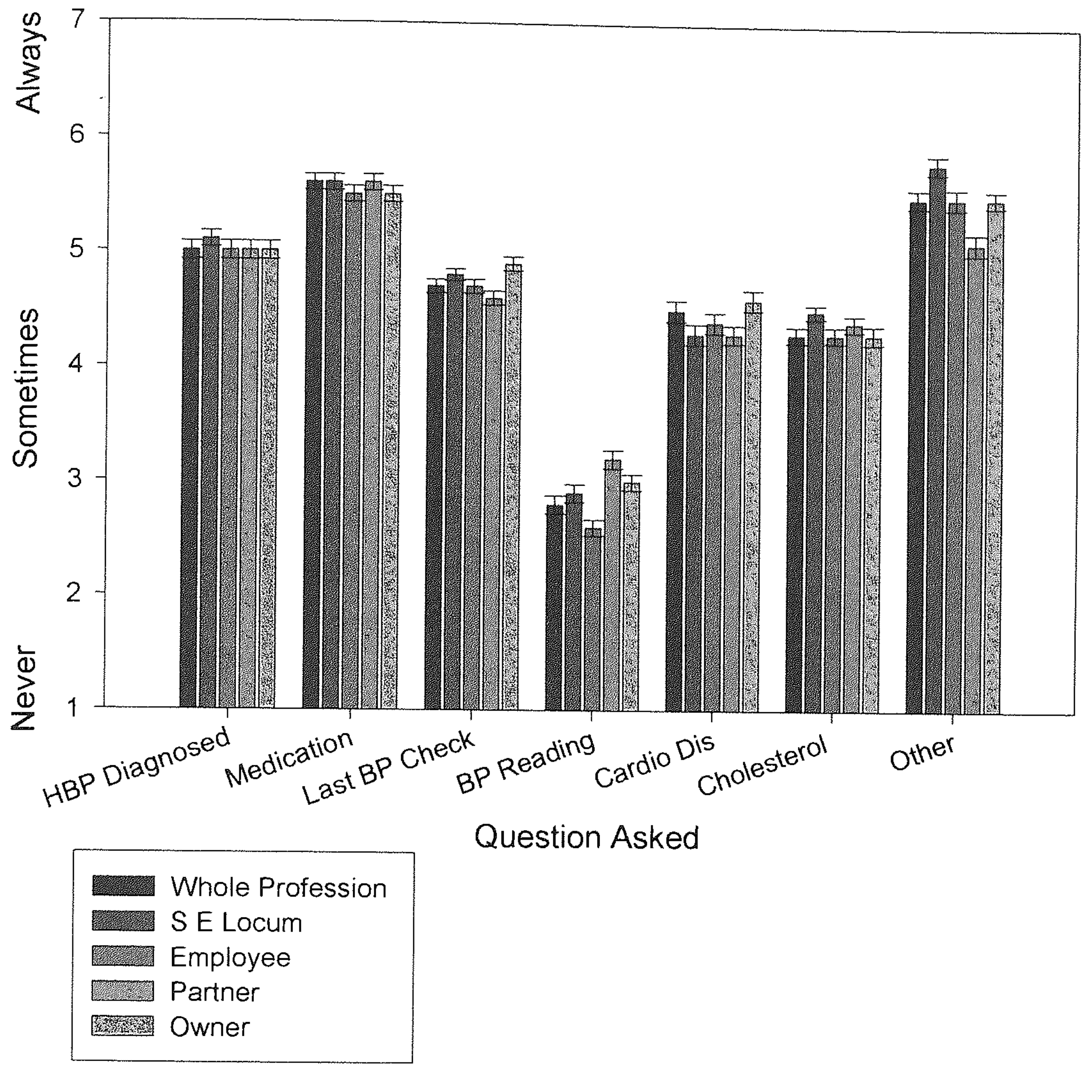


Figure 2.06: History and symptoms.

Questions concerning cardiovascular disease – employment modality.

(Error bars = 1 S.E.M.)

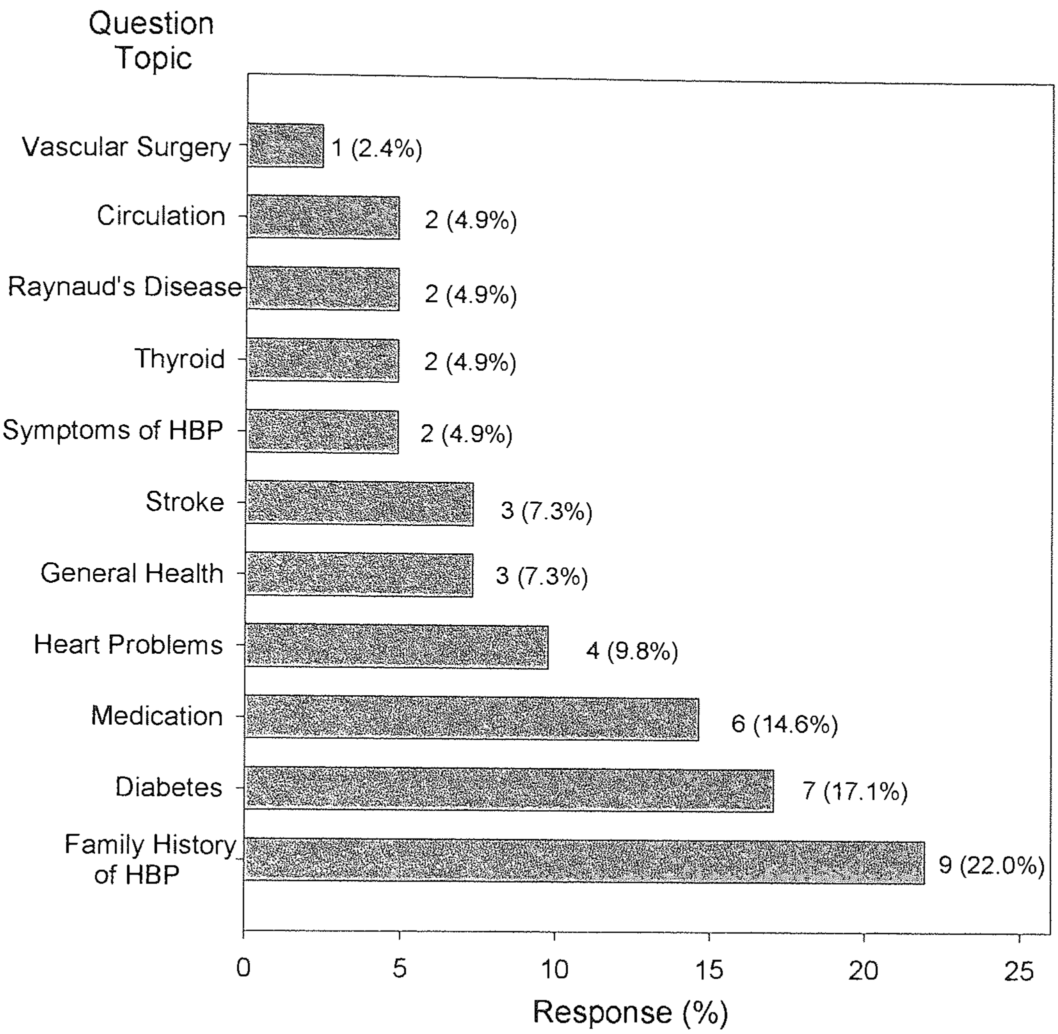


Figure 2.07: History and symptoms – specified "other" questions asked.

– whole profession (n=41).

2.34 - Eye Sight Examination for the Systemic Hypertensive Patient

Respondents were asked whether or not they altered their routine for patients they knew or suspected had systemic hypertension. Optometrists were free to list all additional procedures which they would perform, if necessary, in the examination of their suspect / systemic hypertensive patient (range one to six; n=184). The additional tests most widely used in the examination of the systemic hypertensive patient were direct ophthalmoscopy with red free filter 21% (104), fundus lens retinal imaging 17% (85), visual fields 16% (81) and dilation 13% (65), as shown in Figure 2.08. Other additional techniques performed were specified as: detailed examination of the fundus / vessels (2); slit lamp (1); BP measurement (1); and ocular blood flow (1). Employees were the most likely group to adapt their routine when examining a systemic hypertensive patient and partners the least (Figure 2.09).

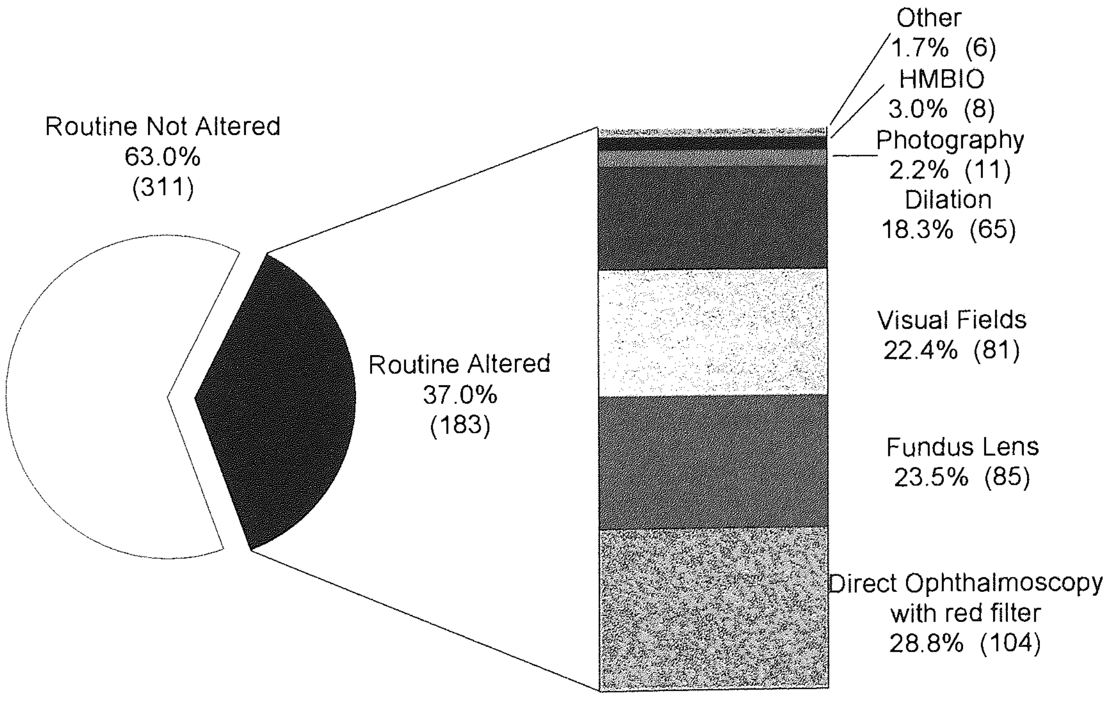


Figure 2.08: Additional procedures carried out in the examination of the systemic hypertensive patient (184 optometrists).

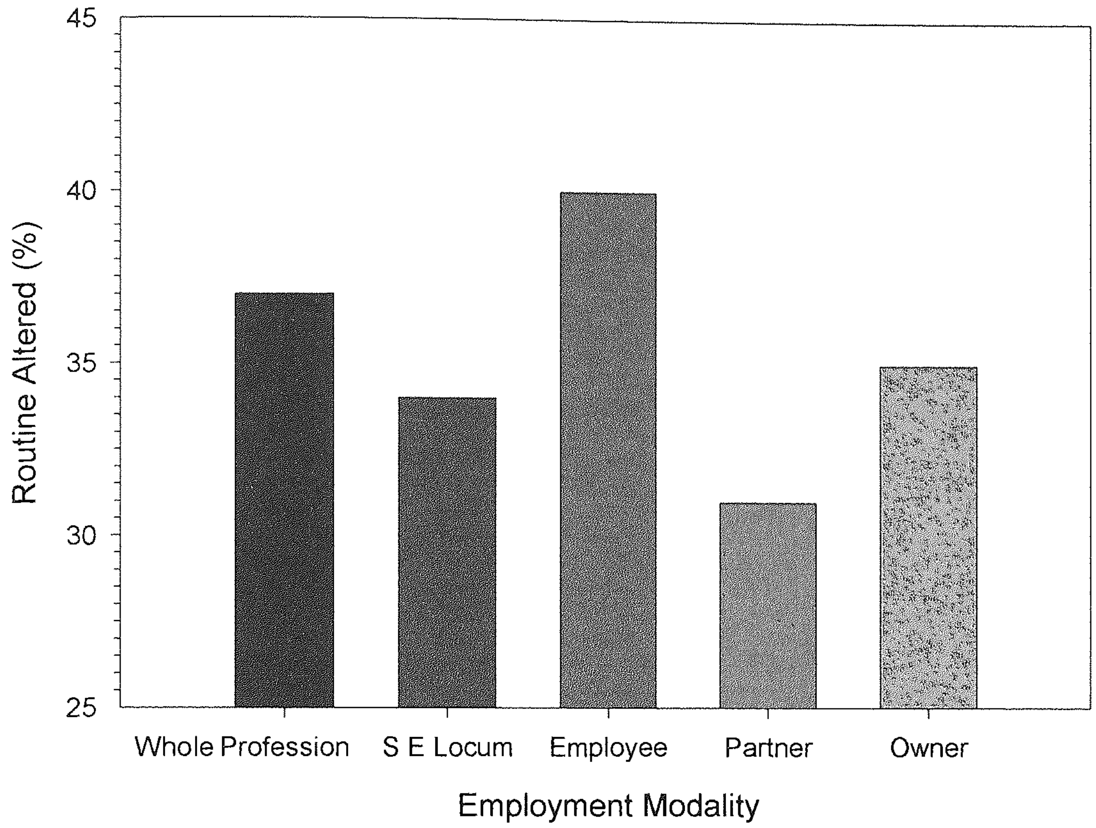


Figure 2.09: The use of additional procedures on systemic hypertensive patients with employment modality.

2.35 - Blood Pressure Monitors in Optometric Practice

The availability of BP monitors in optometric practice was 11% (54; Figure 2.10). The automatic BP monitor was the most popular, present in 85% (46) of the practices with BP monitors. Five practices had several types of machines: mercury column and automatic (1), aneroid and automatic (3) and mercury column, aneroid and automatic (1). The response stated as not sure (1) was from a hospital optometrist where the nurses record the patients' BP. On average, 1 in every 8.5 optometrists knew they had access to a BP monitor. The breakdown with work modality was: 1:3.7 (Owner); 1:7.9 (Partner); 1:20.8 (Employee) and 1:59.0 (Locum).

The frequency of use of the BP monitors with different patient groups is illustrated in Figure 2.11. The additional patient groups were: patients with fundus changes (e.g. retinal vein occlusion; 2); diabetics (2); patients who do not visit their GP (1): patients who experience "dizzy spells" (1); as part of a full private sight test (1); and on a patient's request (1). Five respondents specified 'other' but did not complete any details.

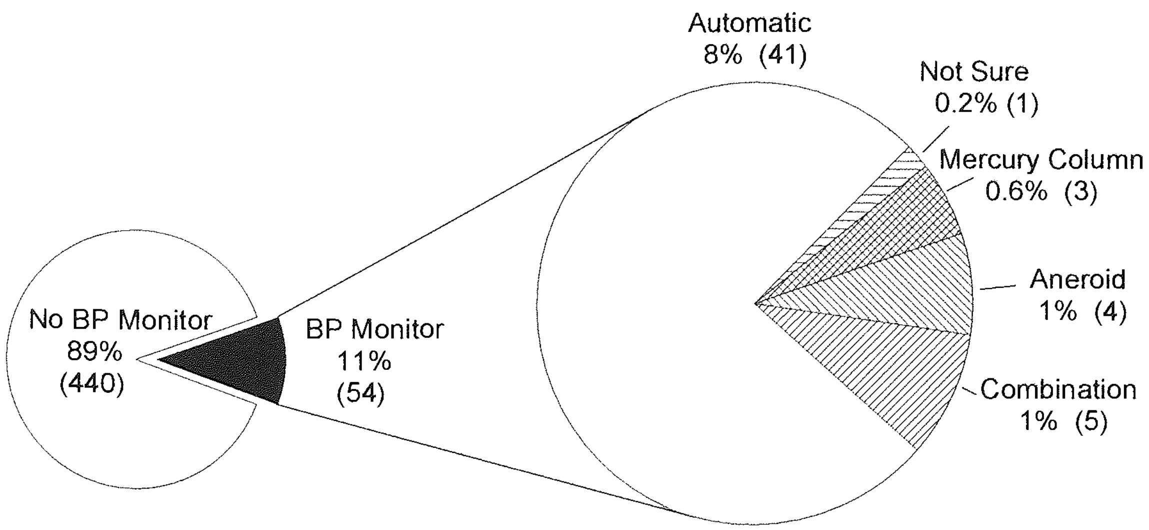


Figure 2.10: Availability of BP monitors in optometric practice.

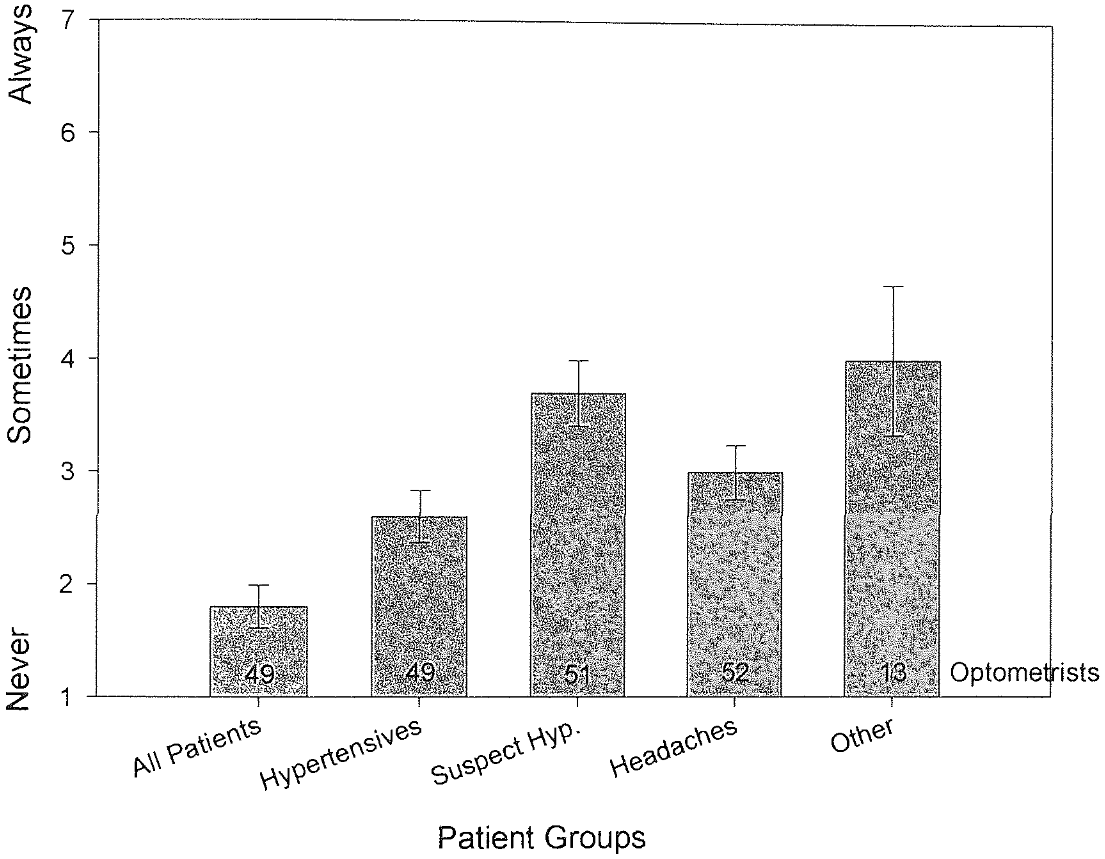


Figure 2.11: Frequency of use of Blood Pressure monitors in optometric practice.

(54 optometrists; Error bars = 1 S.E.M.).

2.36 - Referral Criteria for Patients with Suspected High Blood Pressure

The relative importance of the clinical findings from the sight test in determining the referral of a patient for suspected systemic hypertension is shown in Figures 2.12 (whole profession) and 2.13 (variation with employment status). Haemorrhages (malignant systemic hypertensive change) are the most important finding in influencing a practitioner's referral criteria. The next greatest influence on referral is the findings of focal constriction and A/V crossing changes. These opinions are mirrored in the response split into employment modalities. One response stated that the combined findings were more important than the individual ones.

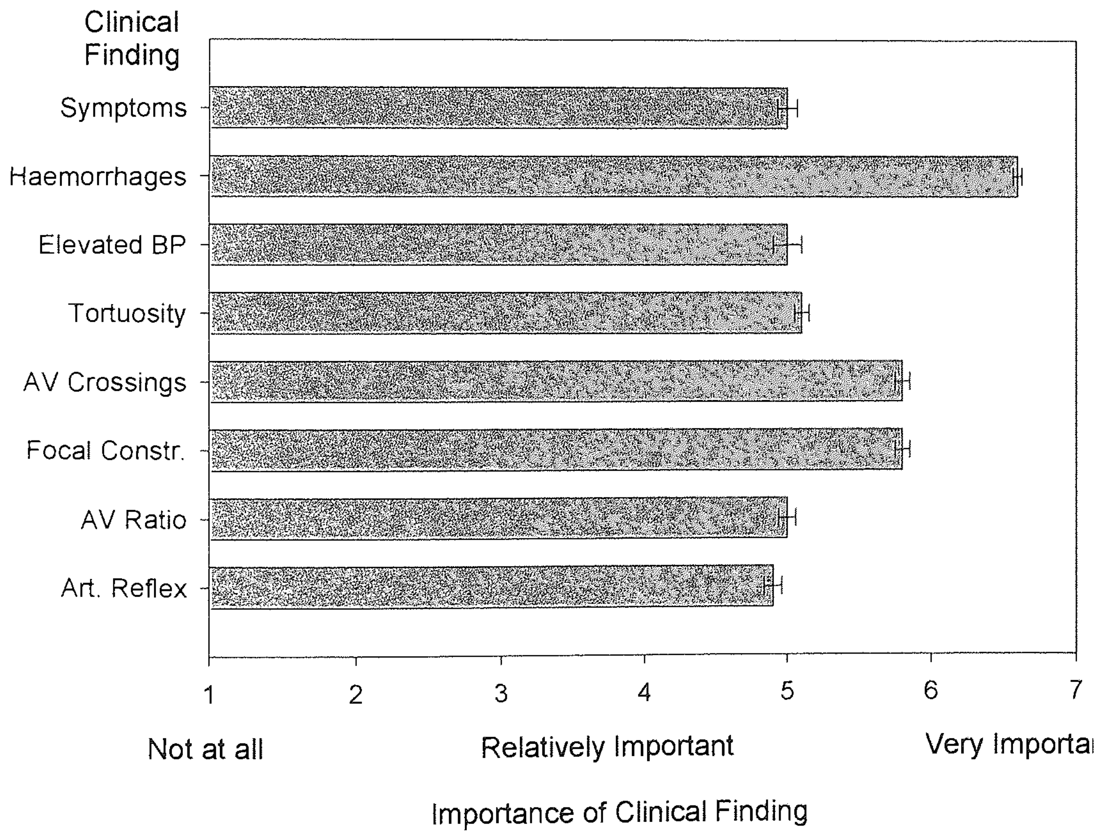


Figure 2.12: Importance of clinical findings in the referral of the systemic hypertensive patient. Whole profession (error bars = 1 S.E.M.).

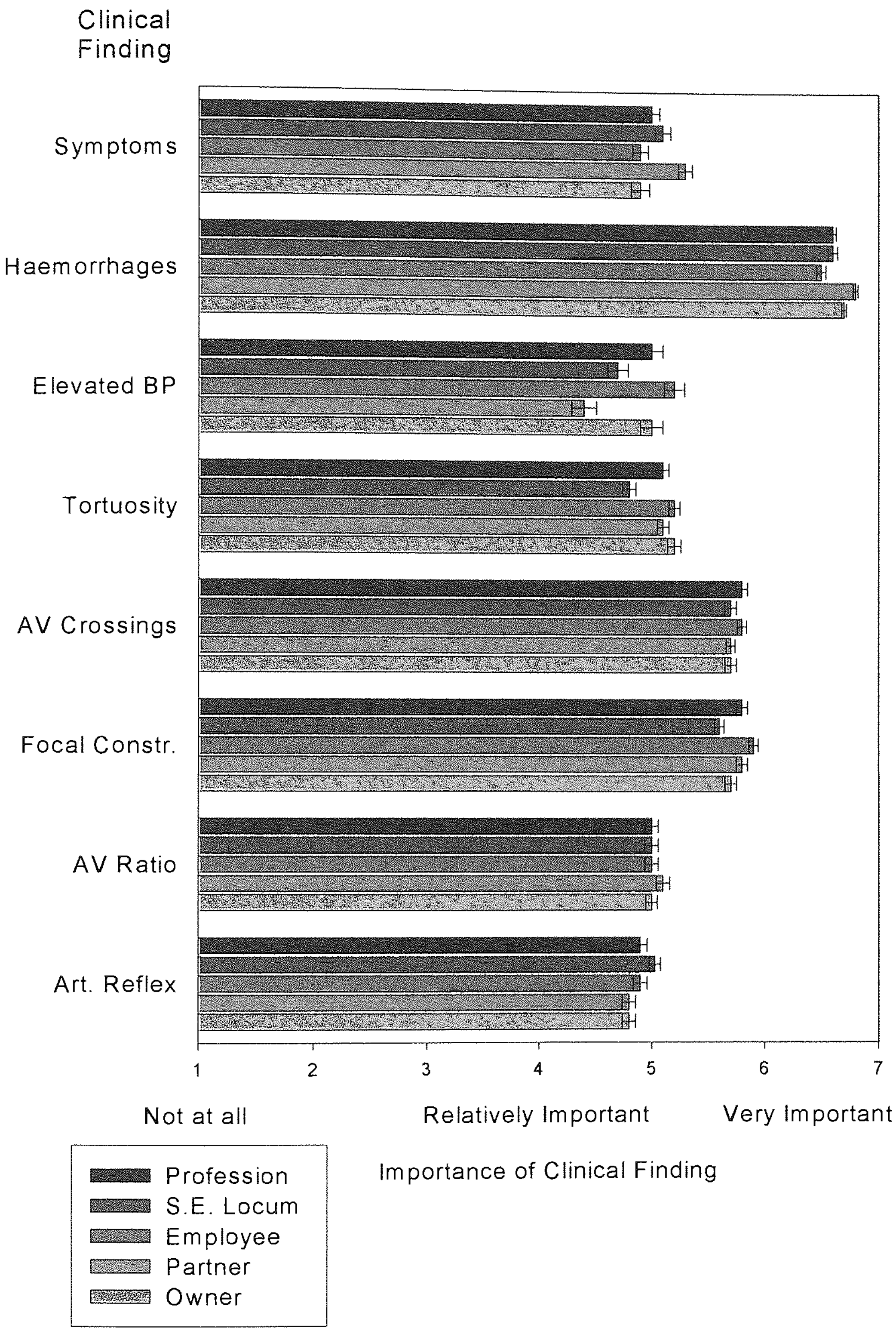


Figure 2.13: Importance of clinical findings in the referral of the systemic hypertensive patient. Variation with employment modality (error bars = 1 S.E.M.).

2.40 - Discussion

2.41 - Survey Demographics

The demographics of the population of optometrists sampled would suggest that those who responded to the questionnaire are representative of the optometric profession. In England and Wales, children leave school at 18 years old after completing their A levels and the optometric degree course is 3 years in duration, with an additional year to undertake the Professional Qualifying Examination of the College of Optometrists. If no gap years are taken and no major re-sits are needed, then one can enter the profession at the age of 22. At the present time in the civil service, men are required to retire at the age of 65 years and women at 60 years. Therefore, the average career of an optometrist is in the order of 40 years. As there has been an increase in the number of people graduating with an optometry degree over the past decade, the average optometrist will have been qualified for just under 20 years, as was true of our population.

Although initially, the optometric profession was dominated by men (as were many professions), there has been a gradual increase in the number of women optometrists in recent years. This balance is reflected in the demographics of the population sampled: survey 45.3% female versus profession 46.4% female (General Optical Council, 2002). A large proportion of the respondents had trained at Aston University, as would be expected in a sample of optometrists in the Midlands of the United Kingdom, although a reasonable number of universities were represented.

The response rate of 37.0% equated to 5.7% of the optometrists registered in the UK in 2000 (General Optical Council, 2002). This response was over twice (17.3%) that of a questionnaire by the Directorate of Continuing Education and Training (D.O.C.E.T.)

who sampled the whole profession for views on Continuing Education (D.O.C.E.T., 2001). Both of these are lower than that recorded by other surveys of the optometric profession: 68% by Willis and colleagues (2000) and 88% by Korb (2000). These response rates are perhaps higher as they are aimed at niche treatments (glaucoma and dry eye management respectively) from a limited sample of the profession, rather than a general opinion on investigative techniques from a broad spectrum of the profession.

2.42 - Employment Modality

A larger than expected percentage of respondents stated they were working in a single practice. As some optical chain stores work on a franchise basis, the differentiation between 'multiples' and 'independents' has been blurred. However, using these titles in questions regarding the nature of optometric practice is known to cause a reaction against 'labelling' by some optometrists and was therefore avoided. As was expected, the majority of optometrists are employees, with approximately one quarter owning their own practice and a further 11% being a partner in a practice. Twelve percent of respondents were self-employed locums, a mode of practice encouraged by the shortage of optometrists and the resulting high salaries on offer. With the increase in the numbers of optometrists being trained, it is likely that this employment group is likely to decrease over the next few years.

2.43 - Optometric Opinion on Blood Pressure Measurement

The results of this study indicate that on average, optometrists are fairly neutral towards the measurement of BP in optometric practice, even though the whole range of questionnaire grading responses were utilised. The balance of opinion was that although the measurement of BP in practice had limited effect on chair time and was financially viable, it should be measured by them (not an optical assistant), on indication (not routinely). This finding is the opposite of that found from a survey of American optometrists which revealed that of all the optometric procedures the measurement of BP was considered to be the primary job which should be delegated to an optical assistant (90% of respondents; Eger, 1982).

It was felt that the measurement of BP would advance the profession, being appreciated by both patients and GPs, but is not necessary and optometrists are not sure they would be able to interpret the results. It is perhaps surprising that BP measurement was felt to be the optometrist's role, when many other additional health screening tests used as part of the optometric routine, such as visual fields and tonometry, are performed by optical assistants in many practices. Maintaining BP measurement as the optometrists' role may suggest the involvement of skill in its measurement (unlikely with modern automated BP measurement devices) or a sensitivity issue (perhaps towards the patient). The results from the American survey into the impact of delegating the pre-screening was not considered a threat to the future of optometrists by 76% of the sample and 78% felt that patients accepted the fact that these screening tests were performed by optical assistants rather that the optometrist (Eger, 1982).

Optometrists generally felt their knowledge of interpreting BP results was average, so continuing education in this area would be warranted if optometrists were to take a more active role in BP monitoring. The optometric opinion towards BP measurement was generally mirrored by all the employment modalities of optometric practice (measurement of BP did not encroach on the GPs' territory), except for self-employed locums who on balance thought that BP measurement encroached on the GPs' domain, and therefore, were less enthusiastic about measuring BP on indication than their colleagues. In addition, practice partners were more inclined to allow optometric assistants to measure BP on their behalf, while the rest of their opinions were similar to those of other practice modalities. The differing response towards the management of the suspect / systemic hypertensive patient in optometric practice from the various employment modalities could be seen as being financially motivated.

2.44 - History and Symptoms Record Keeping

Most optometrists ask some questions relating to cardiovascular disease in their history and symptom taking, although even more general questions (such as what medication the patient is taking) were not asked by all optometrists. The results are almost identical for each of the optometric employment modalities investigated. It is essential that eye-care practitioners are aware of whether a patient has been diagnosed with systemic hypertension and of all the systemic medications they are taking. Systemic β-blockers used to control systemic hypertension may interact with topical glaucoma medication, such as by increasing side effects or affecting intraocular pressure. In addition, the presence of significant cardiovascular disease may be a contraindication for non-selective β-blocker therapy (e.g. timolol). Systemic absorption of phenylephrine hydrochloride through conjunctival vessels or nasal and oral mucosa after topical instillation can cause a rapid rise in systemic BP (Garston, 1975). Unfortunately, even with an optometrist asking direct questions it has been suggested that patient reporting of hypertensive history is notoriously unreliable (Scheie, 1953; Wolffsohn *et al.*, 2001).

The question asked least often concerned the actual BP reading and the last time it was measured. Although it could be felt that the last person to measure the BP should be responsible for responding to the level found, many people now self-monitor their BP level and may not be aware of the implications of their results. The BP level also influences the progression of disease conditions such as the prevalence of retinopathy in systemic hypertension and visual field defects in glaucoma. It is important to note that the duration of systemic hypertension will also have some bearing on the prevalence of hypertensive retinopathy. Of the 41 respondents who asked additional questions (recorded as 'other'), the most frequent was to enquire if there was a family history of high BP (22%; n=9). A family history of systemic hypertension related mortality increases an individual's mortality by threefold and is, therefore, an important question to include in the history and symptom taking of a systemic hypertensive patient (Grundy, 1990). Questions regarding heart problems and diabetes mellitus were also frequently asked, both of which relate to the patient's vasculature health. Several of the other replies indicated more global questioning such as 'general health' and 'general medication', but such general questions are known to have a poor accuracy and often overlook the subject's vascular health (e.g. Wolffsohn *et al.*, 2001).

2.45 - Systemic Hypertensive Sight Examination

One-third of optometrists were found to change their routine when they knew or suspected their patient was suffering from systemic hypertension. Of the additional techniques added to their routine, approximately 95% were conventionally available in optometric practice. Most of the techniques were aimed at improving the observation of the retina: photography, dilation, use of a red free filter, head-mounted binocular indirect ophthalmoscope or fundus lens. Nearly half (44%) of those who altered their routine would perform a visual field assessment, which would be of limited assistance in detecting pre- and possibly also malignant hypertensive retinopathy. Employees were most likely to alter their routine for a patient with systemic hypertension and partners least likely. As employees tend to be at an earlier stage of their career than partners, this finding could suggest an improved level of university training over the past decade, or that partners have a higher confidence in their ability or a more relaxed attitude than their younger colleagues.

2.46 - Availability of Blood Pressure Monitors in Optometric Practice

Of the 494 respondents, 11% knew that they had access to a BP monitor at their practice and the majority of these were automatic (>75%), probably due to their ease of use, objective nature and high repeatability. The breakdown of access to a BP monitor with employment modality would suggest that most practices do have a BP monitor, but the less the optometrist is involved in the running of the practice, the less likely they are to know about its presence. An alarming number of self-employed locum optometrists did not know of the presence of a BP monitor in the practices in which they worked (>98%). Automated BP monitors are inexpensive, small and portable and could easily be carried from practice to practice by a locum optometrist if they so wished.

Even when the optometrist knew of a BP monitoring devise in their practice, it was rarely used. Very few measure the BP of all their patients and even on people with known or suspect hypertension or headaches it is only sometimes used (on average). Again, the full range of the questionnaire scale was used for each sub-question indicating that some people always tested each of the groups, whereas others never tested them. In addition to the circumstances for measuring BP suggested, respondents highlighted that they sometimes measured BP on people with fundus retinopathy (who are suspect hypertensives or diabetics), diabetics and those who experience dizzy spells (one of the few symptoms of systemic hypertension). In addition, BP screening was performed by a few optometrists on the patient's request or for those who admitted to not visiting their GP regularly.

2.47 - Systemic Hypertensive Retinopathy

The clinical finding of most significance to an optometrist indicative of systemic hypertension was the presence of haemorrhages. This is a sign of malignant systemic hypertension, but also occurs in diabetics and approximately 6% of the healthy population (Hayreh, 1989; Klein, 1993, 1994). Despite their non-diagnostic nature and relatively late onset in the progression of systemic hypertension, their presence is easily determined with an ophthalmoscope (Michaelson *et al.*, 1967). Focal arteriolar constriction and A/V crossings of the blood vessels were graded as the second most important factor in the referral of a patient with systemic hypertension, with all other clinical findings, including the presence of elevated BP and symptoms rated as only relatively important. Focal constrictions of the retinal blood vessels would appear to be the most important retinal feature of cardiovascular disease and the only retinal sign unique to systemic hypertension (Dimmitt *et al.*, 1989; Klein *et al.*, 1993, 1997). Together with elevated BP, the research literature would suggest that this is the most diagnostic sign of systemic hypertension, particularly in the pre-malignant stage, when the benefits of medical treatment may be greatest.

2.48 - Additional Comments

Additional comments which where made about the use of BP monitors in optometric practice (7% of respondents) were mainly of a negative stance. These comments suggested that there was no time within an eye examination to measure BP and that there was no financial remuneration. In addition, some optometrists thought they were not trained enough to monitor BP in their patients (it was the role of the GP) and by doing so they would open themselves to the possibility of legal dispute. The few favourable comments proposed that optometrists who measured BP not only saved the GPs' time, but also the patients' time, and that a knowledge of a patient's BP assisted the optometrist in the monitoring of eye disease, such as diabetes and glaucoma.

2.50 - Conclusion

In conclusion, therefore, there is a wide range of opinion towards the monitoring of BP by optometrists within the optometric profession. Knowledge of the relative diagnostic significance of the retinal signs of systemic hypertension is sketchy and the quality of eye examination, both in terms of a thorough history and symptoms and the use of additional diagnostic tests, received by patients with systemic hypertension is variable. Many optometrists do not believe they have access to a BP monitor, but it would appear that they are more common in practice than they think. Therefore, if BP monitoring is to become a more integral part of the optometrists' role in the future, both a change in attitude and an increase in knowledge in this important disease will be necessary.

CHAPTER 3 - OBJECTIVE GRADING OF THE RETINAL VASCULATURE

CROSS-SECTIONAL STUDY

3.10 - Introduction

The appearance of the retinal vasculature reveals information on the state of the disease that is recordable in terms of vessel diameter (radial stretching), colour and tortuosity (longitudinal stretching; Gang *et al.*, 2002; Heneghan *et al.*, 2002). Variation in the vessel's appearance can also be due to its response to ageing (Brinchmann-Hansen *et al.*, 1987). These changes are presently determined in optometric practice qualitatively, through examination of the fundus with direct observation or fundus photographs, and recorded in descriptive terminology (chapter 2). The incorporation of fundus photography into the sight examination, even if no subjective grading is performed, provides a firmer baseline for evaluating longitudinal change than descriptive record keeping (Davis *et al.*, 1985; Gilchrist[a], 1987). The interpretation of fundus photography has been found to be twice as sensitive as ophthalmoscopy (Palmberg *et al.*, 1981).

The changes in the retinal vessels in the pre-malignant stage are subtle (chapter 1) and, therefore, require reliable accurate detection and analysis to monitor and assist in the management of the systemic hypertensive patient (Newsom *et al.*, 1992). Computer based detection and analysis could offer increased accuracy in the monitoring and classification of these subtle retinopathic changes (Gilchrist[a], 1987).

Computer assisted algorithms designed to detect the location and orientation of vessel edges take two forms: edge detection and filter matching. Edge detection determines the location along a path at which a threshold value is reached. The shortest distance between two such "edges" along the line perpendicular to the vessel will identify the diameter. Filter matching locates the edges of the vessel through convolving the vessels with a filter selected to be a suitable model of vessel profile, the output of which reaches maximum when the filter alignment matches the vessel (Wu *et al.*, 1995; Gang *et al.*, 2002).

3.11 - Fundus Photography

The problem with colour images is the extraction of the blood vessel from the background retina (Akita and Kuga, 1982). Monochromatic illumination (red-free filter) can enhance the visibility of various ocular features accentuating the difference in reflectance between the structure and the background. The light reflected back off the structures is determined by the pigment in the erythrocytes (melanin and haemoglobin), light absorption and light scattering by the tissues (Delori *et al*, 1977). For example, the retinal vessels, haemorrhages, and microaneurysms have their optimum visibility between 530-590nm (Duerey *et al.*, 1979; Weinberger *et al.*, 1999). In general, as the illumination wavelength is increased there is a sharp increase in the apparent light penetration in the layers of the fundus. However, the choroidal circulation is essentially masked by the retinal pigment epithelium (Xu *et al.*, 2002).

The contrast, between the vessel and the background, is improved by passing it through a green filter to produce a high contrast black and white image (Wu *et al.*, 1995). The contrast of the retinal image can be improved further in those photographs taken with the assistance of fundus fluorescein angiography (FFA; Heneghan *et al.*, 2002).

Fundus photographs, coupled with computer image processing, will reduce the loss of information which occurs in written records of a patient's fundus, giving a permanent record of any retinopathy and allowing an improved accuracy in the monitoring of subtle changes in the retinal vasculature over time (Gilchrist[b], 1987; Eaton and Hatchell, 1988; Newsom *et al.*, 1992).

3.12 - Previous Analysis of the Retinal Vasculature

Early attempts to quantitatively measure the width of blood vessels involved the projection of a fundus image onto a screen for manual measurement with a gauge (Hodge *et al.*, 1969). Over the last decade, improvements in technology have allowed objective and higher resolution measurements using computer edge detection (Eaton and Hatchell, 1988; Rassam *et al.*, 1993, 1994; Kergoat and Lovaski, 1995; Wu *et al.*, 1995; Sugiyama *et al.*, 2000). These research projects have developed the computer algorithms to extract and analyse the retinal blood vessels. Further research into the clinical application of these computer algorithms in the detection of the influence of systemic hypertension on the retinal appearance is sparse.

Previous studies have suggested that a change in BP will have little effect on the retinal vasculature due to autoregulation (Tso and Jampol, 1982). The limited amount of specific research utilizing image analysis of retinal vessels with relation to systemic hypertension has shown that the diameter of blood vessels decrease after exercise (Kergoat and Lovaski, 1995), vary with the cardiac cycle (Chen *et al.*, 1994), and increase by administration of a carbonic anhydrase inhibitor (Rassam *et al.*, 1993). There is debate over whether the change in blood vessel width is correlated with ocular blood flow (Wolf *et al.*, 1998; Sugiyama *et al.*, 2000) and BP level: larger in hypertensives (Houben *et al.*, 1995) or normotensives (Hill and Dollery, 1963). The paths of the retinal blood vessels have also been found to change over time with epi-retinal membranes (Weinberger *et al.*, 1999).

3.13 - Blood Vessel Width

The apparent width of the retinal vessel observed with white light is the width of the streaming column of erythrocytes as the surrounding plasma zone and vessel wall are transparent (Brinchmann-Hansen and Heier, 1986). The measurement of the complete blood vessel width (erythrocyte column and plasma zone) is possible with FFA, as the fluorescein mixes with the plasma. The contribution of the plasma zone to the vessel diameter has been recorded as between 3% (Deupree *et al.*, 1985) and 11- 22% (Hodge *et al.*, 1969). These variations could be in part due to the variability in fluorescein concentration and flash intensity (Wu *et al.*, 1995). Brinchmann-Hansen and Heier's (1986) theoretical modelling showed that the thickness of the vessel wall, its refractive index and the width of the plasma zone have only a negligible influence on the apparent width of the blood column. Therefore, complete blood vessel width can be measured from fundus images without the use of FFA if the threshold is appropriately set (Rassam *et al.*, 1994). The plasma volume is lower in the systemic hypertensive patient to reduce intra-vascular volume in order to return cardiac output to normal level (Davis *et al.*, 1977).

3.14 - Artery Vein (A/V) Ratio

The variation in the A/V ratio has been reported as one of the earliest retinal signs of systemic hypertension, but also as the most difficult retinal vasculature feature to quantify objectively (Wong *et al.*, 2001). Published data on the subjective assessment of the A/V ratio from ten points along the vessel pairs between the optic nerve head and the first branching indicated similar ratios between those with atherosclerosis and systemic hypertension: 1:1.51 ± 0.05 and 1:1.53 ± 0.08, respectively (Majewska *et al.*, 1976).

3.15 - Retinal Tortuosity

The retinal vessel lies within the plane of the retina, therefore the true length of the tortuous vessel can be determined by assessment of the retinal photograph (Lotmar *et al.*, 1979). Retinal vasculature tortuosity in 290 normotensive subjects was examined objectively by Williams (1982) by tracing the path of the central arteriole. Twenty point co-ordinates along a 3mm section of this vessel were entered into a computer and the length of the path between these points compared to the distance between the first and last point to give an index of tortuosity. Findings indicated that the tortuosity of the older age group (50-60 years) were not significantly different from that in a younger group of subjects (~20 years). This index does not take into account the degree of tortuosity within the vessel itself. A vessel with one large sinusoidal arc (e.g. a vessel arcing around the macular) could have the same index as a vessel with numerous smaller sinusoidal arcs. Improved attempts of quantifying tortuosity of retinal blood vessels were made by Hart and colleagues (1999), who found their measures agreed well with ophthalmologists' perception of tortuosity. However, no findings of tortuosity in patients were presented.

3.16 - Focal Arteriolar Calibre Change

The assessment of calibre changes has been previously assessed subjectively, but not objectively, and found to be associated with elevated BP (Dimmitt *et al.*, 1989; Hubbard *et al.*, 1999) and age (Klein *et al.*, 1997; Hubbard *et al.*, 1999).

3.17 - Outline of Research

To date there has been little published work into the application of image analysis in the monitoring of retinal vessels in systemic hypertensives. Conversely, image analysis has been used widely in the detection and assessment of diabetic retinopathy (Klein *et al.*, 1984; Gilchrist[b], 1987; Phillips, 1993; Gillow 1999). The early changes in the diabetic fundus tend to be more marked (e.g. haemorrhages, and exudates) than those associated in the pre-malignant hypertensive fundus. This chapter assesses the appearance of the retinal vessels in terms of their diameter, A/V ratio, tortuosity and focal arteriolar calibre changes to determine if image analysis can assist in the measurement and monitoring of patients with pre-malignant systemic hypertensive retinopathy in practice.

3.20 - Method

Subjects were recruited from the staff, students and patients of the Optometry Department of the School of Life and Health Sciences, Aston University. The research was approved by the university ethics committee and conforms to the declaration of Helsinki. Subjects signed a consent form to take part in the study and a release form to allow communication, about the patient's general health, between the researcher and their GP. The subjects were aged between 18 and 86 years, and for analysis purposes were grouped into three groups according to age: group 1; 18-40 years (n = 65, average age 19.3 ± 3.3 years), group 2; 40-60 years (n = 25, average age 49.2 ± 5.6 years) and group 3; over 60 years (n = 46, average age 71.9 ± 6.5 years).

3.21 - Blood Pressure Measurement

The patient's BP was recorded with an OMRON 705 CP automatic BP monitor. The 705 CP has been found to be accurate and reliable, conforming to the criteria of the Association of Advancement of Medical Instrumentation and the British Hypertension Society (Artigao *et al.*, 2000). The subjects were seated in a quiet room of constant temperature (22°C) for five minutes and asked to refrain from postural changes prior to the measurement of BP. Subjects had not eaten, smoked, been exposed to cold or exercised for at least 30 minutes before the measurement. The left arm (whose arteries are located closer to the aorta) was supported on a level surface at the height of the heart, with muscles relaxed (as the BP in the arm increases as the arm is lowered from the level of the heart). The centre of an appropriate sized inflatable bladder (cuff) containing the microphone was placed over the brachial artery. A second reading of BP was taken after two minutes had elapsed and an additional measurement(s) made if the readings varied by more than 5mmHg (J.N.C., 1997).

3.22 - Patient Questionnaire

The subjects completed a questionnaire about their general health, medication and life style (appendix 2). A single examiner (P.H.) completed the questionnaire with all subjects to ensure consistency. Interviewing the subject, rather than requiring them to self-complete the questionnaire, allowed the order of questioning to be fixed and prevented revision of answers in the light of subsequent questions.

3.23 - Fundus Photographs

Non-mydriatic 45° fundus photographs, centred on the optic disc, were taken using a Topcon TRC-NW5S Fundus Camera. The digital fundus photographs were saved as tiff files with an image size of 1.26MB. The background illumination within the fundus camera was set at 3.5, the flash intensity at medium and the gain setting at 12 for all patients. At least one photograph per eye was taken of each subject to ensure the image analysis was performed on the best quality image for each individual. The regular fixed spacing of the Charged Couple Device (CCD) video imaging elements allows improved repeatability compared to film processing techniques (Gilchrist[a], 1987).

The photographs were taken in the same part of the cardiac cycle (closure of the aortic and pulmonic valves) by timing the camera trigger with the second heart sound detected through a stethoscope. Timing the photograph with the same part of the cardiac cycle minimizes the 6% variation in vessel diameter due to pulsation (Rassam *et al.*, 1994; Hill and Crabtree, 1994). The diaphragm of the stethoscope was held in place by the patient over the aortic area (the second intercostal space close to the sternum). The aortic area does not correspond to the anatomic location of the valve but the site at which the sounds from the valve are best heard (Andreoli *et al.*, 1983). The stethoscope was lengthened (1.3m) to allow the patient to hold the diaphragm in place while the examiner (P.H.) sat behind the camera with a finger on the trigger listening to the heart sounds.

3.24 - Image Analysis

Photographs were analysed in a random order, separate from any information on each patient's medical status and BP, to reduce possible bias. The four main pairs of retinal arterioles and venules in each photograph were analysed with a purpose written computer edge detection program (Labview and Vision Software, National Instruments, USA), appendix 3. Edge detection computer analysis allows an objective and quantitative measurement of blood vessel width, which is not possible with an ophthalmoscope (Brinchmann-Hansen *et al.*, 1990).

The vessel width of the major arterioles and venules was determined at the edge of the optic disc and then every two millimetres (on the computer monitor - determined by a hand held calibre) until the margin of the photograph was reached or the vessel became indistinct from the background. Where the vessel branched, crossed or was crossed by another vessel a reading of "0" was scored.

The blood vessel width was calculated from the intensity profile of a line drawn perpendicularly across the vessel, Figure 3.01. The background intensity of the retinal fundus on either side of the blood vessel was averaged (I_B) as the reflectance of the background retina varies due to differences in the RPE, blood filling of the choroid and Hb saturation (Bracher *et al.*, 1979). The minimum intensity (as the blood vessel appears darker than the background fundus; I_V) of the intensity profile was measured and the difference between this intensity and the background retina was used to determine the half-height of the blood column intensity (I_O). A quadratic function was fitted to the intensity staircase across the vessel, allowing the vessel width (W_O) to be determined at the half-height intensity threshold (I_O), with a resolution of 1/1000th of a pixel on either side. The use of interpolated pixel values is less influenced by noise than discrete pixel values.

The width of a blood vessel measured at its half-height is not significantly affected by aberrations, focusing errors and the intensity of the light streak (Brinchmann-Hansen, *et al.*, 1986, 1990; Rassam *et al.*, 1994). To avoid spurious readings the examiner was given the opportunity to accept or reject the detected edges, which were displayed as white circles overlaying the retinal image (appendix 3).

Intra-operator repeatability of the measurements was assessed by repeat measurement of five photographic retinal images on a separate occasion. The repeatability of the timing of the fundus photographs with the second heart sound was assessed through repeat photographs (x5) and these images were each measured five times. The quality of the retinal images was graded to account for media opacities, poor focus, and poor field definition (small pupils, blink reflex).

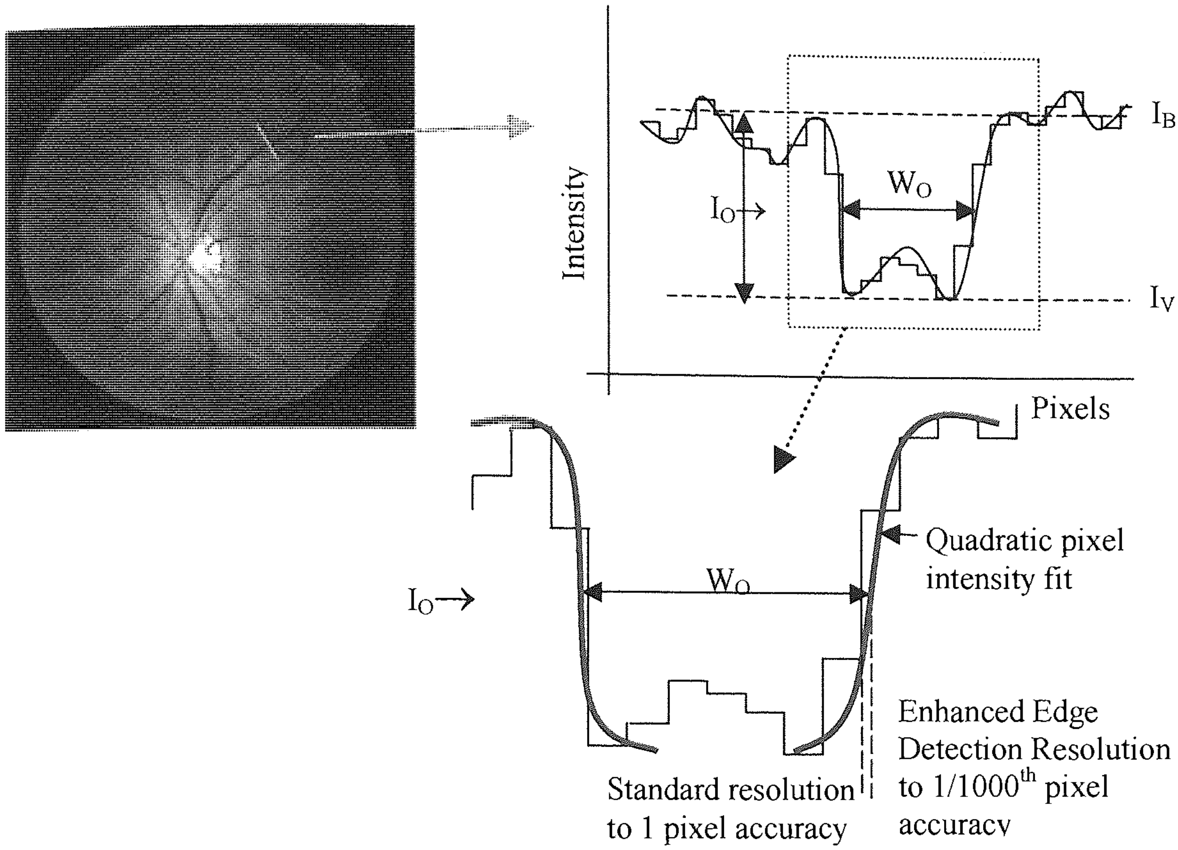


Figure 3.01: Schematic intensity profile across a retinal vessel and extrapolation of vessel width, redrawn from Wolffsohn *et al.*, 2001.

Key: Io - Half-height blood vessel intensity, Wo - blood vessel width (at Io).

3.25 - Calculations

The results (co-ordinates of the vessel edges) from the edge detection program were automatically fed into an excel spreadsheet. Edge detection readings which were absent (scored as "0"), e.g. due to vessel branching, were filled in by the assumption that the missing value would lie half way between the pre and post segment edge points, Equation 1, Table 3.01. The influence of magnification on the retinal image was calculated from image analysis of a retinal photograph of a regular checkerboard grid, which had been attached to the retina of a dummy eye (with adjustable axial length for refractive status), Figure 3.02. The findings from the dummy eye permitted the patient's refractive error (best sphere) to be taken into consideration when converting the blood vessel width from pixels to micrometers, Equation 2, Table 3.01.

The central point of each vessel pair was calculated by Equation 3, Table 3.01. Vessel tortuosity was calculated by two methods. The first compared the chord of the vessel (a direct line connecting the first (optic disc margin) and last point on the vessel) to the actual path length of the vessel. The second determined the average displacement of the vessel from the chord, Equations 4 and 5, Table 3.01 and Figure 3.03. A tortuous vessel would be longer than the chord and show an increase in deviation away from the chord path. Previous research by Williams (1982) had assessed the length of the vessel to the chord in determining tortuosity (method 1). However, this method does not take into account the actual degree of tortuosity, for two vessels may have the same length but vary in their severity of tortuosity, which can be determined by the second method. The A/V ratio was calculated by comparison of the width of the venule with that of the arteriole at equal eccentricity from the optic nerve head. Marked focal changes were separated from slight focal changes with application of the equation that the segment must be no more than 2/3 the width of the pre or post vessel segment (University of Wisconsin Madison, 2002). The application of the arbitrary figure of 5/6 for slight change permitted differentiation between none and slight focal calibre change.

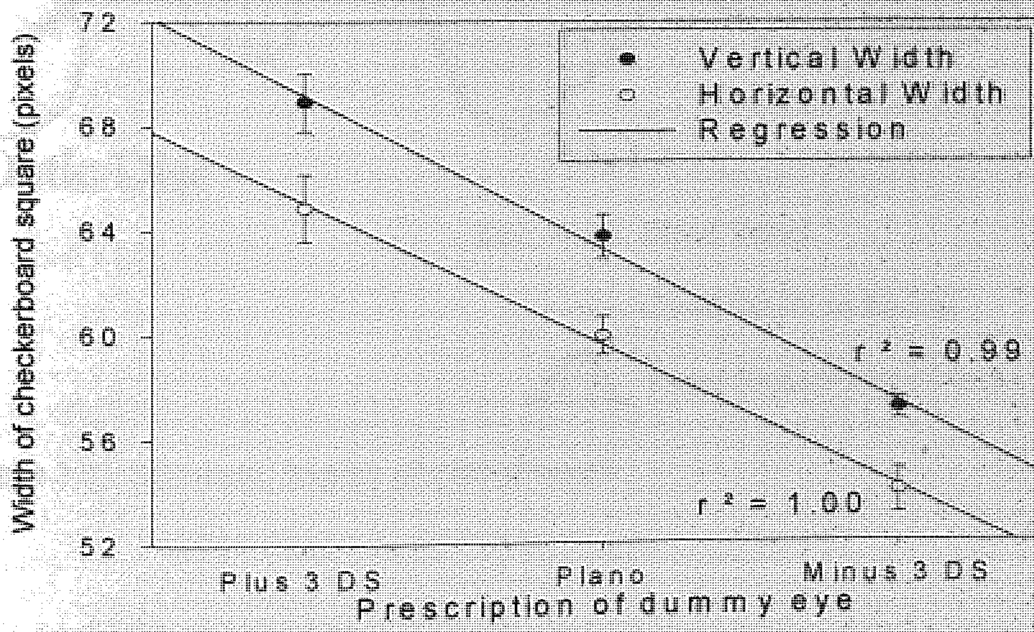


Figure 3.02: Variation in apparent width of retinal feature with prescription.

Missing edge data points $((X_{n+1} + X_{n-1}) / 2) + X_{n-1}$	Eq. 1
Vessel width in micrometers (61.7 x (0.395 x (Pixel width x (48.61 / ((((1.099 - 1) / (3 / Refraction)) + 1) x 48.61)))))	Eq. 2
Mid-point of vessel $((X1_2 - X1_1) / 2) + X1_1$	Eq. 3
Displacement of blood vessel from straight line (BV D) SQRT ((SUMSQ (X2 - X1)) + (SUMSQ (Y2 - Y1))) x (SIN ((PI () / 180) x (((ATAN ((Y2 - Y1) / (X2 - X1) x (180 / PI ()))) - ((ATAN ((Y_n - Y1) / (X_n-X1)) x (180 / PI ()))))))	Eq. 4
Distance along chord (BV C) SQRT (((SUMSQ (X2 - X1)) + (SUMSQ (Y2 - Y1))) - (SUMSQ (BV D)))	Eq. 5
Key: SQRT = Square Root SUMSQ = Squared SIN = Sin ATAN (α x (180/PI()) = Inv Tan α	

Table 3.01: Excel spreadsheet equations used for analysing vessel co-ordinates.

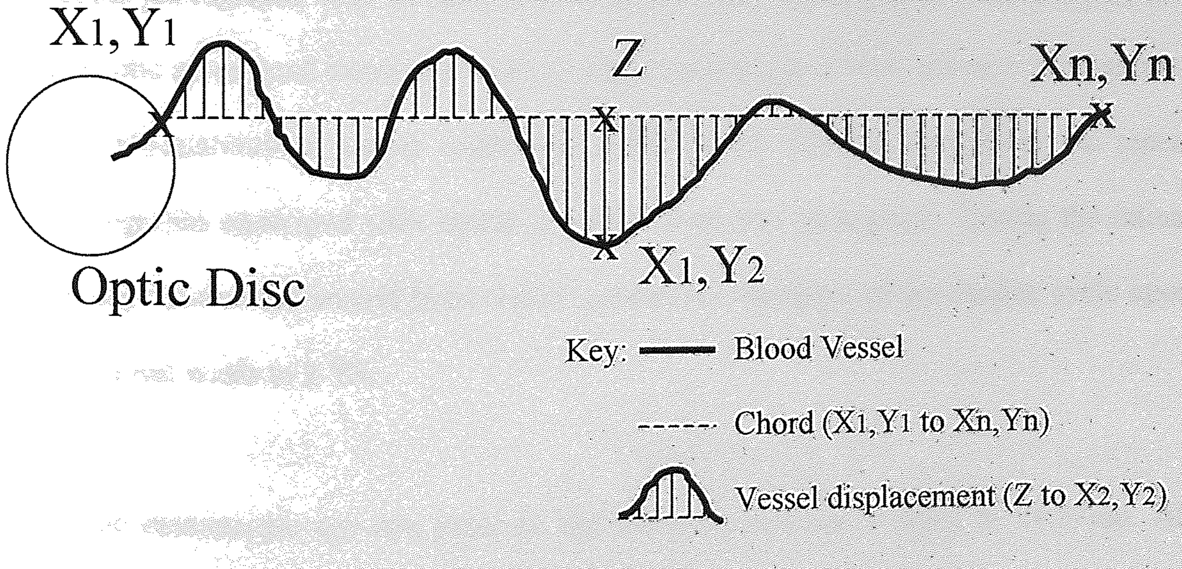


Figure 3.03: Schematic diagram of a blood vessel.

3.30 - Results

Fundus photographs and questionnaires were completed for 137 patients. Approximately half of the patients were male (51.1%; n = 70) and 22.2% (n = 29) were taking medication for systemic hypertension. Image analysis was not possible in 0.7% (n = 2) of the fundus photographs due to media opacities. Despite all photographs being optimised for clarity, 12.8% of vessels could not be measured and analysed due to poor image quality. Measurements from 956 vessels were taken, yielding 23,636 data points; 71.9% of a possible 32,880 if 30 measures were taken from each vessel. Average findings are shown as the mean ± 1 standard deviation.

3.31 - Repeatability

The blood vessels of one retinal image were measured ten times to assess the repeatability of the image analysis program. Taking photographs of one patient's eye on five separate occasions, over two sittings, assessed the repeatability of the timing of the retinal photographs with the second heart sound. These photographs were analysed and the optic nerve head location centred to allow comparison of data between photographs. The repeatability of vessel width was worse in the measurements from the repeat photographs compared with repeat measures from one photograph. Timing the retinal photographs to the second heart sound reduced the influence of the cardiac cycle upon the vessel width to 2.9%.

In the emmetropic eye one pixel on the computer monitor is equal to 24.37μm. All measurements were recorded using the same computer monitor to avoid any changes in magnification factors when determining the distances between measurement points using the hand held calibres.

Focal changes showed the lowest degree of coefficient of variation, indicating a high degree of reproducibility between measures and photographs. The lowest reproducibility was found with the tortuosity measure calculated through the degree of displacement for both repeat measurements and repeat photographs, Table 3.02.

Variable	Repeat Measure	Repeat Photograph	Coefficient of variation (%) (Sd / mean) x 100	
			Repeat Measure	Repeat Photograph
Venular Diameter (um)	140.11 ± 5.85	144.21 ± 6.08	4.18	4.22
Arterial Diameter (um)	96.00 ± 6.17	97.95 ± 7.45	6.43	7.61
A/V Ratio (2:x)	2.45 ± 0.10	2.56 ± 0.15	4.08	5.86
Tortuosity Index (1:x)	1.09 ± 0.01	1.09 ± 0.01	0.92	0.92
Displacement (um)	463.68 ± 37.46	423.18 ± 37.01	8.08	8.75
Focal Changes Marked	0.00 ± 0.00	0.25 ± 0.00	0	0
(frequency %) Slight	0.25 ± 0.00	0.50 ± 0.00	0	0

Table 3.02: Reproducibility of image analysis (average measure ± 1 S.D.)

3.32 - Patient Groups

For analysis purposes the patients were divided into four groups to take into account variations in age and BP control, Table 3.03. Retinal photographs were selected for analysis from the database to remove the influence of variations in retinal pigment due to patient ethnicity. Groups with less than five patients were not analysed.

	RC	n =	Age (yrs)	SBP (mmHg)	DBP (mmHg)	PP (mmHg)	MABP (mmHg)
All	1	88	51.56 ±23.36	130.67 ±20.21	79.55 ±9.98	51.13 ±15.28	96.59 ±12.28
Group 1	1	28	21.36 ±6.03	115.96 ±13.30	71.21 ±8.89	44.75 ±9.12	86.13 ±9.65
Group 2	1	16	47.94 ±4.92	125.06 ±11.68	82.69 ±7.86	42.38 ±6.25	96.81 ±8.83
Group 3 N	1	25	69.76 ±5.37	140.24 ±16.41	85.56 ±8.82	54.68 ±12.33	103.79 ±10.38
Group 3 BP	1	19	75.16 ±6.71	144.47 ±23.31	81.26 ±6.17	63.21 ±21.58	102.33 ±10.15

Table 3.03: Patient group demographics.

Key: Group: 1 = 20-40 years; 2 = 40-60 years; 3 = >60 years;

Group 3 N = White European normotensive;

Group 3 BP = White European systemic hypertensive.

(>160/95mmHg and/or hypertensive medication).

3.33 - Vessel Demographics

The average vessel diameter for both arterioles and venules in all four quadrants showed a reduction with increasing patient age (one-way ANOVA: F = 2.09; p = 0.15), Figure 3.04. Comparison of group 1 and group 3 average vessel widths revealed a significant narrowing with age (t-test - two tailed: p <0.001). There was no significant difference in the width of the vessels of the normotensive or hypertensive (>160/95mmHg and/or hypertensive medication) of group 3 (t-test - two tailed: p = 0.34), Figure 3.05. For all patient groups the venule was approximately 10% wider than the arteriole: group 1, 12.1%; group 2, 8.9%; group 3 normotensive, 13.6%; and group 3 hypertensive, 13.2%. The temporal vessels' diameter for all patient groups was significantly wider than the corresponding nasal vessels (t-test - two tailed: $p < 0.001$).

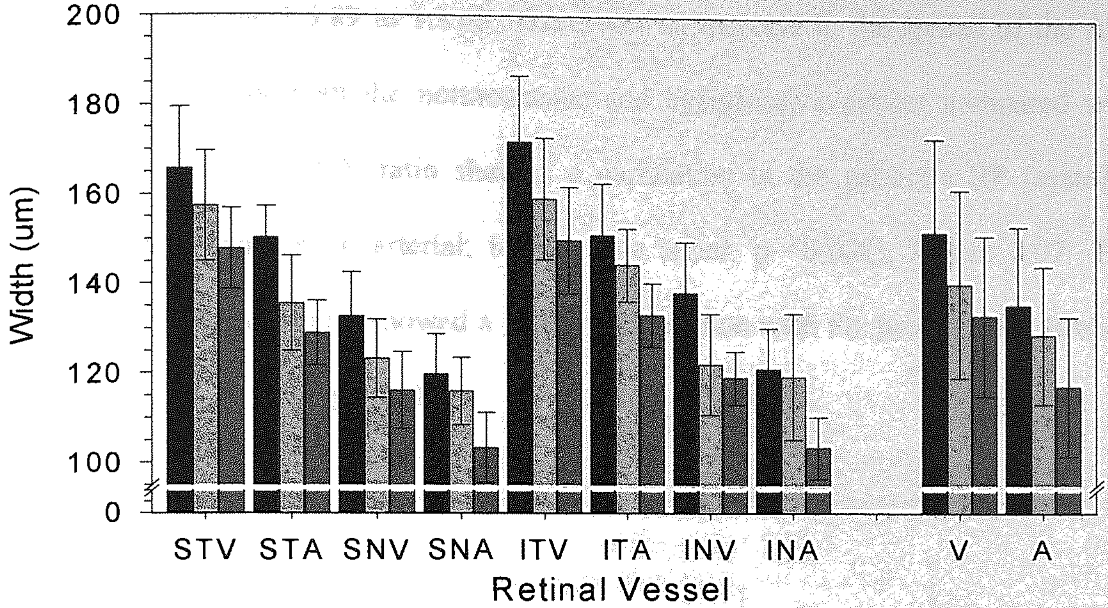


Figure 3.04: Retinal vessel diameter variations with patient age (normotensives).

Key: ■ Group 1 (n = 28), ▨ Group 2 (n = 16); ■ Group 3 (n = 25).

S = Superior; I = Inferior; T = Temporal; N = Nasal.

V = Venule; A = Arteriole.

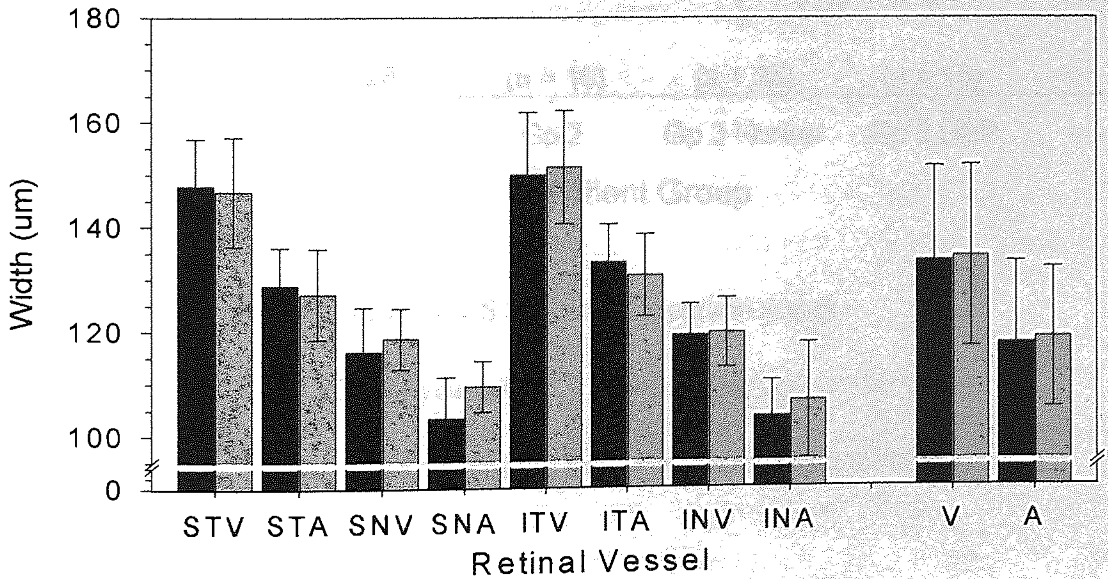


Figure 3.05: Retinal vessel diameter

Group 3 normotensive versus systemic hypertensive.

Key: ■ Normotensive (n = 25), ▨ Systemic hypertensive (n = 19).

3.34 - A/V Ratio

The average A/V ratio showed no significant difference between the patient groups (one-way ANOVA: F = 0.67; p = 0.57), Figure 3.06. The average A/V ratio was 1:1.14 ± 0.11 with a range 1:0.89 to 1:1.65. There was an increase in the spread of the A/V ratio in group 3 for both the normotensive and hypertensive patient compared with groups 1 and 2. The A/V ratio showed a correlation to the patient's BP (systolic, diastolic, pulse and mean arterial; t-test - two tailed: p <0.001), Figure 3.07. The variability of the A/V ratio showed a positive correlation with the patient's BP (t-test - two tailed: p <0.001), Figure 3.08.

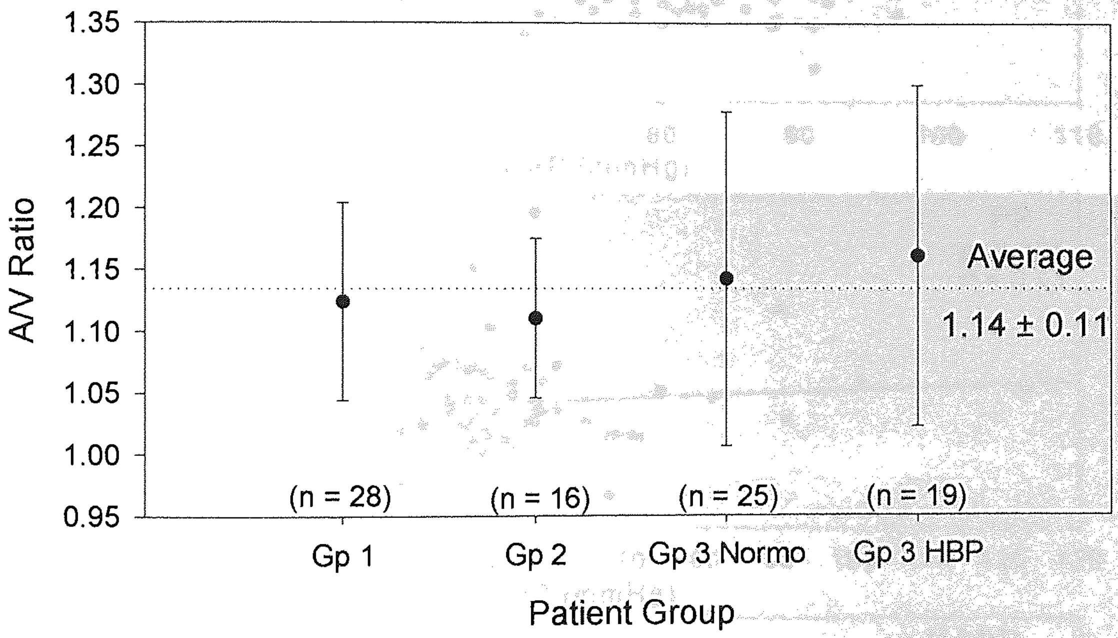


Figure 3.06: Average A/V ratio (± 1 S.D.) for each patient group.

Key: Gp1 = 20-40 years; Gp2 = 40-60 years; Gp3 = >60 years;

Normo = normotensive; HBP =Systemic hypertensive.

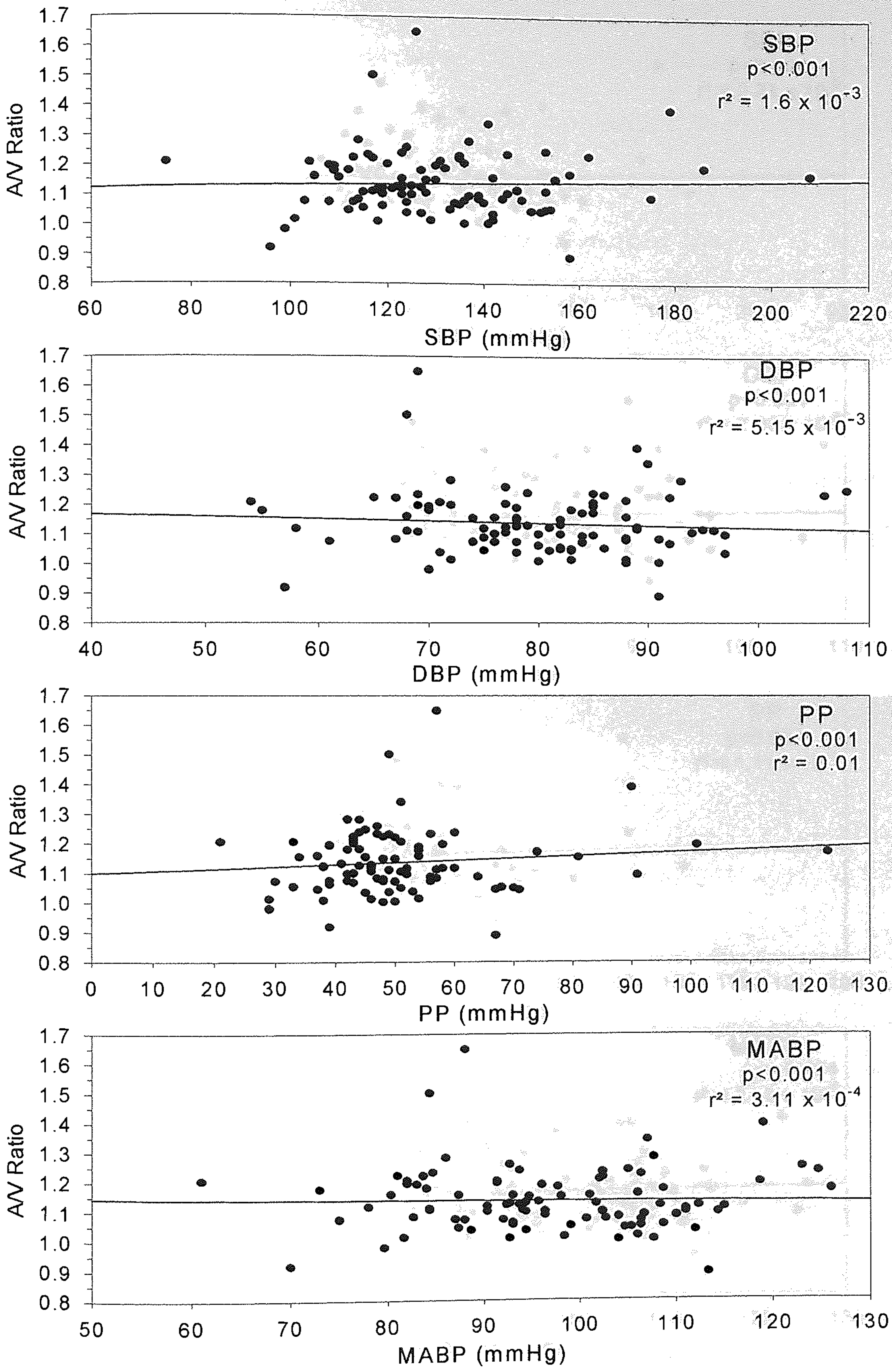


Figure 3.07: A/V ratio versus Blood Pressure - Systolic (SBP), diastolic (DBP), pulse pressure (PP) and mean arterial (MABP; n = 88).

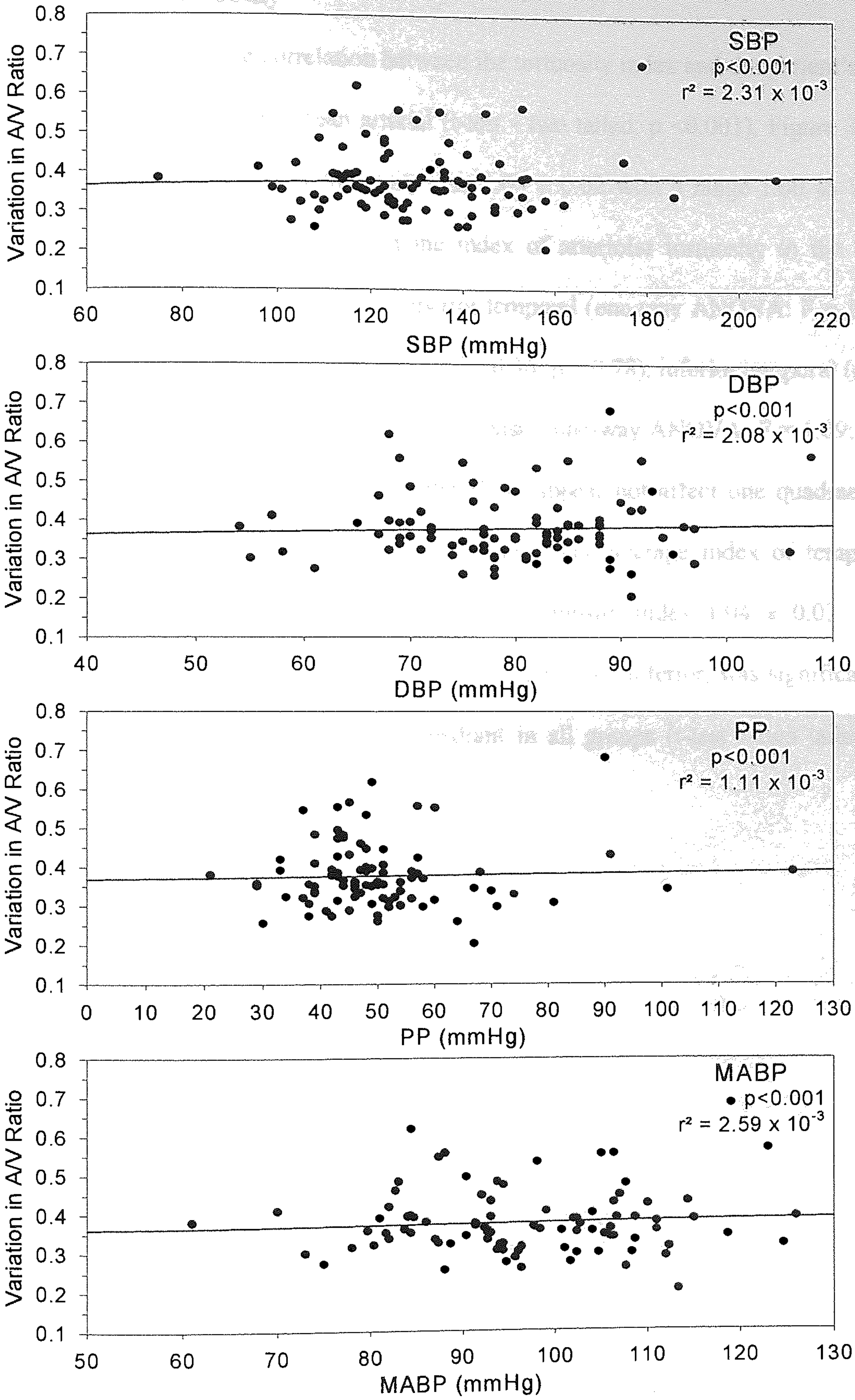


Figure 3.08: Intra-subject variation in A/V ratio versus Blood Pressure - Systolic (SBP), diastolic (DBP), pulse pressure (PP) and mean arterial (MABP; n = 88).

3.34 - Arteriolar Tortuosity

There was a weak positive correlation between the tortuosity index and the patient's BP (systolic, diastolic, pulse and mean arterial (t-test - two tailed: p <0.001), Figure 3.09. The average index of arteriolar tortuosity was 1.06 ± 0.02 with a range 1.00 to 1.16. There was no significant difference in the index of arteriolar tortuosity in the four quadrants between the patient groups: (superior temporal (one-way ANOVA: F = 1.01; p = 0.39), superior nasal (one-way ANOVA: F = 0.36; p = 0.78), inferior temporal (one-way ANOVA: F = 1.65; p = 0.18), and inferior nasal (one-way ANOVA: F = 1.09; p = 0.35); Figure 3.10). Elevated BP would, therefore, appear not affect one quadrant in preference to the others in the pre-malignant stage. The average index of temporal tortuosity index was 1.07 ± 0.04 and the nasal tortuosity index 1.04 ± 0.03. The tortuosity index of the temporal arterioles, both superior and inferior, was significantly higher than those of the superior nasal quadrant in all groups (t-test - two tailed: p <0.001).

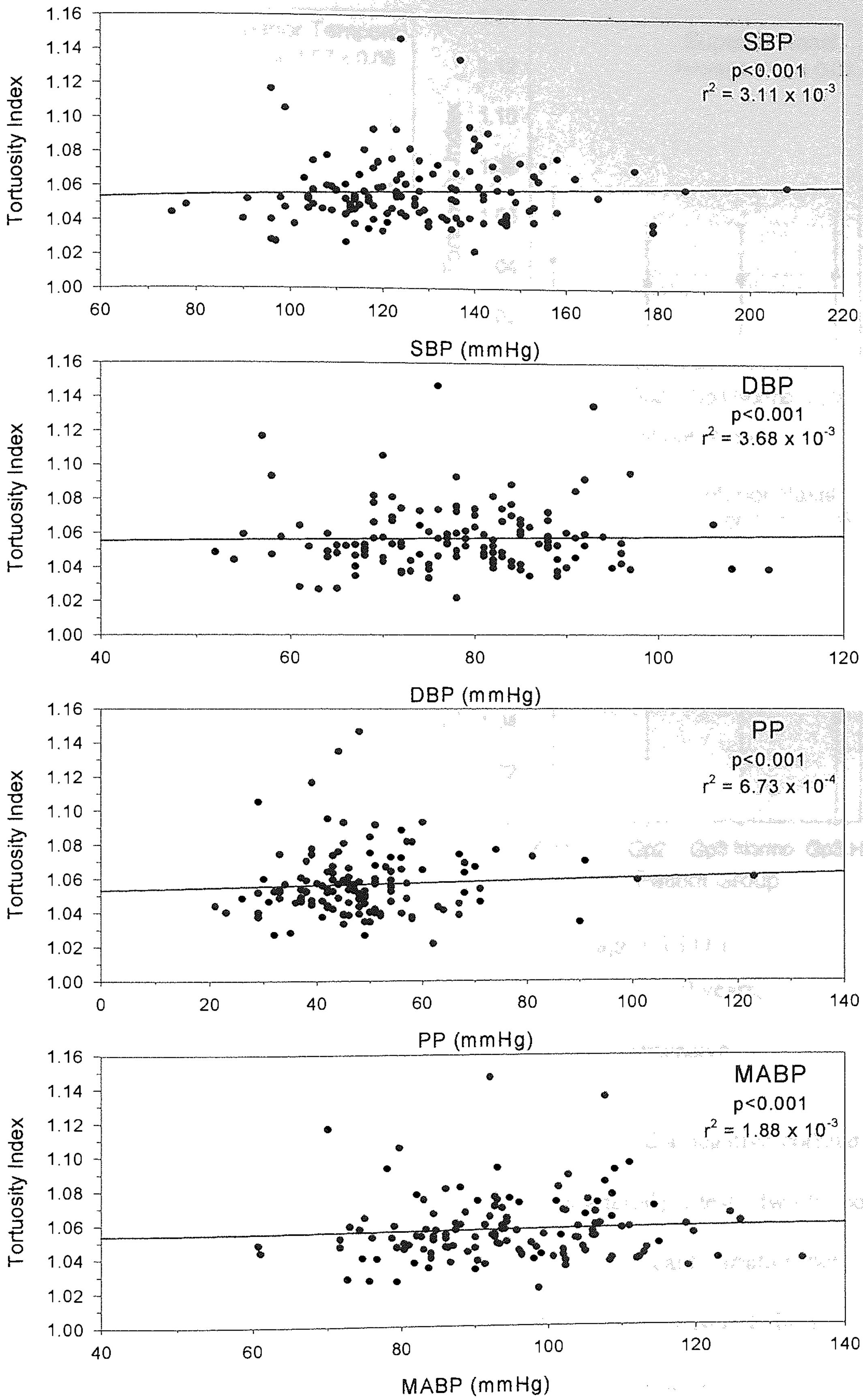


Figure 3.09: Tortuosity index versus Blood Pressure - Systolic (SBP), diastolic (DBP), pulse pressure (PP) and mean arterial (MABP; n = 88).

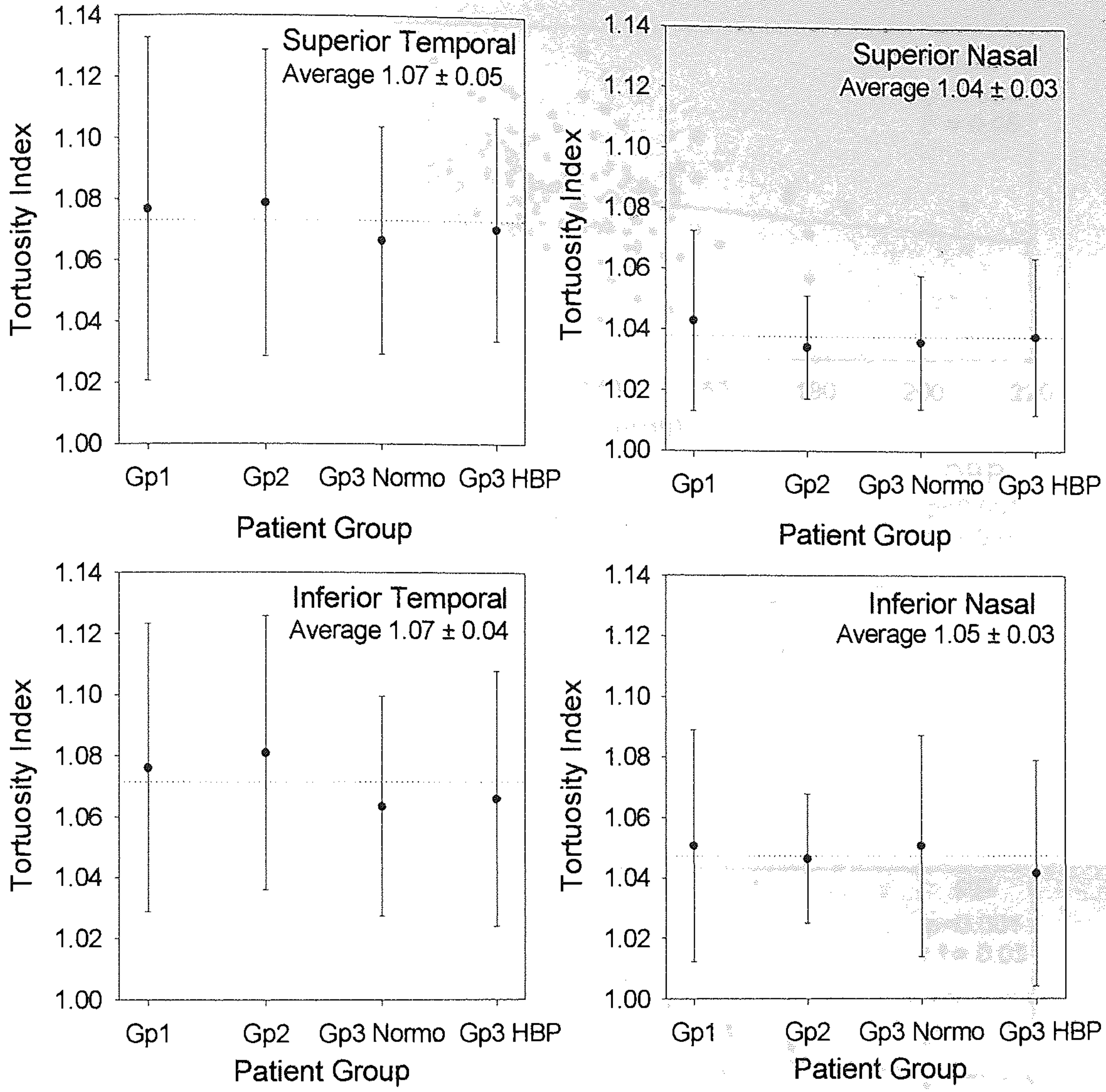


Figure 3.10: Quadrant tortuosity within patient groups (average ± 1S.D.).

Key: Gp1 = 20-40 years; Gp2 = 40-60 years; Gp3 = >60 years;

Normo = normotensive; HBP =Systemic hypertensive.

The degree of displacement of the vessel from the chord showed a negative correlation with the patient's BP (systolic, diastolic, pulse and mean arterial) (t-test - two tailed: $p < 0.001$), Figure 3.11. The index of tortuosity showed no significant variation between the patient groups (t-test - two tailed: $p = 0.08$). Tortuosity measured through the displacement of the vessel indicated a straightening with age (one-way ANOVA: $F = 6.23$; $p < 0.001$). The arterioles of group 1 were more tortuous than those of group 3 (normotensive and hypertensive; t-test - two tailed: $p < 0.01$; Figure 3.12).

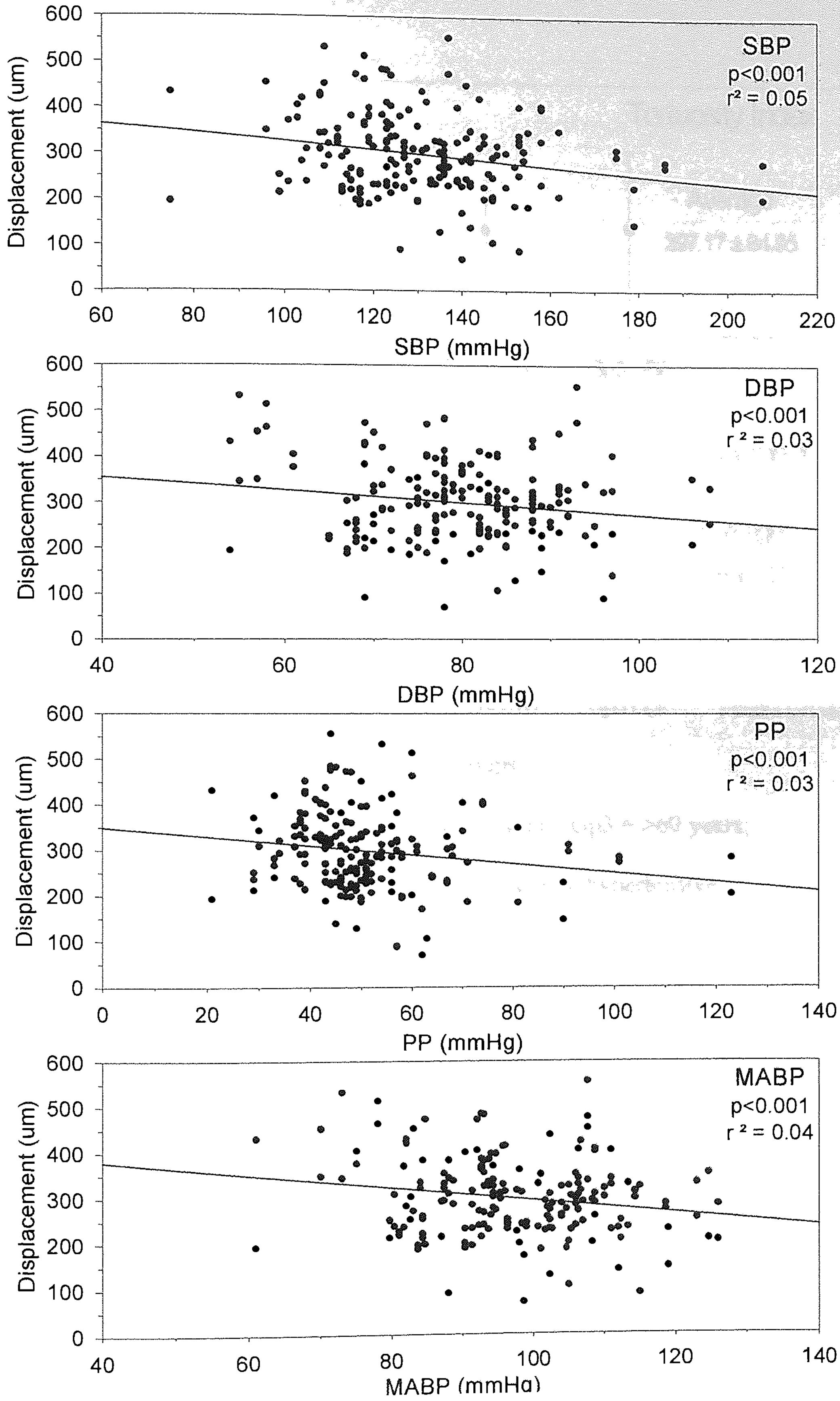


Figure 3.11: Displacement versus Blood Pressure - Systolic (SBP), diastolic (DBP), pulse pressure (PP) and mean arterial (MABP; n = 88).

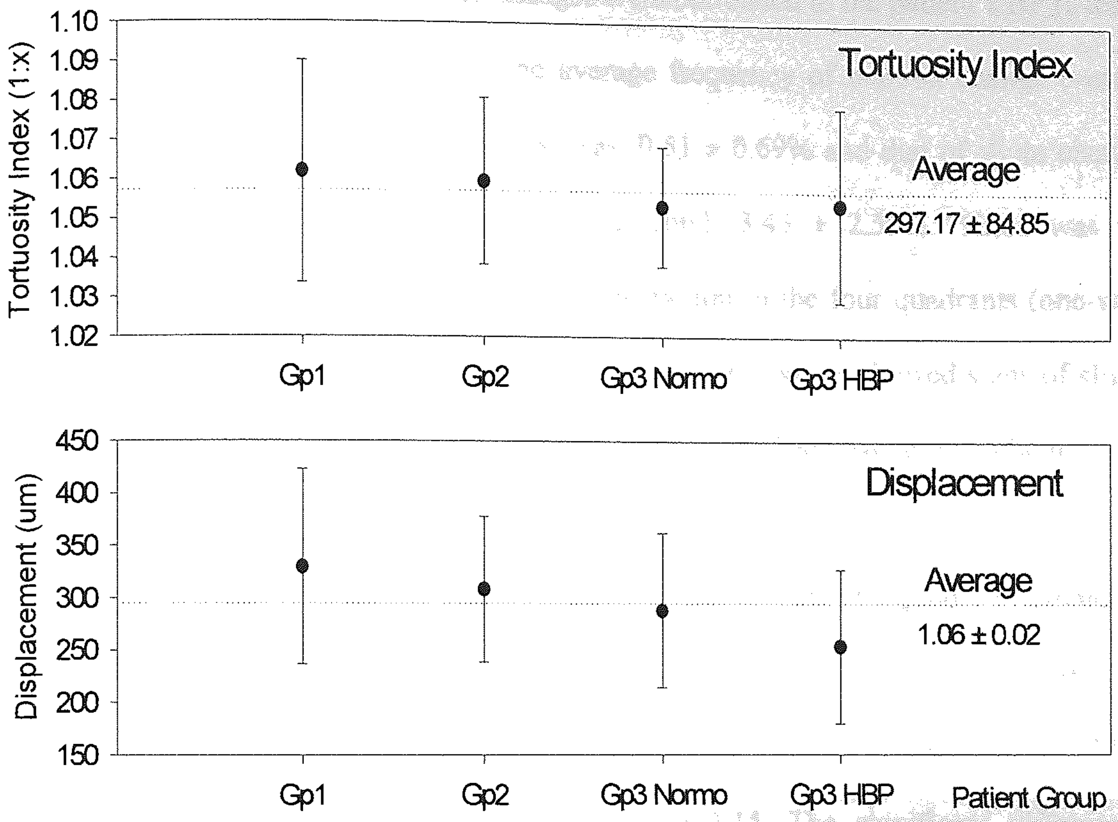


Figure 3.12: Average tortuosity within patient groups

Key: Gp1 = 20-40 years; Gp2 = 40-60 years; Gp3 = >60 years;

Normo = normotensive; HBP =Systemic hypertensive.

3.35 - Focal Arteriolar Calibre Change

Both marked and slight focal calibre changes were correlated to the patient's BP (t-test - two tailed: $p < 0.001$), Figure 3.13. The average frequency of marked change (vessel width 2/3 that of the adjoining segments) was: 0.51 ± 0.69% and that of slight change (vessel width 5/6 that of the adjoining segments): 3.43 ± 2.59%. There was no significant variation in the degree of focal constriction in the four quadrants (one-way ANOVA: $F = 0.01$; $p = 0.99$), Figure 3.14. Nearly every patient showed signs of slight focal calibre changes (95.5%; n = 84) and half of them marked changes (51.1%; n = 45).

The prevalence of focal change was not influenced by the patient's gender or ethnicity. Patients in group 2 showed an increased frequency of both marked (one-way ANOVA: $F = 4.80$; $p < 0.01$) and slight (one-way ANOVA: $F = 6.79$; $p < 0.001$) focal calibre changes compared with the other groups, Figure 3.15. The significant differences between groups in the frequency of marked focal calibre changes were: group 2 from group 1 (t-test - two tailed: $p < 0.01$) and group 2 from group 3 normotensive and hypertensive (t-test - two tailed: $p < 0.05$). Group differences for slight focal calibre changes were: group 2 from group 3 normotensive (t-test - two tailed: $p < 0.01$); group 2 from group 1 (t-test - two tailed: $p < 0.05$) and group 3 normotensive from group 3 hypertensive (t-test - two tailed: $p < 0.05$).

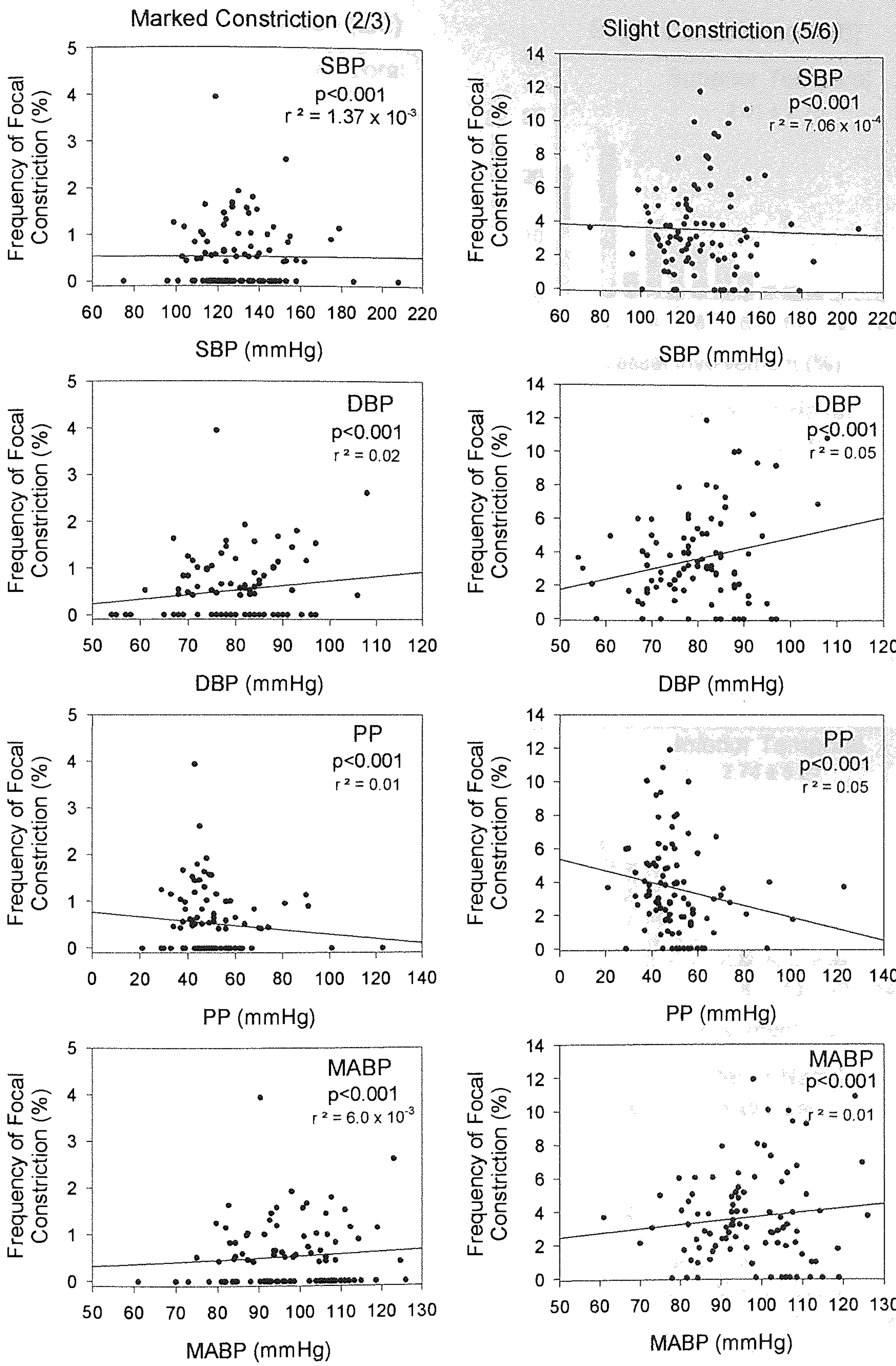


Figure 3.13: Focal calibre change with Blood Pressure - Systolic (SBP), diastolic (DBP), pulse pressure (PP) and mean arterial (MABP; n = 88).

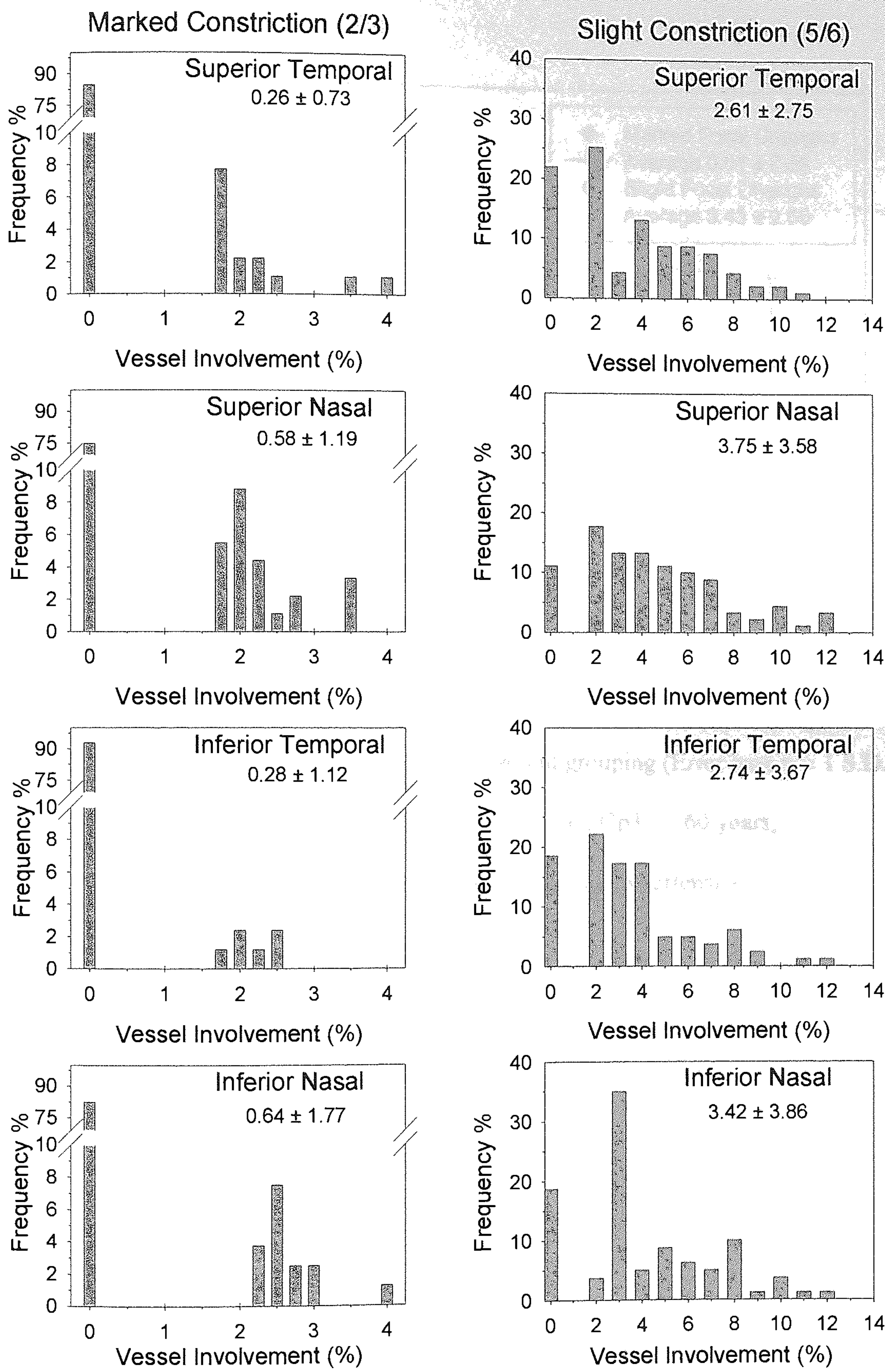


Figure 3.14: Location (retinal quadrant) of focal calibre changes (n = 88).

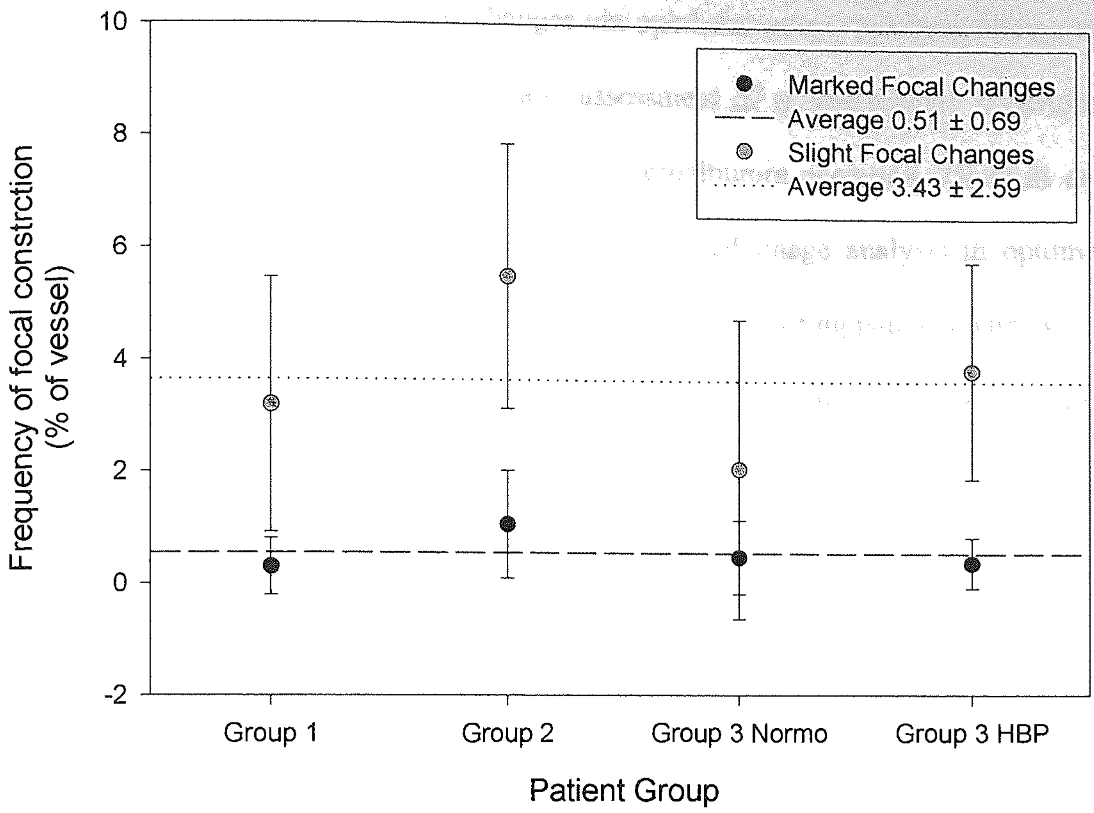


Figure 3.15: Average focal calibre change with patient grouping (Error bars = ± 1 S.D.).

Key: Gp1 = 20-40 years; Gp2 = 40-60 years; Gp3 = >60 years;

Normo = normotensive; HBP =Systemic hypertensive.

3.40 - Discussion

The assessment of retinal vascular changes via ophthalmoscopy has been shown to be prone to variability among observers and assessment of mild-moderate hypertension was better assessed with analysis of urinary microalbumin excretion (Dimmitt *et al.*, 1989). The incorporation of objective fully automated image analysis in optometric practice could make the optometrist more effective in monitoring patients with systemic hypertension, rather than having to take on roles, which are not in their field of expertise.

The use of image analysis removes any observer bias in grading retinal features. The subjective assessment of the vessel width has previously been shown to overestimate the true vessel width (Delori *et al.*, 1977). Present colour photography only permits image analysis of the major vessels. However, in systemic hypertension where the smaller arterioles are most affected, improvements in image capture techniques are necessitated to assist in the image analysis (Parr and Spears, 1974).

3.41 - Repeatability

The measurement of the vessel width at the half height permitted data collection in retinal images which were not in sharp focus due to media opacities. The reproducibility of vessel widths was greater than that previously recorded by Bracher and co-workers (1979), who had a repeatability of ± 9μm from measurements of vessel diameter from projected negatives. The use of image analysis has previously shown a four times greater repeatability of vessel measurements over those measured subjectively (Delori, *et al.*, 1988) Reproducibility of vessel measurements has also been shown to be improved through analysis of FFA photograph (mean coefficient of variation of 0.45%; Eaton and Hatchell, 1988).

The calculation of the magnification factor illustrated that the size of the retinal image was larger in hypermetropic eyes, but at the expense of a reduced field of view. The magnification factor for subsequent calculations was taken as the average across the 45° field (both vertically and horizontally). Increasing errors in blood vessel width towards the periphery of the retinal image will also occur as the whole retina cannot be focused to the same degree of optimal sharpness (Brinchmann-Hansen *et al.*, 1986). Magnification, however, will only have an influence upon real measures; calculations which produce a ratio within the eye (e.g. A/V ratio) will be independent of magnification if the vessels under comparison are close together.

3.42 - Cardiac Cycle

There was a reduction in the reproducibility of the vessel width measurements from photographs taken on different occasions due to the influence of the cardiac cycle (2.9%). Alterations in vessel width with the cardiac cycle have previously been estimated between 3.46% (Chen *et al.*, 1994) and 6.0% (Rassam *et al.*, 1994). The use of an electrocardiograph (ECG) connected to the camera trigger would, therefore, ensure the single frame pictures are precisely at the same stage of the cardiac cycle (Newson *et al.*, 1992). However, photographs timed to the second heart sound through the ECG are still prone to variations in repeatability between patients as the retinal circulation is dependent upon the patient's refractive status; a slower retinal circulation is associated with increasing myopia (Avetisov and Savitskaya, 1977). Within the eye error will also be present due to different parts of the fundus being at different phases of the cardiac cycle (Wu *et al.*, 1995).

3.43 - Vessel Demographics

The average diameter of the retinal arterioles and venules of the patients was comparable to that found through image analysis of retinal photographs by Rassam and colleagues (83.70 to 136.10μm and 113.68 to 176.99μm respectively; 1994). The diameters of all the retinal vessels have been previously determined between 15 to 200μm (Wise *et al.*, 1971). The retinal vessel width can be measured from photographs as the vessel keeps an approximate circular shape due to the high intravascular pressure of the retinal circulation (Brinchmann-Hansen and Heier, 1986).

The temporal veins were found to be wider than the other vessels. This is thought to be due to the temporal retina being larger (approximately 10% larger surface area, assuming the radius of the eye is 12mm; Bennett and Rabbetts, 1994) than the nasal retina and as such, has a higher oxygen demand (Rassam *et al.*, 1993).

Previous research has indicated that the retinal vessel in the systemic hypertensive width is wider (Houben *et al.*, 1995) and narrower (Hill and Dollery, 1963) than that of the normotensive. The findings from this research show no difference between the two age matched groups.

The width of the retinal vessels decreases with eccentricity from the optic nerve head. Even though the individual vessel diameter decreases, the total cross sectional area of the lumen of the vascular system increases at each branching (Parr and spears, 1974). The rate of reduction in vessel width lessened with increasing age, with group 3 showing very little change in vessel width from the optic disc margin to the periphery, corresponding to the effect of arteriolosclerosis (Svardsudd *et al.*, 1978; Fuchs *et al.*, 1995). The arterial blood vessel width decrease with increasing distance from the optic disc is due to its gradual change into a vessel that is truly arteriolar in nature.

Limitations on the camera hardware restricted the research to that of the major arterioles and venules in each eye. Subjective assessment of retinal vessels has previously shown that the constriction of the arterioles in response to systemic hypertension is most pronounced in the foveal region (Salus, 1958).

3.44 - A/V Ratio

The variation in the A/V ratio with BP is in response to a narrowing of the arteriole. Venule diameter has previously been found to be constant with BP (Wong *et al.*, 2002). The findings of this objective study confirmed previous subjective grading by Couper and colleagues (2002) who found that the A/V ratio correlated closely with both current and previous patient BP.

There is a wide spread of opinion on the average A/V ratio. The A/V ratio found in this research, 1:1.14 ± 0.11 (1:0.86 to 1:1.65), was comparable to Nicholls and co-workers (1:1.00 to 1:1.67; 1956) and Wood (1:1.00 to 1: 1.25; 1956). There was no significant difference in the ratio between genders, comparable to the findings of Hubbard and co-workers (1999).

3.45 - Arteriolar Tortuosity

Vessel tortuosity was more marked in the temporal vessels than in the nasal vessels, agreeing with the findings of Bracher (1982). Physiology of the eye would indicate that the temporal vessels would be more tortuous as they have to arc around the macular, whereas the nasal vessels have no geographic feature to circumnavigate during embryological development. Pathologically the reason for increased tortuosity in the temporal fundus may be due to lower threshold to the messengers or metabolites inducing tortuosity (Bracher, 1982). Previous research has shown that at high transmural pressure, tortuosity is a more sensitive indictor of a vessel's response to BP, whereas vessel width is at lower pressures (Kylstra *et al.*, 1986). The reduced displacement of the vessel in the systemic hypertensive patient could be due to the sinusoidal variations in the vessel between the vessel-retina attachment points (vessel branching, crossing) in response to changes in BP.

Of the three features examined with image analysis on colour photographs the A/V ratio and focal calibre changes could be due to plasma skimming (alterations in the amount of plasma in the periphery of the blood column), endothelial cell swelling, changes in the muscular tone, or an artefact due to masking of part of the vessel by retinal oedema, whereas changes to a vessel's tortuosity are only susceptible to muscular tone (Lotmar *et al.*, 1979; Hayreh, 1989).

3.46 - Focal Arteriolar Calibre Change

The presence of focal calibre changes from this study correlated with the patient's BP. Previous research has shown positive association with systolic BP (Dimmitt *et al.*, 1989; Klein *et al.*, 1993, 1997) and with MABP (Hubbard *et al.*, 1999). There is divided opinion on the prevalence of focal changes with age. This research showed no significant change with age in concordance with the Beaver Dam study (Klein *et al.*, 1997), whereas the Atherosclerosis Risk in Communities Study revealed a three times higher prevalence in patients 63-73 years than those 48-54 years (Hubbard *et al.*, 1999). The similarity in the prevalence of focal changes between males and females is comparable to that found by Klein and co-workers (1997) of odds ratio of 1.3 and 1.4 respectively (Klein *et al.*, 1997).

3.50 - Future Advances in Image Analysis

The quality of the image determines the success of the subsequent image analysis. A high resolution digital camera incorporating a red free filter (570nm) would maximise the contrast of the retinal image. The present computer algorithm for edge detection just determines the luminance from the grey scale image of the colour retinal photograph. The improved repeatability, accuracy and full automation of the system could be achieved by the incorporation of a software program which extracts the retinal features (region of interest) from the background (noise). The computer algorithm for this would encompass three aspects:

1. Noise reduction; passing the image through a low pass filter to remove the noise features, which tend to be at higher spatial frequencies. Filter selection is critical to avoid the blurring of the image resulting in a loss of detail.
2. Contrast enhancement; stretching the range of grey scale levels in the image (the present algorithm uses an 8-bit system with 256 levels) to enhance the contrast.
3. Thresholding; having stretched the range of grey levels it should be possible to find a single threshold to separate the retinal vessels from the fundus and produce an outline of the vasculature (Gilchrist[b], 1987). Having extracted the vasculature the image would then be processed by a second fully automated algorithm to select and analyse a line perpendicular to the vessel at regular intervals (e.g. every pixel) along its entire length to permit complete analysis of the vessel.

Fluctuations in the blood vessels with the cardiac cycle could be removed by continuous video recording of the retinal vessel. Subsequent analysis of the alterations in the retinal vessel diameter throughout the entire cardiac cycle may show and indicate disease states and possible pathogenic mechanisms (Chen *et al.*, 1994).

Having extracted the features, the computer program then has to determine whether the vascular appearance is pathological (e.g. systemic hypertension), physiological, senile or acquired in origin. The entry of patient details, medical status and BP measurement as determined from the sight examination into the computer will assist in the differentiation between those vasculature patterns which in the youthful eye are congenital in origin and those in the older eye which are pathological (Salus, 1958).

In summary the fully automated computer detection and image analysis algorithms for detection and monitoring of pre-malignant systemic hypertension would encompass:

1. Detection of all vessel edges and other regions of interest, eg lesions.
2. Calculate the blood vessel width and location from matched edge points.
3. Analyse the retinal vasculature features in relation to: A/V ratio, arteriolar reflex, tortuosity, focal calibre changes, A/V nipping, and vessel branching (Stanton *et al.*, 1995).
4. Record findings and compare the retinal skeleton (image which only illustrates the retinal vessels) with data obtained at the patient's last sight test and with an age and medical history matched group.
5. Assess clinical significance and advise on the management of the patient (Gilchrist[b], 1987).

3.60 - Conclusion

One must be aware that the measurement of BP may not correspond with the retinal appearance, as retinopathy is just a measure of a patient's susceptibility to microvascular damage (Wong *et al.*, 2001). Those changes which are present in the retinal vasculature in pre-malignant systemic hypertension are small and, therefore, require reproducible objective measures to yield beneficial data for future comparison (Newsom *et al.*, 1992). Image analysis has been shown to offer the ability to quantify the condition rather than record qualitative subjective findings (Gilchrist[b], 1987).

The new generation of fundus cameras (e.g. Optomap) combined with the proposed amendments to the image analysis software would have the potential to detect and monitor not only the systemic hypertensive retinal vasculature changes across the whole fundus, but also the underlying choroidal changes masked by the RPE. With the choroidal vessels being amongst the most vulnerable to systemic hypertension due to their short course, limited branching and less effective regulatory mechanisms in comparison to the retinal vessels, there is potential benefit to the patient by the optometrist moving into the domain of automated retinal imaging.

CHAPTER 4 - THE OPTOMETRIC PATIENT

4.10 - Introduction

The optometrist performs a primary health care role and under the terms of conduct stated by the General Optical Council (Opticians Act, 1989) the eye examination is designed to detect ocular disease and systemic disease with ocular manifestations. Systemic hypertension, as described in chapter 1, meets both these criteria.

There are no published surveys on the general health of the nation and the national census (2001), which for the first time incorporated questions on a person's ethnic background and whether the inhabitants cared for a family member with an infirmity, did not examine the health of households (National Statistics, 2003).

The estimation of the prevalence of systemic hypertension in the population and comparison with overseas figures suffers from a lack of conformity of what level of BP is taken as indicative of systemic hypertension. Previous studies on the prevalence of systemic hypertension (>160/90mmHg) in the UK have estimated that between 10 and 15% of the population is affected (Grundy, 1990). Males have been shown to be more at risk of systemic hypertension (>160 and/or >95mmHg than females: 16% (male) versus 14% (female; W.H.O., 1997)).

The rate of referrals by optometrists to all health care providers has previously been reported at 3.8% (Brin and Griffin, 1995). Referrals in an optometric practice which incorporated BP monitoring into the optometrist's routine have indicated that in a middle-aged population 15.7% of patients were subsequently referred, of which 12.9%

were on BP readings alone (Barnard *et al.*, 1991). The patient's lifestyle (tobacco, alcohol consumption, and lack of physical activity, stress) has previously been shown to have a detrimental influence on general health (Barnes *et al.*, 1989; Thomson, 1997; W.H.O., 1997).

This chapter examines the prevalence of systemic hypertension and associated medical conditions in optometric practice, frequency of GP attendance, frequency of BP measurements and details of the patient's lifestyle. Previous research has examined the use of BP monitors in optometric practice, the role that optometrists in the UK perform and wish to perform in the management of the systemic hypertensive patient (2000/2001; chapter 2). The findings on the prevalence of systemic medical conditions and BP in practice will indicate whether there is a public health role for optometrists and whether there is need to adjust their routine to optimise service to their patients.

4.20 - Method

Patients were recruited from four optometric practices in the United Kingdom. The optometric practices sampled comprised four branches of three different multiple optometrists (Coventry, Gateshead, Newcastle-upon-Tyne, and Yate), and one independent optometrist (Coventry). There were three researchers (S.B., G.G. and P.H.) involved in the measurement of BP and completing the questionnaires. All patients, over 18 years of age, presenting for a sight test at the optometrists were asked if they wished to participate in the research. It was explained that non/participation did not have any bearing on the standard of their subsequent sight examination. The sight examination for each participant was not adjusted from that appropriate to the patient's requirement.

The research was approved by Aston University ethics committee and conformed to the declaration of Helsinki. All data collected maintained patients' anonymity. The BP reading and questionnaire were undertaken after the sight examination.

4.21 - Patient Questionnaire

Following explanation of the research and signing of the consent form, the questionnaire was filled in by the researcher in response to the answers supplied by the patient. The questionnaire was designed to obtain details of the patient's medical status and lifestyle to enable an overview of the average patient attending a UK optometric practice (Table 4.01). The design of the questionnaire was similar to that in use for the research patients at Aston University (chapter 3 and appendix 2). However, the questions were designed to elicit patients' medical status with direct questioning, not to test their ability to yield information determined by the wording of the question. The duration of the patient's medical condition(s) was taken as the time since diagnosis. Additional comments were recorded to avoid the loss of any information. The data from the completed questionnaires were entered into a spreadsheet. The patient's ethnic background (Race Code; RC) was classified by the researcher according to the ethnicity code as used by the West Midlands Police Force, Table 4.02.

4.22 - Blood Pressure Measurement

The BP measurements were recorded using automatic BP monitors; OMRON 705CP and OMRON T3, which have both been found to be as accurate and reliable as the mercury sphygmomanometer (Artigao *et al.*, 2000 and Anwar *et al.*, 1998 respectively). The use of automated BP monitors removed clinician variability. Prior to taking a BP reading the subject had been seated in a chair for five minutes, and within the last half an hour had not drunk coffee, smoked, exercised or been exposed to cold (Terry, 1976; Augsburger and Good, 1986). The cuff of the BP monitor was placed around the left upper arm, level with the heart, with the microphone positioned above the brachial artery. Repeat measurements were taken at least two minutes apart to allow the free flow of blood in the brachial artery. At least two readings were taken per subject and averaged to give the subject's BP. The time at which the measurement was taken was also recorded. Additional measurements were performed if the readings varied by more than 5mmHg (J.N.C., 1997). The average reading was calculated from the mean of two similar systolic BP and two similar diastolic BP readings. Pulse pressure was calculated by subtracting the average diastolic BP from the average systolic BP. Further details on the measurement of BP may be found in chapter 1. Patients were supplied with an information sheet detailing the use of the BP monitors and an explanation of how to interpret their results (appendix 4). Patients who were found to have an elevated average

BP reading and had given their consent to the research findings being passed on to their GP were referred.

Blood Pressure Questionnaire Date: . . / . . / . .

Initials:_ _ _ Gender: M/F RC: _ Age: _ _ _

1a) General Health

	Duration (years)	Medication
Blood Pressure (High/Low)	No / yes →	. . . .
Diabetes	No / yes →	. . . .
Heart Disease	No / yes →	. . . .
Angina	No / yes →	. . . .
Kidney Problems	No / yes →	. . . .
Cholesterol	No / yes →	. . . .
Contraceptives	No / yes →	. . . .

1b) Have you had either of the following:	(m/y)	Medication
Heart Attack	No / yes → . . . / . . .	. . . .
Stroke	No / yes → . . . / . . .	. . . .

2) Were you a premature baby? Yes [ ] No [ ] Not Sure [ ]

3a) When was the last time:

You visited your GP . . . . .months

BP measured . . . . .months

4) Certain foods / activities have an influence on your blood pressure. Please list your weekly consumption of the following:

4a) Smoking . . . . . . .cigarettes/week Non Smoker [ ]

4b) Alcohol . . . . . . .units/week Non drinker [ ]

4c) Physical Activity . . . . . . .hours/week None [ ]

4d) Stress - Minimal Extreme

Work	1	2	3	4	5	6	7	. . . . hrs/wk
Home	1	2	3	4	5	6	7	

4e) Diet

Very Poor	1	2	3	4	5	6	7	Excellent/Healthy

4f) Height: . . . . . . ft/ins / cm 4g) Weight: . . . . . . st / kg

Additional Comments

. . . .

. . . .

Table 4.01: Blood pressure in optometric practice questionnaire.

Code	Ethnic Background	Code	Ethnic Background
1	White European	6	Arab
2	Dark European	7	Bangladeshi
3	African Caribbean	8	Chinese
4	Asian	9	Other

Table 4.02: Ethnicity code (5 = out of use).

4.30 - Results

Three hundred and two patients took part in this study. Less than 5% eligible patients refused to participate in the research study. The responses were calculated as percentages and the number of patients included in the category given in brackets. Average findings are shown as the mean ± 1 standard deviation.

4.31 - Demographics

The optometric sample comprised 45.4% (137) male and 54.6% (165) female patients. The age range of the patients was 18 to 93 years and the average age was 50.5 ± 17.4 years, (52.3 ± 16.6 years for males and 49.1 ± 18.0 years for females). The age distribution of the patients is illustrated in Figure 4.01; the most frequent patient group was in their late forties, the early presbyope. The ethnicity background of the optometric sample is shown alongside the ethnic make up of the UK in Figure 4.02; over 95% were white European.

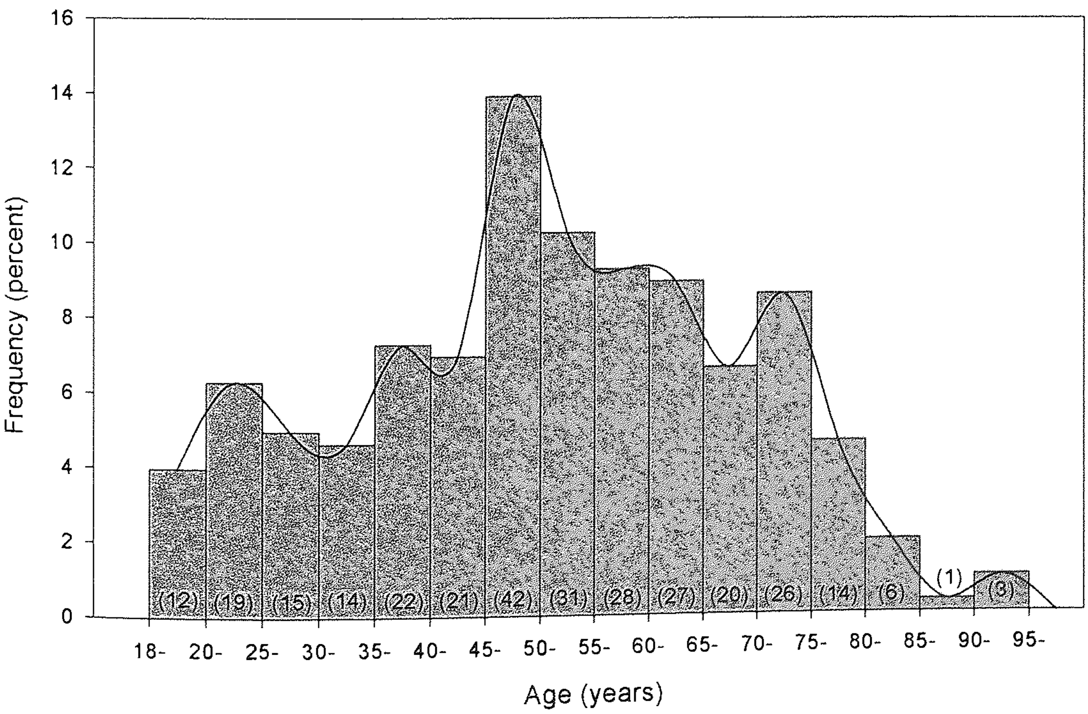


Figure 4.01: Age demographics of optometric sample (n = 301).

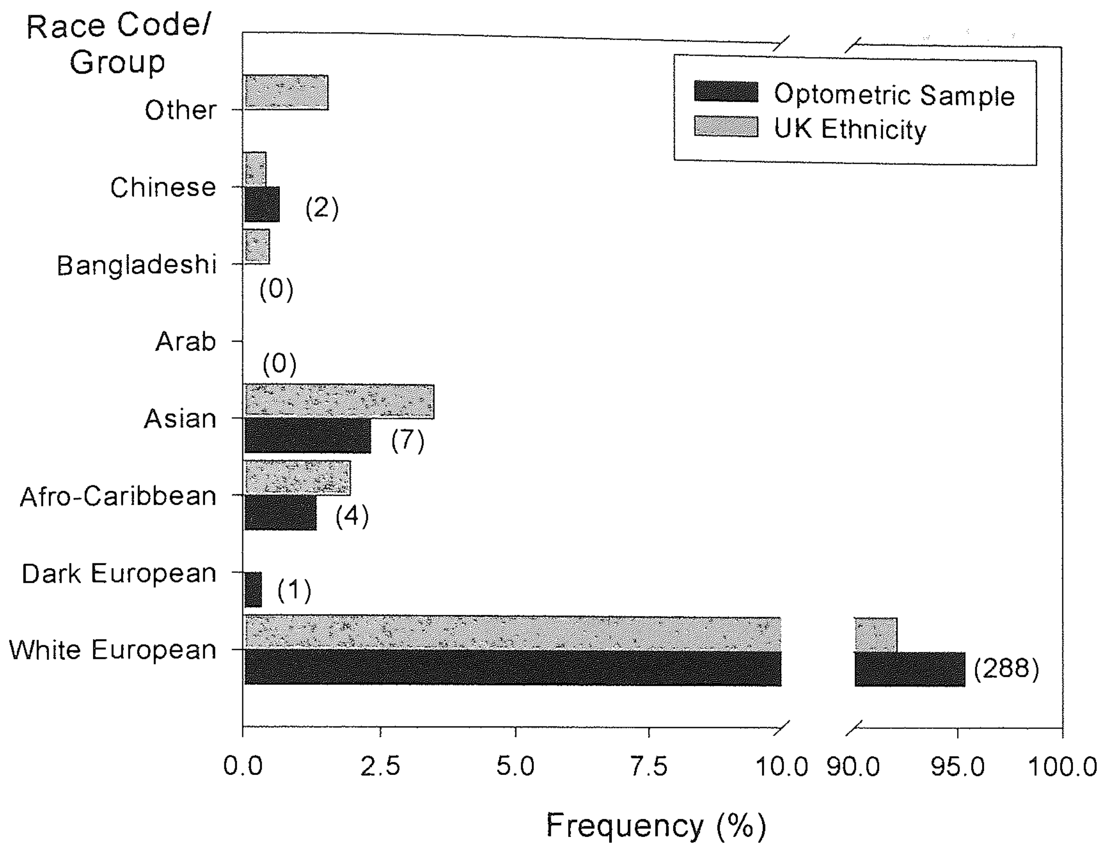


Figure 4.02: Ethnic background of sampled optometric patient (n=302) and UK population. Data from 2001 census (National Statistics, 2003).

4.32 – General Health of Patients in Optometric Practice

The range of general health problems and their prevalence in the optometric sample is shown in Figure 4.03. Within the sample optometric population, diagnosed systemic hypertension is the most prevalent cardiovascular medical condition (20.53%; n = 62). Eighty nine percent of those with diagnosed systemic hypertension were taking medication and the average length of the condition since diagnosis was 5.62 ± 5.54 years. Nearly one third of those with previously diagnosed systemic hypertension had a BP reading >140/90mmHg (29.0%; n = 18). This figure, suggestive of uncontrolled systemic hypertension, represents the BP level at which nearly two thirds of the General

Practitioners sampled in the UK wished to be informed of their patient's BP when measured in optometric practice (chapter 5). The prevalence of isolated elevated systolic BP and diastolic BP in these patients was 32.3% (n = 20) and 79.0% (n = 49) respectively. Classifying systemic hypertension as >160/95mmHg (Klein *et al.*, 1993) reveals that 21.0% of the patients presently taking medication for systemic hypertension were above this level (n = 13). The prevalence of isolated elevated systolic BP and diastolic BP in these patients was 32.3% (n = 20) and 38.7% (n = 24) respectively.

Fifty nine percent (142) of patients who did not report being diagnosed with systemic hypertension or were on any systemic hypertensive medication had an elevated BP >140/90mmHg. The prevalence of BP >160/90mmHg in this group of patients was 5.9% (n=14). The prevalence of isolated elevated systolic BP and diastolic BP in these patients was 11.3% (n = 27) and 14.2% (n = 34) respectively.

The prevalence of cardiovascular medical conditions increases with age. The most prevalent, in all age groups, is that for systemic hypertension. Both systolic and diastolic BP increased with age, averaging 112.8/78.7mmHg in the 3rd decade rising to 158.9/89.4mmHg by the 9th decade of life. Separating the medical conditions into those individuals with and without high BP indicates that systemic hypertensives have a higher prevalence of co-existing systemic medical conditions, Figure 4.04.

The average BP of the optometric sample was 136.2 ± 23.6 / 84.2 ± 12.4mmHg (n = 301), the distribution of BP is illustrated in Figure 4.05. BP of the males was similar to that of females (140.1 ± 22.6 / 85.5 ± 12.5mmHg (n = 137) versus 132.9 ± 23.9 / 83.0 ± 12.3mmHg (n = 162) respectively (t test - two tailed; systolic BP p = 0.21 and diastolic

BP p = 0 .29). Systolic and diastolic BP had a significant positive correlation with age (t test - two tailed; p <0.001), whereas that for pulse pressure was not significant (t test - two tailed; p = 0.11).

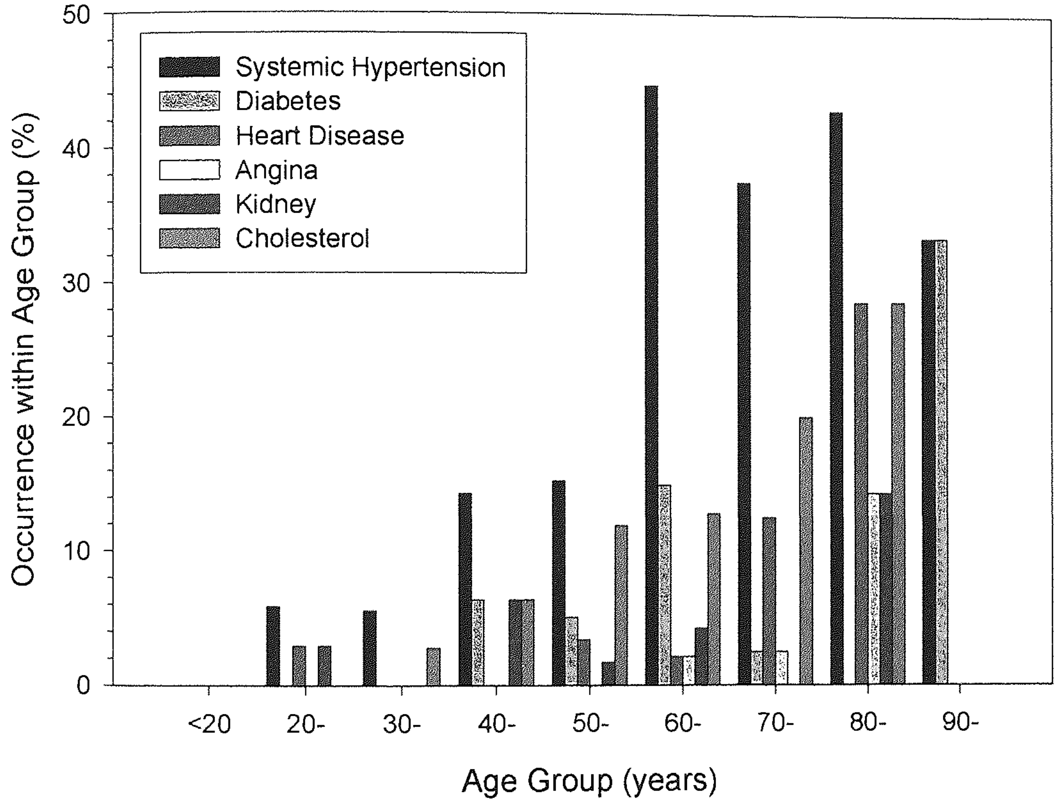


Figure 4.03: Prevalence within age groups of systemic medical conditions (n = 302).

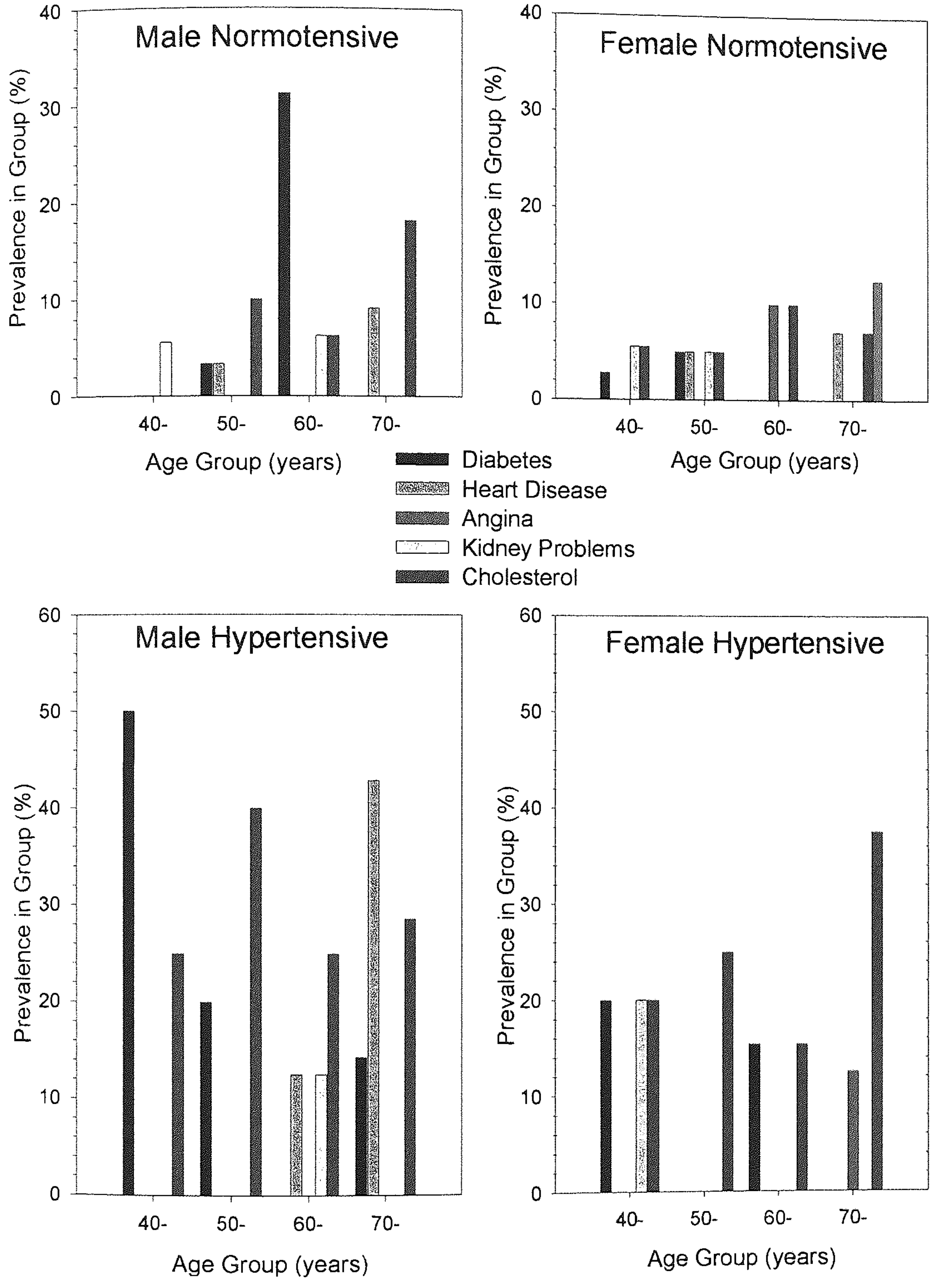


Figure 4.04: Prevalence of medical conditions within age groups. Gender and systemic hypertension breakdown. (Groups contain more than 5 subjects; n = 302).

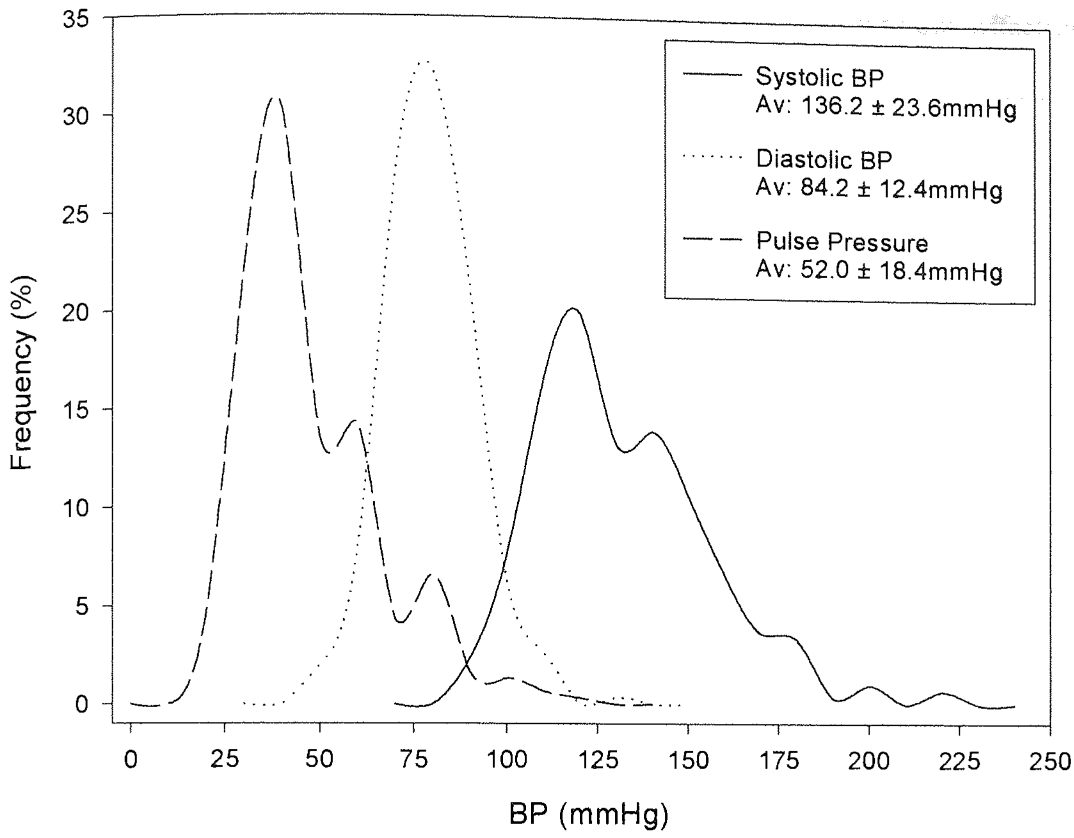


Figure 4.05: Distribution of BP in sample (n = 301).

Nearly one fifth of the females of childbearing age (18 to 55 years) used oral contraceptives (19.3%; n = 20). The average duration was 6.5 ± 4.7 years, range 7 months to 18 years. The BP of those taking oral contraceptives was slightly higher, but not significantly, than an age matched female non-user group: 118.6 ± 13.4 / 78.9 ± 9.6mmHg (n = 20) versus 114.4 ± 12.3 / 77.8 ± 10.6mmHg (n = 32: t test - two tailed; systolic BP p = 0.47 and diastolic BP p = 0.61).

Six patients reported having had a heart attack, the average age on occurrence was 69.0 ± 9.1 years (all male) and present BP reading was 154.8 ± 30.9 / 82.3 ± 14.7mmHg. Seven patients reported having had a stroke (four male and three female), the average age on occurrence was 54.7 ± 13.9 years and average present BP was 156.6 ± 18.1 / 88.5 ± 5.5 mmHg.

The length of time since diagnosis of the systemic medical conditions affecting the patients' circulation is illustrated in Figure 4.06. The longest duration of the medical condition was found in patients suffering with heart disease (14.6 years). The average age at onset of all but one of these conditions was the second half of the 5th decade to the first half of the 6th decade. The onset of angina generally occurred later, in the 7th decade of life.

The length of time since a visit to a GP was on average 7.8 ± 14.0 months and the time since the last BP reading was 15.5 ± 24.4 months, with 6.3% (19) of patients not having had a BP reading taken before. The time since the last GP appointment was significantly lower in systemic hypertensives than normotensives: 3.8 ± 5.5 months versus 9.6 ± 17.1 months (t test - two tailed; $p < 0.01$). The time since the last BP measurement was also on average significantly lower in the systemic hypertensives: 4.4 ± 8.4 months versus 19.4 ± 26.9 months (t test - two tailed; $p < 0.01$). The average age of the patients who had not had their BP measured before was 42.0 ± 12.6 years. The length of time since being seen by their GP and their last BP measurement is illustrated in Figure 4.07. There was a trend towards a non-significant longer time intervals since the patients' last BP check compared to their previous visit to the GP (t test - two tailed; $p = 0.09$). There was no significant difference in the date of the last BP check with gender (one-way ANOVA: $F = 1.93$, $p = 0.17$) or with age (one-way ANOVA: $F = 1.93$, $p = 0.49$). The frequency of GP visits was also not related to the patient's gender (one-way ANOVA: $F = 1.38$, $p = 0.24$) or their age (one-way ANOVA: $F = 0.73$, $p = 0.66$).

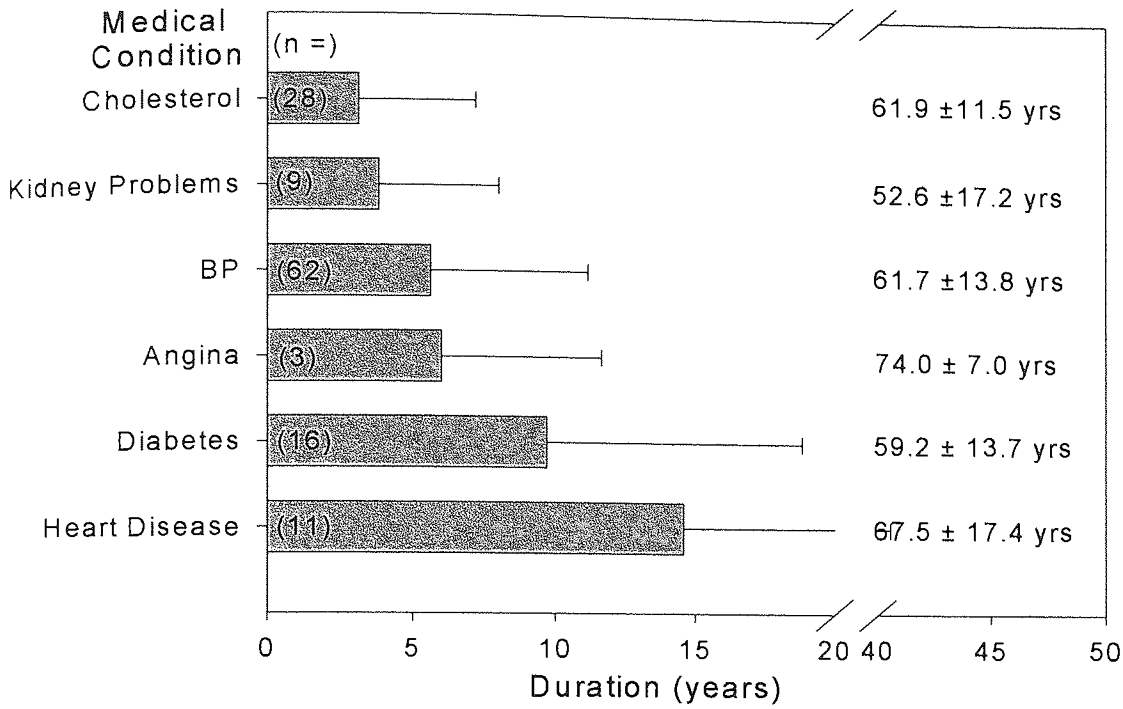


Figure 4.06: Duration of systemic medical condition.

Number of subjects affected in brackets on bar.

Average age ± 1 S.D. of the patient group is on the right.

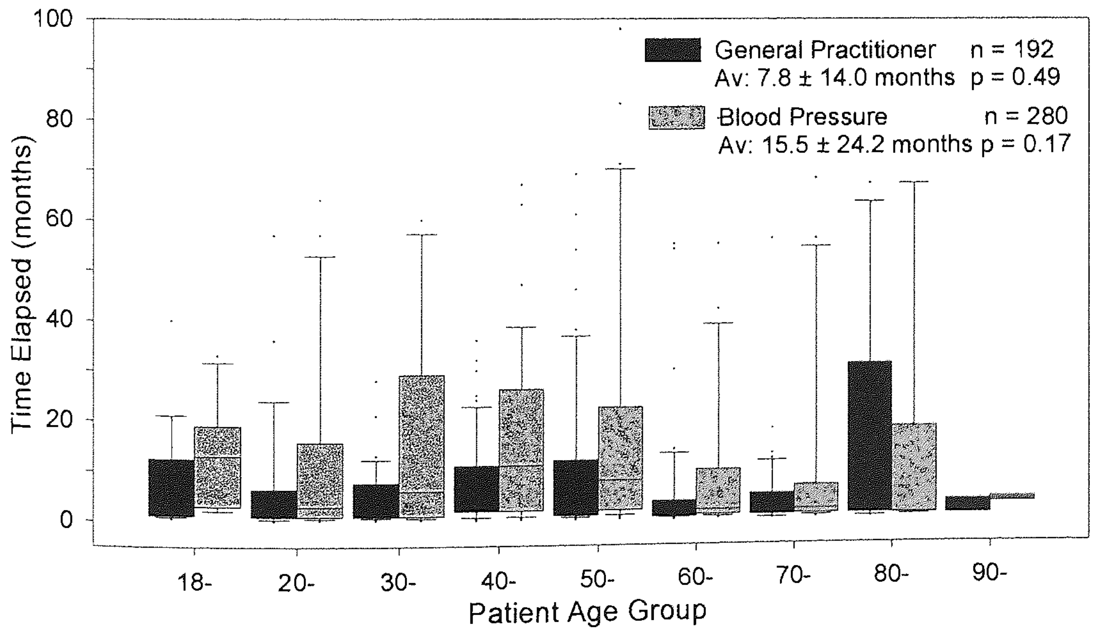


Figure 4.07: Time elapsed since last General Practitioner appointment and

Blood Pressure measurement.

Whiskers equal 10th and 90th percentiles.

4.33 - Lifestyle

The relationship between the patients' stated weight and height is illustrated in Figure 4.08. From the data collected 58.2% (n = 157) of patients would be classified as being above their ideal weight, of which 14.4% (n = 39) would be classified as being obese. Patients classified as being underweight numbered 7.4% (n = 20), of which over two thirds were female (70%, n = 14). Data was not available for 32 patients as they were unsure of one or both of these figures. The Body Mass Index (B.M.I.) is the subject's weight in kilograms divided by the square of their height in metres (Bailey and Ferro-Luzzi, 1995). The B.M.I. is plotted against the subject's BP in Figure 4.09. The subject's systolic ($r^2 = 0.19$) and diastolic ($r^2 = 0.22$) BP and pulse pressure ($r^2 = 0.10$) positively correlate with B.M.I. (t test - two tailed; $p < 0.001$). The B.M.I. of patients presently diagnosed with systemic hypertension was fractionally higher than normotensive and undiagnosed individuals (27.07 ± 5.12kg/m^2 versus 25.83 ± 4.77kg/m^2 respectively: t test - two tailed; $p = 0.61$).

The relationship between the patients' perceived level of stress at home and work environment is plotted in Figure 4.10. In the work environment with an increase in the patients' stress, there is a significant rise in BP (t test - two tailed; $p < 0.001$). Conversely BP decreases as the stress level in the home rises (t test - two tailed; $p<0.001$;). The pressure level is elevated when the patient reports a lower level of stress at home compared with a similar grade at work, and at the high end of the stress grade the pressure is similar whether at home or work.

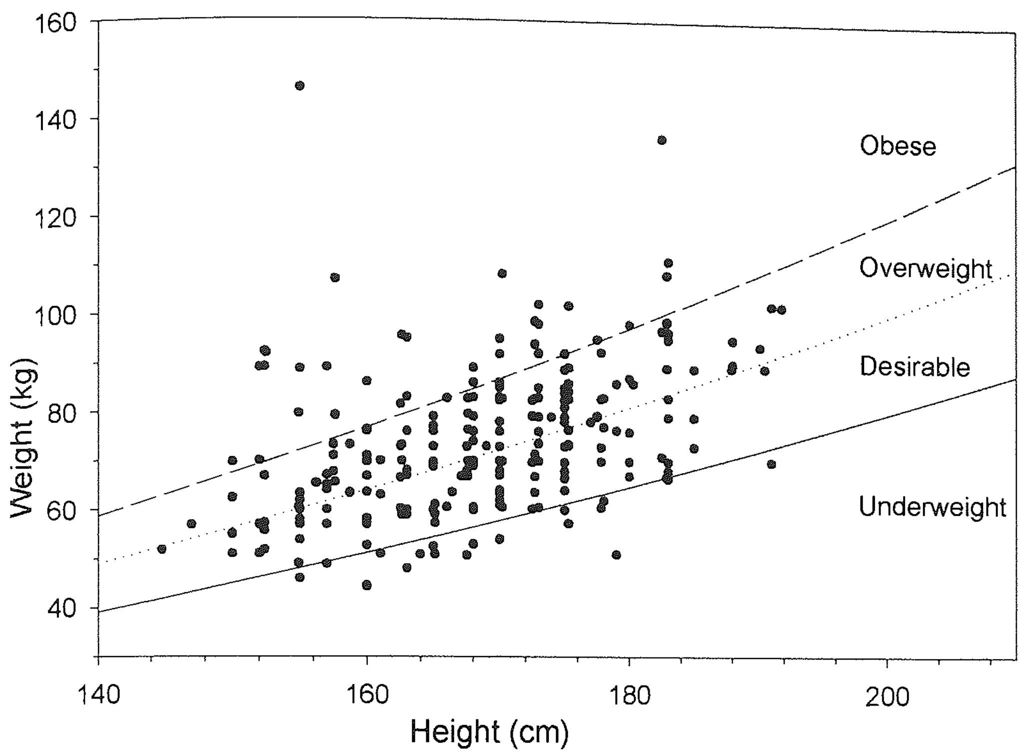


Figure 4.08: Patient height against weight (n=270).

(B.M.I. classification from Bailey and Ferro-Luzzi, 1995).

The influence of smoking on BP revealed no significant difference from an age and gender matched group of non-smokers (137.5 ± 23.2 / 85.8 ± 13.4 mmHg versus 132.7 ± 19.0 / 83.6 ± 9.6mmHg; (t test - two tailed; systolic BP $p = 0.65$ and diastolic BP $p = 0.32$). One quarter of those questioned about their lifestyle revealed that they smoked ($n = 70$). Amongst those patients who smoked, the average number of cigarettes smoked per week was 89.5 ± 62.2. The range in the number of cigarettes smoked per week was 0.5 to 280 (40/day). The number of cigarettes smoked per week revealed a significant positive correlation with systolic BP (t test - two tailed; $p < 0.001$) and no correlation with diastolic BP (t test - two tailed; $p = 0.30$).

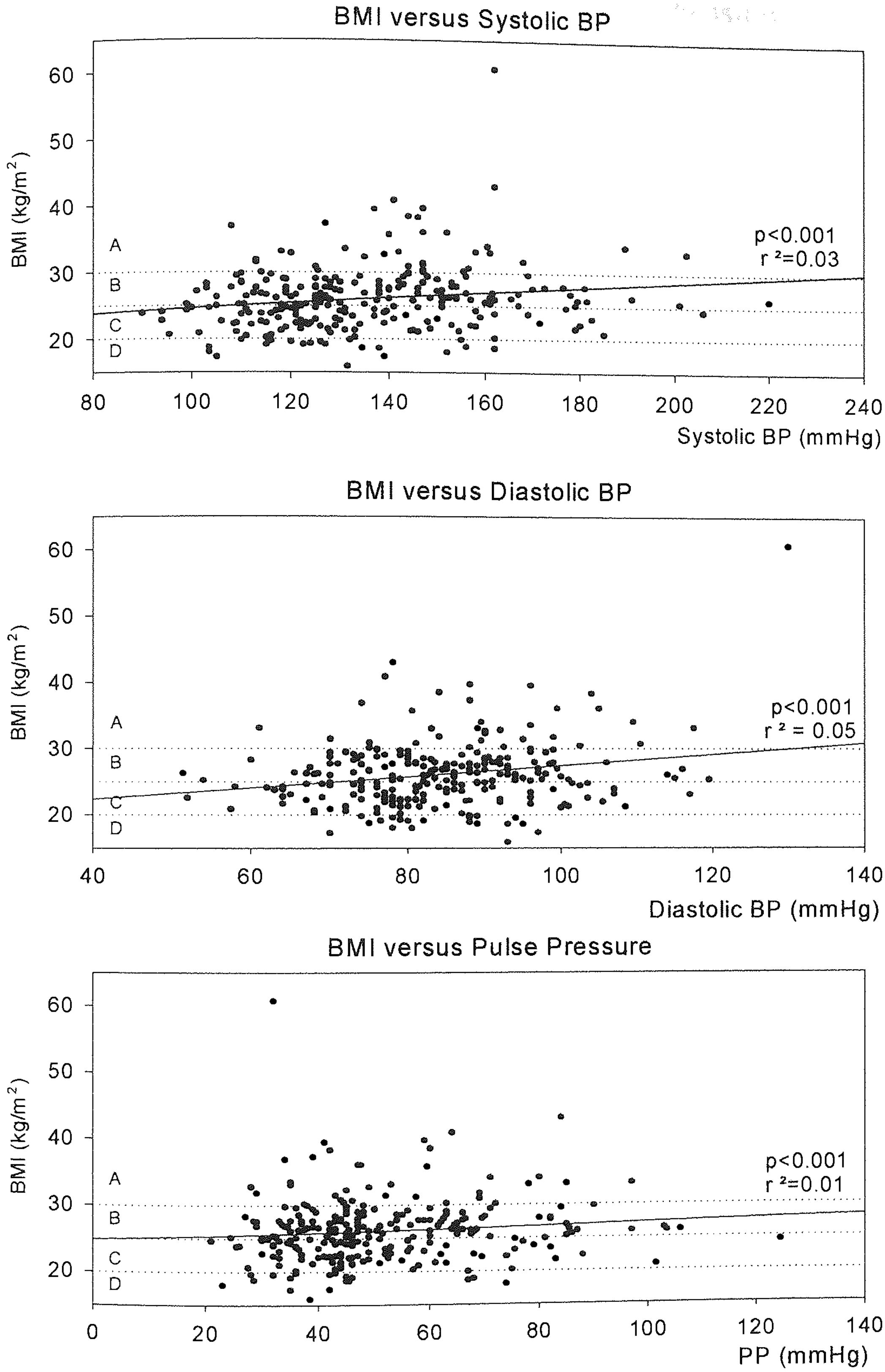


Figure 4.09: B.M.I. versus systolic BP, diastolic BP and pulse pressure (n=270).

Key: A - Obese; B - Overweight; C - Desirable; D - Underweight.

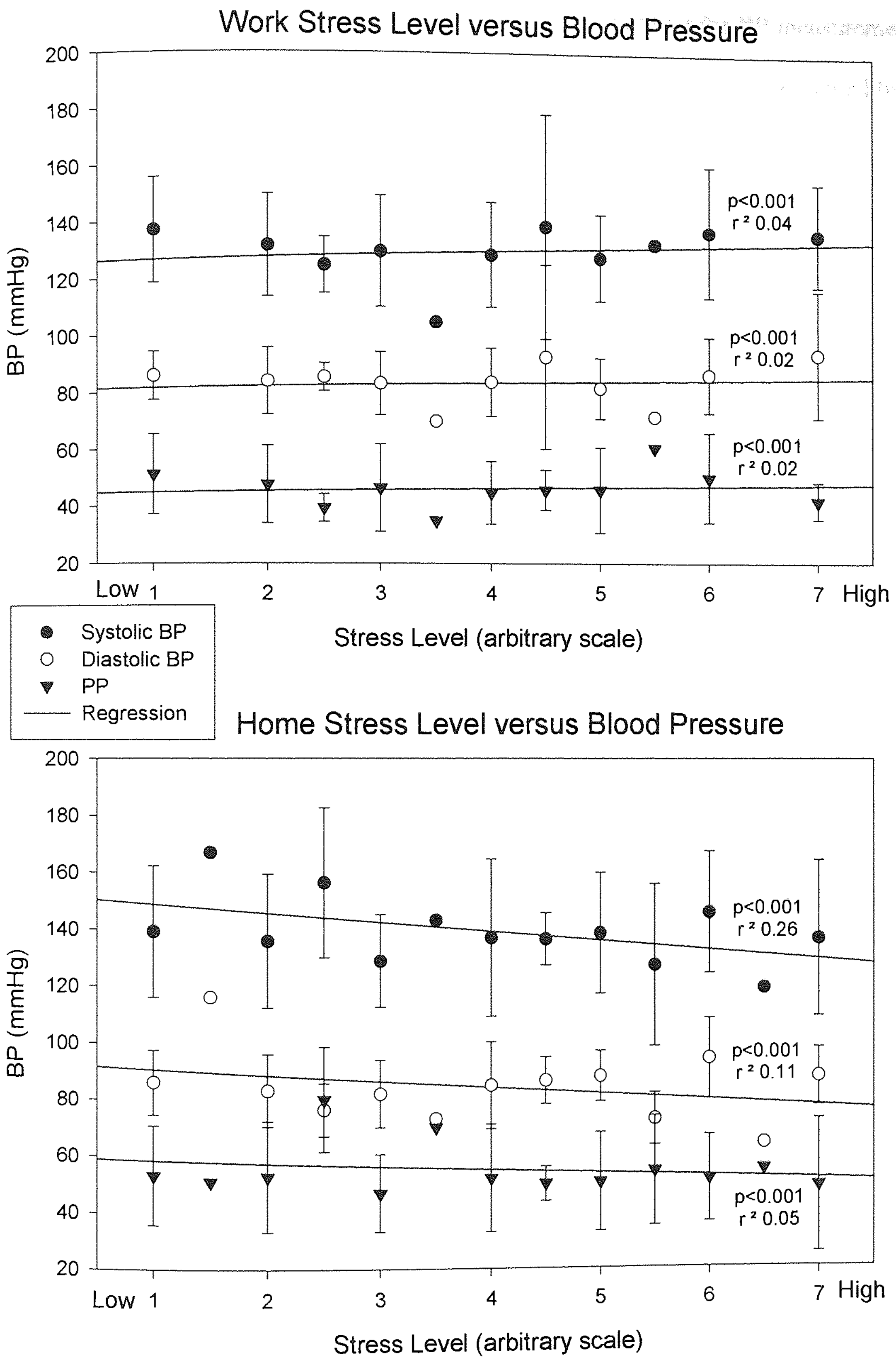


Figure 4.10: Stress levels and Blood Pressure (error bars ±1 S.D.).

The relationship between the patient's stated quality of diet and the BP measurement is plotted in Figure 4.11. This illustrates that as the quality of the diet, as perceived by the patient, improves; a slight elevation in BP and pulse pressure is observed (t test - two tailed; p <0.001).

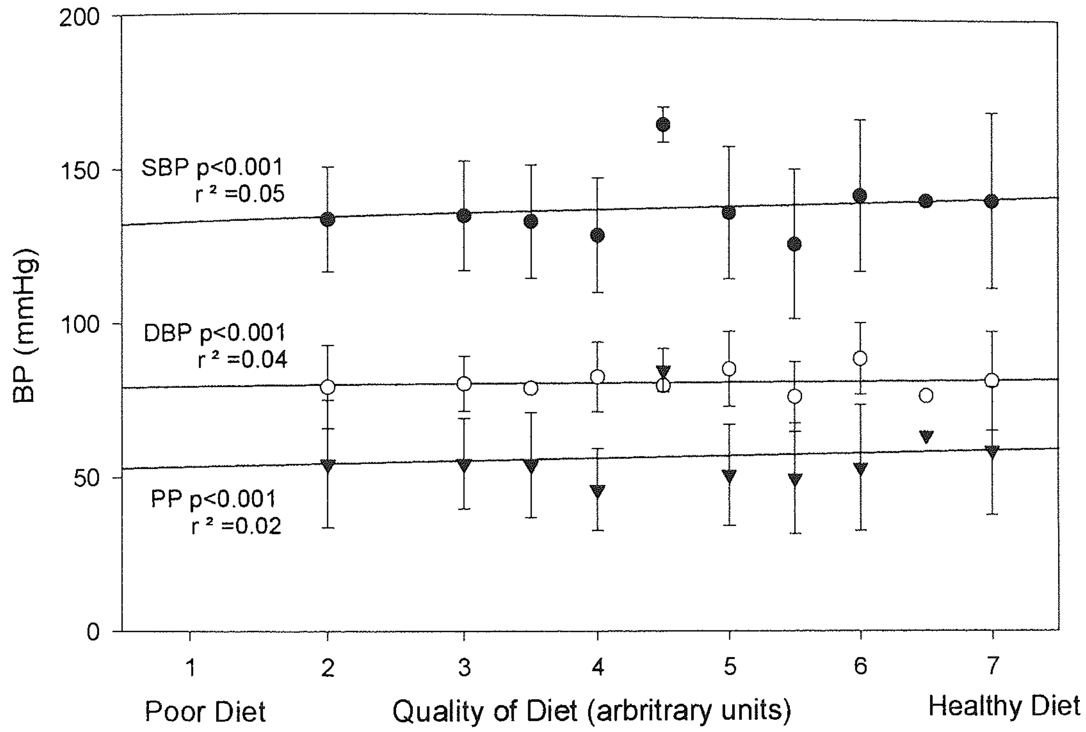


Figure 4.11: Quality of Diet versus Blood Pressure (error bars ±1 S.D.).

The number of patients who did not undertake any physical activity was 19.2% (25) of the males and 23.3% (35) of the females. The BP, both systolic and diastolic of those who participated in physical activity (12.9 ± 14.4 hours) was not significantly higher than an age and gender matched group who did not undertake any physical activity: 139.3 ± 24.5 / 87.6 ± 12.3 mmHg versus 135.9 ± 20.9 / 82.6 ± 10.8 mmHg (t test - two tailed; systolic BP p = 0.38; diastolic BP p = 0.05 and pulse pressure p = 0.67).

Over two thirds (69.6%) of the population drank alcohol on a regular basis (n = 195), with the amount consumed varying from 0.5 to 110 units/week. The government white paper on recommended alcohol intake of 21 units/week for males and 14 units/week for females was exceeded by 19.2% (n = 25) of the male and 9.3% (n = 14) of the female patients (NHS Direct Online, 2003). Patients who have a dependence upon alcohol (above 35 units/week) represented 3.1% (n = 4) of males who consumed alcohol or 16% of those males who exceeded the recommended weekly allowance. There was no significant difference in BP between those who regularly consume alcohol (10.2 ± 8.7 units/week) and age and gender matched teetotallers (137.4 ± 25.6 / 86.4 ± 13.1mmHg versus 135.9 ± 22.1 / 81.8 ± 10.2mmHg: t test - two tailed; systolic BP p = 0.72 and diastolic BP p = 0.03). The variation in BP with recommended alcohol consumption is plotted in Figure 4.12. With increase in alcohol consumption the BP of males stays constant; 138.5 ± 19.2 / 82.8 ± 10.3mmHg to 139.4 ± 15.6 / 85.5 ± 10.8mmHg (t test - two tailed; systolic BP p = 0.77 and diastolic BP p = 0.46). Female BP shows a non-significant drop in BP with alcohol consumption: 136.3 ± 21.4 / 83.5 ± 12.6mmHg to 120.7 ± 14.0 / 81.6 ± 14.1mmHg (t test - two tailed; systolic BP p = 0.48 and diastolic BP p = 0.27); non-drinker to exceeding recommended weekly allowance).

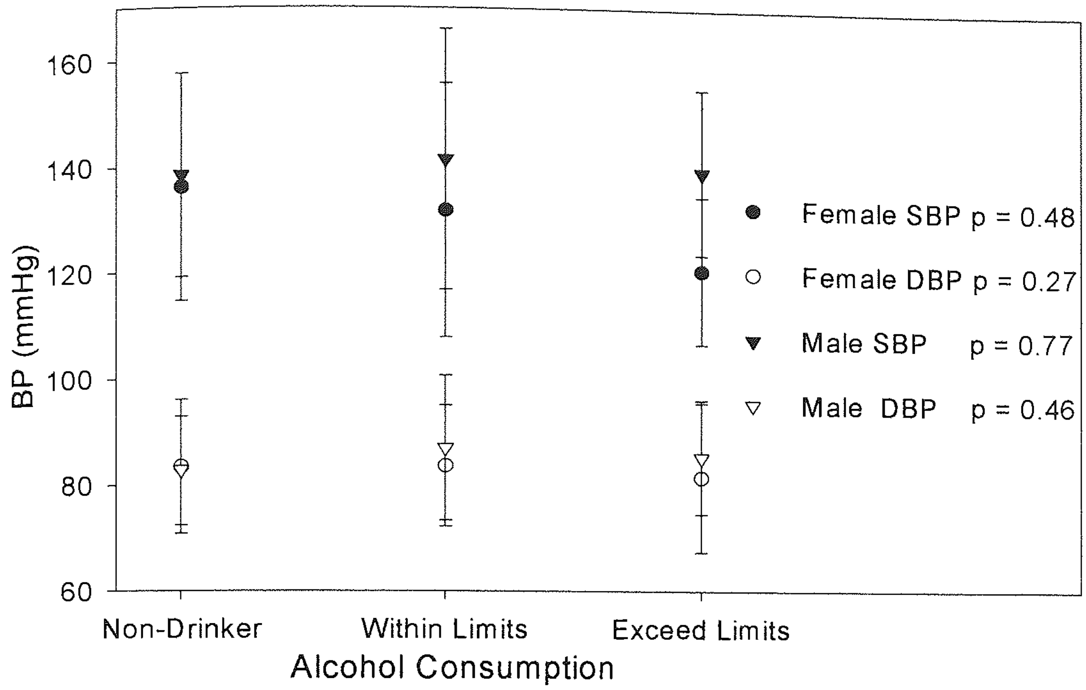


Figure 4.12: Blood Pressure variation with alcohol consumption (error bars ±1 S.D.).

Recommended alcohol consumption - male 21 units/week,

female 14 units/week.

4.40 - Discussion

4.41 - Practice Demographics

There are few surveys on the demographics of the optometric patient in the UK, while there are several large-scale, often cited, surveys of visual characteristics of the general populations from over-seas: Beaver Dam Study in America and the Blue Mountains in Australia. The optometric sample, from this UK study, just examined the adult population (>18 years), to calculate the prevalence of systemic hypertension and associated medical conditions in optometric practice. Comparison of the gender split of this sample with the 2001 Census indicated a similar composition of males and females (males: 45.4% versus 48.6%; National Statistics, 2003).

The average age of the optometric patient for a routine examination was 50.5 ± 17.4 years, comparable with Kaplan (1982) whose average was 57.5 years (no standard deviation stated, n = 273). The most prevalent patient age group were those in their late forties, which coincides with the onset of presbyopia. Port (1988) reported that virtually all of the population over the age of 45 would visit the optometrist for a presbyopic correction. The life expectancy in the UK is 73.6 years for men and 79.2 years for women (W.H.O., 1997).

The ethnic background of this sample population was similar to that of the UK. Across the country there will be variations in the ethnic make up of the patient base in optometric practice. Therefore, the optometrist needs to be aware of the ethnicity of his patient base, for the prevalence of medical and ocular conditions and health needs of all patients will be dependent upon their genetic background and environment (Sharp *et al.*, 1995; W.H.O., 1997). For example, patients born in the Indian subcontinent have an increased prevalence of ischaemic heart and cerebrovascular disease, and those from the Caribbean an increased prevalence of cerebrovascular disease. Prevalence rates of medical conditions are influenced by environmental conditions, for example ischaemic heart disease is more prevalent in the north of England (4 times more prevalent in this sample; W.H.O., 1997).

4.42 - Optometric Blood Pressure Measurement

Currently the majority of BP monitoring occurs within the GP surgery (79.3%, n = 124; chapter 5). With 29.0% of the diagnosed systemic hypertensives and 59.4% of normotensives with BP above 140/90mmHg there is a need for the widespread use of BP monitors in the primary health care sector to routinely screen all optometric patients. However, appropriate screening is only cost effective if drug therapies are effective. The prevalence of elevated BP (>150/95mmHg) in normotensives of 14.2% (n = 34) is significantly higher than that found in a survey of American optometrists who graduated from the University of Alabama (2.6%; Kleinstein *et al.*, 1982). Optometric graduates in America are trained in the measurement and assessment of BP, and routinely measure BP as part of their optometric routine. Therefore, it can be presumed many systemic hypertensives would have already been referred prior to the collection of the study data.

The elevation in BP with age confirms the findings of Duthie (1982); the elevation in systolic BP increases with age (46.2mmHg from the 3rd to 9th decade) whereas the diastolic BP plateaus in the 6th decade (10.7mmHg rise from the 3rd to 9th decade).

4.43 - Prevalence of Medical Conditions in Optometric Practice

The prevalence of systemic hypertension was just over one fifth (20.5%) of the optometric population. This is similar to the 15% prevalence of systemic hypertension in the UK stated by Grundy (1990). However, both these figures are much lower than that previously reported in the general population (34.3%; Klein *et al.*, 1993) and in a clinic for low earners (45.5%; Wolffsohn *et al.*, 2001). The lower prevalence could be due to the under reporting (found to be 31% between self reporting and GP records) of systemic hypertension (Wolffsohn *et al.*, 2001) and that systemic hypertension has been found to be more prevalent in the older population; 43-84 years (Klein *et al.*, 1993; Wolffsohn *et al.*, 2001).

The increase in prevalence of the medical conditions in those individuals with high BP indicates that they are more susceptible to disease states as their body system is compromised. The average elderly patient will be suffering from at least two chronic diseases and will visit the health care provider in relation to: circulatory problems, diabetes, arthritis or eye problems (Rumsey, 1988).

The prevalence of diabetes in this sample was 5.3%, which is lower than that found in Beaver Dam (10.3%; Klein 1992) and could be due to the multi-racial older age group sampled, which is associated with an increase in type II diabetes mellitus. The future holds an increase in elderly patients with diabetes mellitus due to longer life expectancy (of the diabetic as well as the normal patient) and an increase in obesity (Rumsey, 1988).

4.44 - Oral Contraceptives and Blood Pressure

The slight increase in the systolic and diastolic BP of patients taking oral contraceptives is similar to the elevation in systolic BP of 6.6mmHg and diastolic BP of 2.6mmHg recorded by Weinberger (1974). The oestrogen component of the oral contraceptives is responsible for the elevation in BP and will cause a rise in 5% of patients (Weinberger, 1974). Best practice states that these patients should have their BP measured every 6 months; in those patients who could recall the date of their last BP check (n = 14), three patients exceeded this limit (range 7 to 57 months). On the cessation of oral contraceptives BP will return to normal in half of users and remain elevated in the rest (Weinberger, 1974).

4.45 - Ischaemic Heart and Cerebrovascular Disease

Heart attacks are an indication that the cardiovascular system has failed to adjust to stress on the system. There is a high mortality rate associated with cardiac failure, with 62% of males and 42% of females dying within 5 years (Rumsey, 1988). The prevalence of strokes in UK optometric practice (2.3%) was lower than that reported in Beaver Dam (3.0%; Klein, 1992). Adjusting the UK figures to the same age group as Beaver Dam (43 to 84 years) the prevalence of strokes in the population rises to 3.4% (n = 7). This figure represents the high street prevalence and does not take into account those individuals who have had at least one stroke and are subsequently reliant on domiciliary optometric visits. To optometrists, the patient presenting with symptoms of temporary visual disturbance may have experienced a transient ischaemic attack (TIA). One third of these patients will experience additional TIAs while another third will progress onto a stroke. Given that there is a fifty percent mortality rate in the first few weeks following a stroke (Rumsey, 1988) there is a need for optometrists to measure the BP of patients reporting a TIA and to notify the patient's GP of their findings.

4.46 - Aging Population

With an aging population, the optometrist must be aware that the prevalence of medical conditions found in practice will increase. Screening of healthy patients who volunteered for medical research revealed that the prevalence of previously undiagnosed medical conditions increased above the age of 35 years. Systemic hypertension was found to be the most prevalent undiagnosed medical condition (1.2%) in the subjects (average age not stated; Singh, 1999). The average age of the patient in this sample of the optometric population was 50.5 ± 17.4 years so, as well as requiring assistance for presbyopia, the optometrist must also be aware that the patient is entering the decade where, on average, systemic medical conditions (BP, diabetes, heart disease, angina, kidney problems and cholesterol) are more prevalent.

4.47 - General Practitioner Attendance

The optometric patient is advised to have regular eye examinations once every one to two years, whereas they tend to visit their GP on an irregular basis when they feel unwell. The average time since the last visit to their GP was 7.8 ± 14.0 months. The GP is ideally placed and the patient's first port of call when he is feeling unwell, but the average time elapsed since the measurement of BP (not only by the GP) of 15.5 ± 24.4 months (2 days up to 13.5 years) is below the best practice guidelines of once every two years for the normotensive (Marshall and Malinovsky, 1998). Nearly one fifth (19.2%) of patients in the study had not had a BP measurement in the last two years. In a condition such as systemic hypertension, where the symptoms only appear when the complications in the target organs develop, there is a need to adjust our routine to serve these patients better.

The prevalence of BP >160/95mmHg was 8.3% in the whole sample. Therefore, an optometrist who incorporated sphygmomanometry into the sight test would refer on average, on BP reading alone, at least one patient a day to their GP for systemic hypertension (1 in 12.1 patients). Brin and Griffin (1995) in a review of referral rates in optometric practice found that the median of patients referred for systemic hypertension was 7.2% (range 5.3-47.2%). The patient demographics determine the referral rate, for referrals to all providers was twice that for the optometrist working with elderly patients (Hobley *et al.*, 1992; Brin and Griffin, 1995). These figures would indicate that there is scope for the optometrist to work alongside the GP in this area of public healthcare and measure the patient's BP as a routine part of the sight test.

The referral rate, on BP alone found in this study, is markedly higher than that revealed in several surveys on optometric referral to all providers: 4.2 ± 0.26% (Port and Pope, 1988), 6.05 ± 0.26% (Southgate, 1989) and 2.86 ± 0.44% (Hobley *et al.*, 1992). The opinion of the optometrists and GPs on this area of health care is discussed in chapters 2 and 5.

A survey of American optometrists revealed that of the optometric procedures the measurement of BP was considered to be the primary job which should be delegated to an optical assistant (90% of respondents). The dispensing of optical appliances, presently carried out by opticians (dispensing opticians in UK), was the task that nearly all optometrists (94%) felt should be delegated (Eger, 1982). The impact of trained optical assistants performing the pre-screening was not considered a threat to the future of optometrists by 76% of the sample and 78% felt that patients accepted the fact that these screening tests were performed by optical assistants rather than the optometrist (Eger, 1982).

The measurement of BP as part of the battery of tests in the pre-screen would improve the quality of the routine eye examination supplied in detecting systemic conditions that have a bearing on the ocular tissues. The future of the shared care management of the systemic hypertensive patient is discussed in chapter 5, and one of the areas of discussion this highlights is the need to arrange criteria, between the General Optical and Medical Councils, for referral of a patient on BP alone.

4.48 - Somatic Risk Factors

The patient's lifestyle, in terms of diet, physical activity (or lack of), smoking and excessive drinking are a leading cause of premature death from cardiovascular disease and cancer. Social group and socio-economic status influence a patient's lifestyle. Improvements in the patient's lifestyle have tended to occur in the privileged groups within the social and economic ladder (W.H.O., 1997).

Over half (58.2%) of the sample would be classified as being overweight of which 24.8% of them would be classified as being obese. Obesity is a pre-disposing factor to the development of non-insulin dependent diabetes mellitus, heart disease and high blood pressure (Field *et al.*, 2001; Vinicor, 2002). It may, therefore, be appropriate for the optometrist to provide lifestyle advice to patients in addition to the present role of screening for diabetic retinopathy. Cholesterol levels were not examined as part of the research as no validated test that can be performed in the optometric practice has been designed. Over a quarter (28%) of the adult population have a moderate or severely raised serum cholesterol level, which is associated with obesity, heavy smoking and alcohol consumption (W.H.O., 1997).

The grading of the patient's stress level is highly subjective and dependent on their interpretation of the situation. In times of stress, adrenaline is produced by the body, which increases BP. The effect of stress on the patient will vary, causing a variety of complaints: headaches, depression, lower resistance to disease and emphasis of existing bodily weaknesses (Barnes *et al.*, 1989). The negative correlation for stress levels in the home could be due to a drop in BP, as recorded in the optometric practice, while the patient is away from the stressful environment.

Nutrition

The grading of the quality of the diet by the patient is very subjective and is based on their perceived intake of the five food types: fat (long-term complications due to excessive intake: cancer and heart disease), cholesterol (heart disease); salt (systemic hypertension); sugar (dental decay); and fibre (long-term complication due to lack: cancer, diabetes mellitus; Barnes *et al.*, 1989). The positive correlation between the quality of diet and the BP could be due to the quantity of produce consumed (not examined in this research). With a change in the nation's diet from one lacking in vitamins, minerals and protein to one of excess, there is a need for primary health care providers to promote a healthy lifestyle in their patients (Vinicor, 2002).

Tobacco Consumption

Cigarettes constrict the arteries and induce an elevation in BP and pulse. However, with the BP measurement being recorded thirty minutes after the last cigarette, the subject's circulation should have returned to the resting state, accounting for the similar BP of the two groups (Barnes *et al.*, 1989). The prevalence of smoking was greater in males (29.2%) than in females (24.6%), which is slightly less than previously reported for the UK: 35% and 29% respectively (W.H.O., 1997). This lower prevalence in smoking matches the current trend in the reduction of smoking in the adult population. The trend in teenage smokers (11 to 15 years) has been relatively stable since the 1980s, which could be due to a change in marketing of cigarettes to the younger population, who have yet to realise the long-term risks of cigarette smoking upon the circulation: plaque formation, cholesterol, arteriosclerosis, stroke and heart disease (higher for women on the contraceptive pill; Barnes *et al.*, 1989).

Alcohol Consumption

The prevalence of patients who exceeded recommended safe limits for alcohol consumption was similar to the UK average (18% male and 7% female; NHSdirect online, 2003). The effect of moderate amounts of alcohol on the cardiovascular system is the dilation of the small blood vessels, which lowers the subject's BP and reduces the strain on the heart (Thomson, 1974). The development of arteriosclerosis may be retarded with a daily unit of whisky (Barnes *et al.*, 1989).

Physical Activity

The number of patients with sedentary lifestyles was similar to that of the UK population: males 19.2% versus 18.0% and females 23.3% versus 20.0% (W.H.O., 1997). The lower resting BP of those with sedentary lifestyles masks the fact that these patients put their cardiovascular system under increased workload (greater elevation of BP and pulse rate) during periods of stress or exertion compared with those who undertake regular exercise. In such patients the observation of the retinal vasculature may be more indicative of their systemic health than isolated BP measurements. Regular exercise (at least one hour a week) has been shown to be beneficial to the cardiovascular system (Barnes *et al.*, 1989).

The effect of lifestyle on the patient as a whole is vast and the questions asked mainly assessed those factors directly affecting the patient's cardiovascular status (to avoid the stress of intruding onto personal matters). Questions concerning economic and educational factors were not discussed; for example; systemic hypertension has been shown to be more prevalent in lower income and lower educated groups (Kleinstein *et al.*, 1982; W.H.O., 1997).

4.50 - Conclusion

The optometrist must be fully aware of the patient's general health and lifestyle; for in an aging population where the inhabitants often have a high stress lifestyle, limited leisure time and unhealthy diets, systemic hypertension is a major health concern. The three main causes of death in the UK are: external (e.g. accidents) cancers and cardiovascular disease, which are due to health and related to the patient's habits and behaviour (W.H.O., 1997). Literature in the optometric practice should be informative and promote the health of both the eye and the body. The optometrist should not only be a primary health care provider, but with the range of patients that will be seen, should provide preventative health care.

Retinal examination provides the optometrist with the opportunity to observe changes in the retinal vasculature due to systemic hypertension (Terry, 1976). Funduscopy will give an indication into the duration of the systemic hypertension, but does not indicate acute BP elevation, for which it is necessary to undertake sphygmomanometry. The incorporation of BP measurement into the optometric practice, for all patients or those at risk (e.g. age, systemic disease or B.M.I.) would increase the screening for a potentially fatal condition.

CHAPTER 5 - CURRENT GENERAL PRACTITIONER OPINION ON OPTOMETRIC BLOOD PRESSURE MEASUREMENT

5.10 - Introduction

The majority of the optometrists in the UK presently evaluate the condition of the body's vasculature network to determine the presence of systemic hypertension through fundus examination alone (chapter 2). The importance of these ophthalmoscopic signs is in part determined by the patient's history and symptoms recorded at the start of the sight examination. There is, therefore, need to evaluate how reliable patients are in passing on their correct medical status to their optometrist through both general and direct questioning. This has previously been shown to be poor in a group of Australian optometric patients attending a large national health centre in Melbourne (Wolffsohn *et al.*, 2001). The reliability and accuracy of the patient to give an accurate history and symptoms will be assessed by confirmation of their medical status by their General Practitioner (GP).

The monitoring of BP in optometric practice involves taking a piece of medical equipment that the general public associates with doctors and utilising it in the high street location. Incorporating an additional medical role would require educating optometrists in the use of BP monitors and the interpretation of the findings (chapter 2). The multi-disciplinary optometric practice performing BP measurement would operate in close collaboration with the GP, referring those patients requiring further investigation.

There are no published articles on the opinions of GPs on the involvement of the optometrist in the screening for systemic hypertension in the UK. Communication presently between optometrists and GPs is mainly through patient referral letters, for which several studies have examined referral rates from optometric practice: 4.20 ± 0.26% (Port and Pope, 1988) and 2.86 ± 0.44% (Hobley *et al.*, 1992). Communication towards the optometrist, a copy of the letter sent to the GP from the ophthalmologist, has been calculated at 15.9% (Whittaker *et al.*, 1999). This feedback allows confirmation of the optometric findings to assist future patient management, but does not indicate the type of patient or presenting symptoms the doctor would wish to see in the future. There is a need, especially in the case of systemic hypertension where there is no firm dividing line between normal BP and elevated BP, to identify what level of BP UK GPs would like to be informed about to enable appropriate referral.

The current optometric referral letter/form (GOS 18) elicits precise details about the patient's risk of developing glaucoma (disc appearance, IOP and visual fields). For all other ocular conditions, it is generic in construction and does not prompt the optometrist to divulge precise information. Referral letters used for diabetic screening shared care are specific to the findings of the examination enabling dissemination of precise information onto the ophthalmologist. There is a need to assess what a GP would wish to see on the referral letter (generic form or letter) for the systemic hypertensive patient. Introduction of a pro forma referral letter, in South Africa, to provide clear concise information for the GP, consultant and patient, has been found to improve the quality of the referral letter but not influence the rate and quality of the replies (Couper and Henbest, 1996).

The opinion of the optometric profession on the use of BP monitors in practice has been previously examined (chapter 2) and the prevalence of cardiovascular medical conditions in optometric practice (chapter 4). This chapter examines the patient's ability to recollect correctly their medical status and the opinions of GPs on the possible future incorporation of BP measurement in optometric practice.

5.20 - Method

Eighty-four subjects were recruited from those who were participating in the cross-sectional study of retinal vasculature (chapter 3). The subjects were all supplied with an information sheet on the procedures to be undertaken (appendix 2) and signed a consent form permitting correspondence with their GP (appendix 2). The only criterion for patient selection, from the initial collection point, was consent for correspondence between the researcher (P.H.) and the patient's G.P. The research was approved by Aston University ethics committee and conformed to the declaration of Helsinki.

The initial research session with the patient involved completion of a medical and lifestyle questionnaire (appendix 2), BP measurement and fundus photography; described in detail in chapter 3. Information passed onto the patient's GP consisted of BP measurement and fundus photographs. Any patient whose research findings warranted further investigation was referred to his/her GP for future management (if consent was given).

5.21 - General Practitioner Questionnaire

The GPs were supplied with the questionnaire, Table 5.01, to confirm the patient's medical status and gauge their opinion on the role of optometrists in BP measurement. Consent for this information on their patient's medical status to be released had already been given by the patient. Sixty two GP practices/surgeries were sampled, of which the majority were based in the West Midlands, with three patients' GPs located further afield: Devon (1) and Wiltshire (2). A stamped addressed envelope was supplied with the questionnaire to optimise the ease of response.

The data provided by the GPs was compared against both the responses supplied by the patients in response to general (e.g. "How is your general health?") and direct questioning (e.g. "Do you have high blood pressure?"). These findings would determine the usefulness of such question types by optometrists to glean information from the patients. The duration of the medical condition was taken as the time since the patient was diagnosed and recorded in months.

5.22 - Blood Pressure Measurement

The first section of the questionnaire completed by the GPs, asked for confirmation of the date of the patient's last BP reading at the GP surgery and the date of their next scheduled review. This data would allow analysis on the frequency of BP readings at the GP surgery and the patient's ability to state correctly the dates of their last and next BP measurement. The precise BP reading in the GP's records on this occasion was also requested to assess the patient's ability to correctly recollect their last BP measurement. In those patients who were only able to supply details of their last BP reading in terms of: "high, slightly high and okay", the BP supplied by the GP was converted into a similar phrase with the formula adapted from the Joint National Committee guidelines on BP classification (JNC, 1997): systolic BP: <130mmHg = "okay", 131-159mmHg = "slightly high" and >160mmHg = "high" and diastolic BP: <85mmHg = "okay", 86-99mmHg = "slightly high" and >100mmHg = "high".

The clinic BP measurements supplied to the GP were all recorded using the OMRON 705CP automatic BP monitor, which has been found to be as accurate and reliable as the mercury sphygmomanometer (Artigao *et al.*, 2000). All BP measurements and the time at which they were taken were recorded. The average of two readings within

5mmHg of each other was taken as the patient's BP (J.N.C., 1997). The GP was informed of the average BP measurement, the time of the reading and the name and type of BP monitor used. Further details on the measurement of BP may be found in chapter 1.

5.23 - Patient Medical Status

For those patients with systemic hypertension and cardiovascular disease the GPs stated the type of cardiovascular disease, duration and the current medication prescribed. The information supplied by the GPs permitted comparison with the details supplied by the patient in the initial questionnaire (appendix 2) to assess their ability to supply accurate information on their medical status and current medication.

5.24 - Fundus Photographs

Non-mydriatic 45° fundus photographs, centred on the optic disc, were taken using a Topcon TRC-NW5S digital fundus camera (gain setting 12). At least one photograph per eye was taken of each subject to ensure the best quality image. The photographs were taken in the same part of the cardiac cycle (closure of the aortic and pulmonic valves) by timing the camera trigger with the second heart sound detected through a stethoscope. Timing the photograph with the same part of the cardiac cycle minimizes the variation in vessel diameter due to pulsation (~6%; Hill and Crabtree, 1994). The diaphragm of the stethoscope was held in place by the patient over the aortic area (the second intercostal space close to the sternum). The aortic area does not correspond to the anatomic location of the valve, but the site at which the sounds from the valve are best heard (Andreoli *et al.*, 1983). The stethoscope was lengthened (1.3m) to allow the patient to hold the diaphragm in place while the examiner (P.H.) sat behind the camera with a finger on the trigger listening to the heart sounds. The digital photographs were printed onto photographic paper and supplied to the patient's GP.

5.25 - General Practitioner Opinion on Optometric Blood Pressure Measurement

GPs were asked for their opinion on BP measurement in optometric practice. Those who were in favour of optometrists measuring BP were asked to state which type of patient (with regard to medical condition) they would suggest routine BP measurements to be recorded. The level of BP at which they would like to be notified upon was also requested. The concept of closer collaboration between GPs and optometrists in the measurement of BP in a Shared Care framework, as is the case with diabetic patients, was also assessed. Additional comments made by the GPs to elaborate on the issues raised were recorded to avoid the loss of any information. The data from the completed questionnaires were entered into a spreadsheet for analysis.

Patient Details: «Title» «FirstName» «LastName», (dob.: «DateBirth»).

When did your patient last come to you for a blood pressure check? __________
What was the blood pressure? ____/____mmHg
When is the next scheduled review of blood pressure? __________

Do you consider your patient to have systemic hypertension? Yes ❑ No ❑
If Yes: How long have they had systemic hypertension? __________
What medications are currently prescribed?

Do you consider your patient to have cardiovascular disease? Yes ❑ No ❑
If Yes: What type? __________
How long have they had cardiovascular disease? __________
What medications are currently prescribed?

Optometric Involvement in the Detection & Monitoring of Systemic Hypertension

	Agree			Neutral			Disagree
Optometrists should measure BP	3	2	1	0	1	2	3

Please complete part a or b:
a) *If you consider this to be unnecessary, please state the reason(s) why:*

---

b) *If you consider Optometrists should measure BP, should this be on (please tick):*

All patients	❑	Known hypertensives	❑	P^xs with cardiac problems	❑
Diabetics	❑	Glaucoma sufferers	❑	P^xs with hypertensive symptoms	❑

When would you find it useful to receive a report on your patient?

If their systolic pressure was >**180** or their diastolic >**110**	Yes ❑	No ❑
If their systolic pressure was >**160** or their diastolic >**100**	Yes ❑	No ❑
If their systolic pressure was >**140** or their diastolic >**90**	Yes ❑	No ❑
If their systolic pressure was >**120** or their diastolic >**80**	Yes ❑	No ❑

	Agree			Neutral			Disagree
A fundus photograph should be included with a referral	3	2	1	0	1	2	3
Shared care schemes should incorporate systemic hypertension	3	2	1	0	1	2	3

Comments:

Would you be interested in receiving the results of this study? *Yes* ❑ *No* ❑

Many thanks for you participation

Table 5.01: General practitioner questionnaire.

5.30 - Results

Sixty-nine (84.1%) completed questionnaires were returned by the GPs. This represented 59 GPs from 55 general medical practices. The responses are calculated as percentages and the number of patients included in the category is given in brackets. Parametric results are presented as the mean ± 1 standard deviation. The average age of the patient, whose GP responded, was 62.2 ± 13.6 years and 50.7% (n = 35) were male. Two fundus photographs were returned as well as a letter from one GP asking for clarification on the fundus photograph supplied to explain the absence of a haemorrhage picked up by the patient's optometrist several years previously.

In the collection of data at this initial session, two patients without any history of systemic hypertension were referred to their GP for elevated BP, and were subsequently placed on antihypertensive medication. Over a two-year period, of those patients who permitted correspondence with their GP, 2.4% (n = 2) patients were diagnosed with systemic hypertension and placed on medication and 7.1% (n = 6) patients had their medication for systemic hypertension changed. Additional referrals to GPs from the research concerned one patient who was found to have a cardiac murmur (aortic stenosis) while the stethoscope was placed over the aortic area for the fundus photographs and one patient who was found to have a choroidal naevi with surface drusen (identified from the fundus picture and not previously noted in the patient's record card).

5.31 - General Practitioner Contact Details

Patients were asked to supply the researcher with the name and contact address of their GP, which was then compared with GP address lists for confirmation. All patients (n = 69) were able to supply the researcher with the name or part name of their current GP, Figure 5.01. Over three quarters of patients were able to recollect correctly the practice's name (21.9% were unable or supplied incorrect information), road (94.2%) and town location (98.6%). Patients' recollection of the second half of their GP's post code (PC2) was the least reliable (10.1% responded correctly).

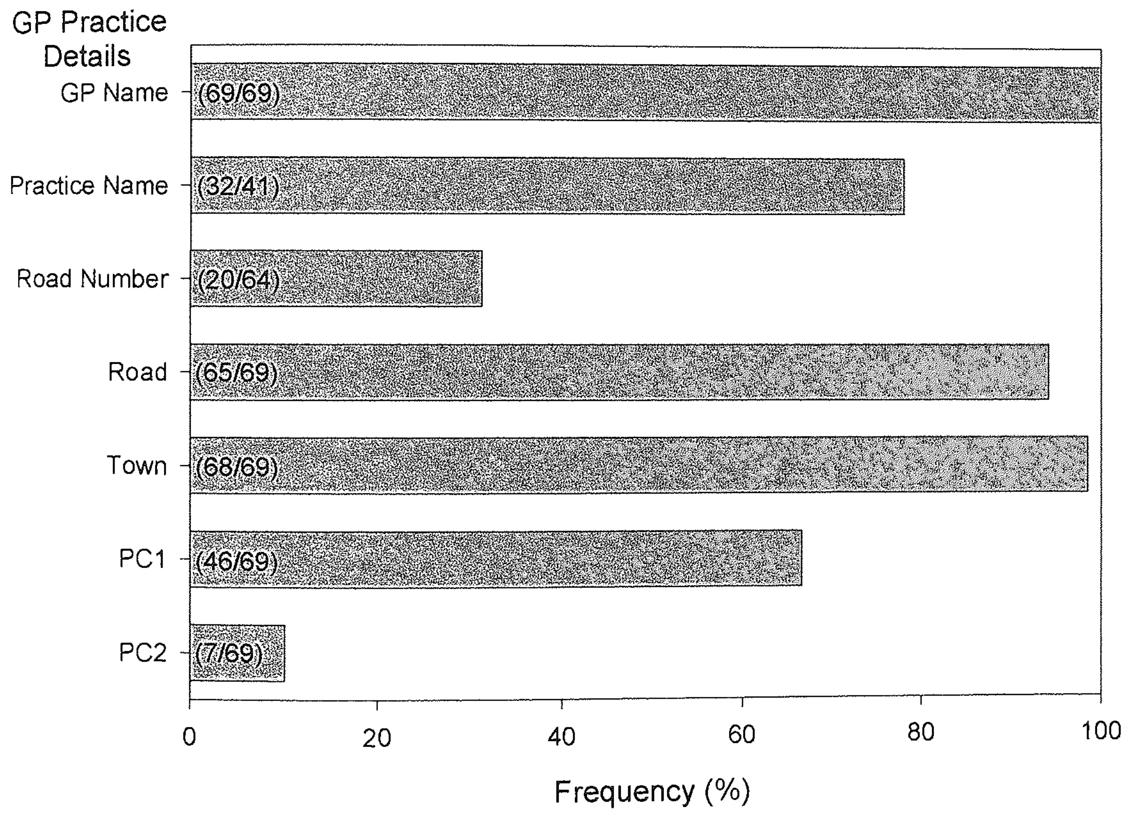


Figure 5.01: Patient recollection of general practitioner contact details.

Key – (number stated correctly / details appropriate to GP address),

PC1 = Postcode area identifier,

PC2 = Postcode street identifier.

5.32 - Blood Pressure Measurement

The patients' ability to recollect correctly the date of their last BP measurement at their GP surgery is illustrated in Figure 5.02. The disagreement between the patients' memories of the date of their last BP reading and that stated in the GPs' records ranged from 0 (correct) to 263 months (21 years 11 months). The average error per patient was just under 17 months. The disagreement in the date of the last BP check was significantly less in the systemic hypertensives than the normotensives, 5.2 ± 5.4 months versus 25.6 ± 46.4 months respectively (t test - two tailed; $p < 0.01$). One GP stated that there was no record in the patient's file stating a preceding BP measurement; although the patient stated that the last measurement taken by the GP was 7 months previous. The average date of the last visit to the GP surgery (according to GP records) for a BP measurement was 13.5 ± 22.8 months. Patients with diagnosed high BP were on average seen on a more regular basis at the GP surgery: 1.4 ± 5.3 months (high BP) versus 22.4 ± 26.5 months (normotensive; $p = 0.07$). There was a negative correlation between a patient's age and the time since their last GP BP measurement (t test - two tailed; $p < 0.001$). The time since the last visit to the GP was greater for group 2 (40 to 60 years) than for group 3 (>60years): 20.0 ± 29.8 months versus 10.5 ± 19.2 months respectively (t test - two tailed; $p < 0.05$).

One fifth (20.3%; n = 14) of the patients were able to provide the researcher with figures (systolic and diastolic components) they associated with their last BP measurement. The average error for systolic BP was 0.31 ± 13.62mmHg and diastolic BP -0.85 ± 6.67 mmHg. The range of error from actual BP measurement is illustrated in Figure 5.03. Only one patient was able to correctly state the BP reading at their last GP surgery, as noted down in the patient's diary. Nearly two thirds of the patients (62.3%; n

= 43) were able to inform the researcher of their BP at the last reading with a verbal description: "high, slightly high or okay". Fifteen of these patients (34.9%) were able to correctly state their BP in agreement with their GP, all of whom had normal BP. Separating BP into the systolic and diastolic component, the patients' ability to correctly state their BP in relation to the GP figures was 39.5% (n = 17) with systole and 55.8% (n = 24) with diastole, Figure 5.04. Comparing the descriptive definition of BP from the patient with the actual reading from the GP, identified that when there was disagreement between the readings, then the odds of the reading as stated by the patient being lower than it actually was is 4.2:1 for systole and 2.2:1 for diastole.

The schedule for the next BP review was on average 3.00 ± 3.00 months according to the GP and 2.5 ± 2.0 months according to the patient (n = 30). Disagreement between GP and patient ranged from one week up to 36 months. The time of the next BP measurement was also stated by several GPs as "due" (2), "soon" (1) "next appointment" (1) and "overdue" (1). Nearly ten percent (7.2%; n = 5) of patients, all normotensive, were not sure of their next BP review. Just under half of the subjects (47.8%; n = 33) stated that there was no review planned, of which a third (33.3%; n = 11) according to the GP records had a scheduled review, three of whom were systemic hypertensives.

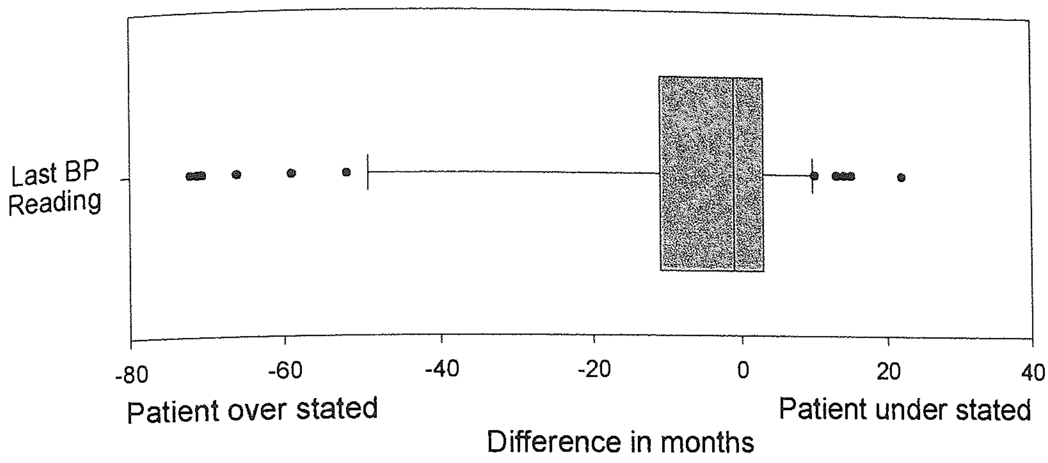


Figure 5.02: Discrepancy between patient and General Practitioner over the date of the last Blood Pressure reading,

Whiskers equal 10th and 90th percentiles.

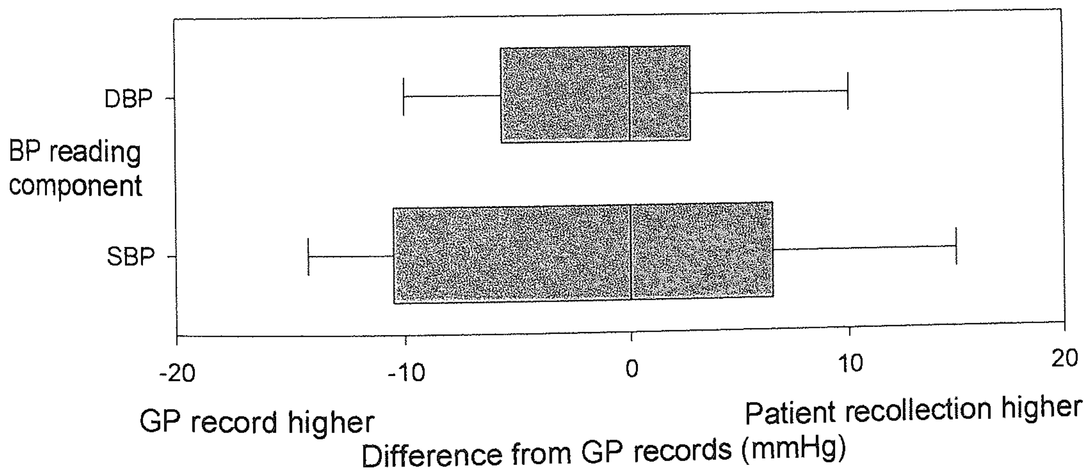


Figure 5.03: Difference between patient recollection and General Practitioner records of last Blood Pressure measurement (actual figures).

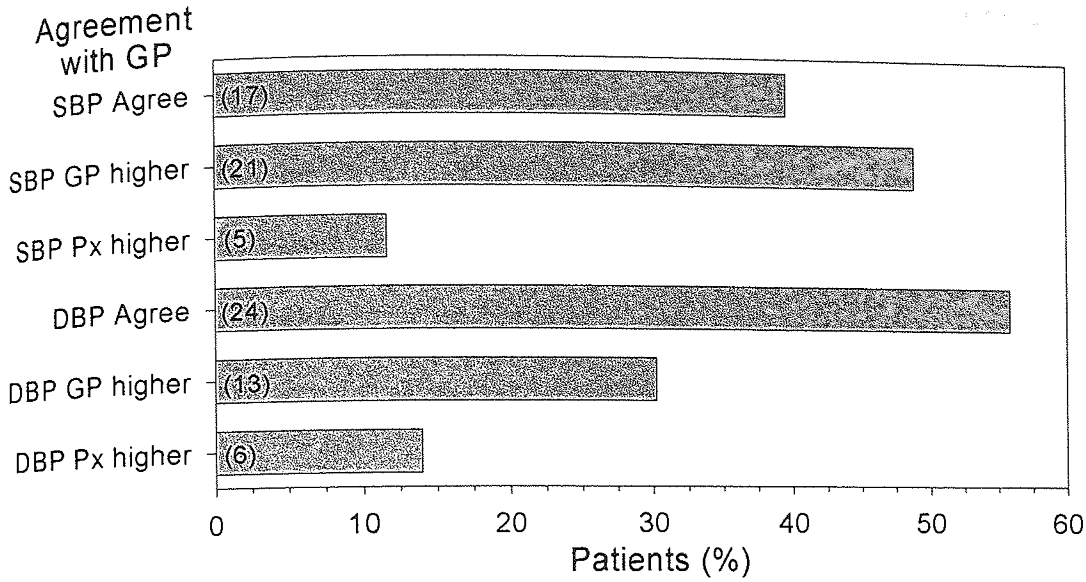


Figure 5.04: Difference between patient recollection and GP records of last BP measurement (descriptive figures).

5.33 - General Health

Patients' response to "Do you have any general health problems?" revealed a prevalence rate of 15.9% of systemic hypertension (n = 12, 42.9% of all systemic hypertensives in the sample). Asking the patients subsequently "Do you have high blood pressure?" raised this prevalence rate to 37.9% (n = 26, 100% of all systemic hypertensives). Confirmation of the prevalence rate of systemic hypertension with direct questioning indicated that all diagnosed systemic hypertensives and normotensives gave the correct information, whereas general questioning missed over half (57.1%; n = 14) of the diagnosed hypertensives.

Asking the patients about their cardiovascular status (angina or heart disease) revealed an 83.3% (n = 10) correct response to a general question rising to 100% (n = 12) response with direct questioning. The various types of cardiovascular disease present in this population are illustrated in Figure 5.05. Ischaemic heart disease is the most prevalent (33.3%; n = 4) form of cardiovascular disease in this population (5.8% of all patients).

The current medication for systemic hypertension and cardiovascular disease taken by this population is illustrated in Table 5.02. These figures represent the medication divulged by the patient with direct questioning and confirmed / supplemented by the GP. 39.3% (n = 11) of the patients presently taking systemic hypertensive and cardiovascular medication were able to correctly state both the name and the dosage of the medication with direct questioning. 10.7% (n = 3) of patients were not able to remember either the name or the dosage of their medication. Table 5.02 (a and b) also states the possible ocular side effects of each of these medications. The main ocular symptoms that patients may present with in the sight examination, which may be a side effect of their hypertensive medications, are: photosensitivity, headaches and dizziness.

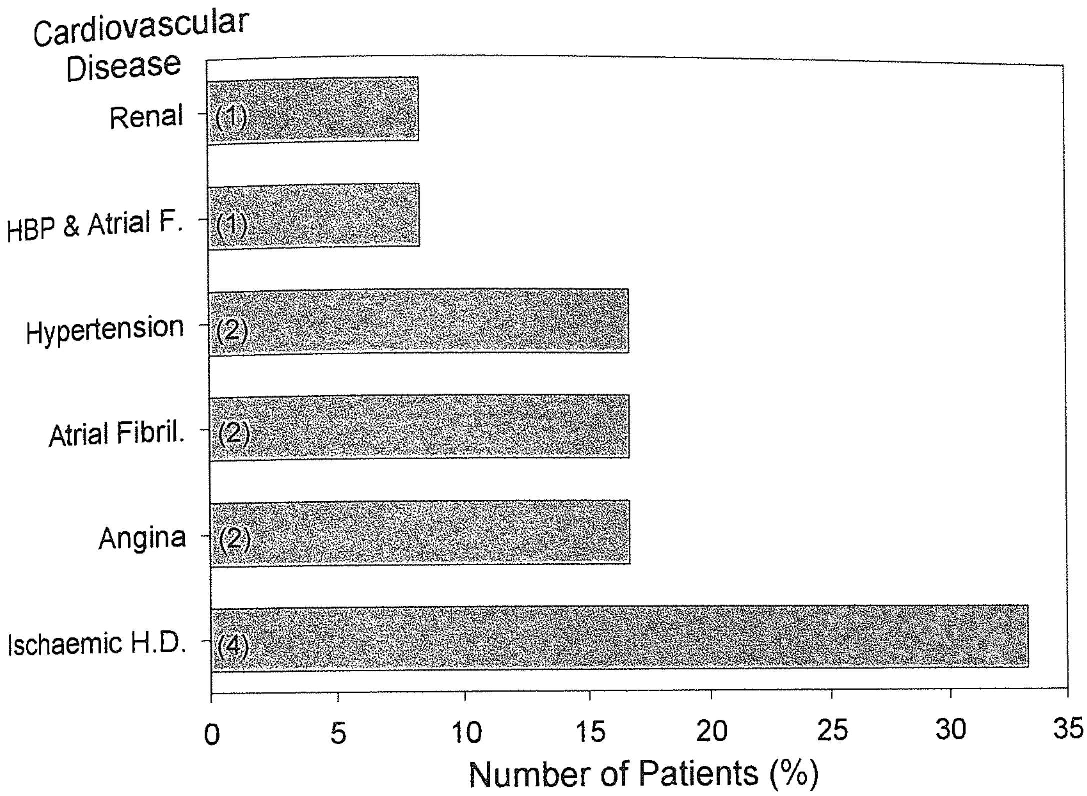


Figure 5.05: Type of Cardiovascular Disease (n = 12).

Key: Renal = Renal Disease;

HBP & Atrial F. = Systemic Hypertension and Atrial Fibrillation;

Hypertension = Systemic Hypertension;

Atrial Fibril. = Atrial Fibrillation;

Ischaemic H.D. = Ischaemic Heart Disease.

Drug mode of action	Drug active ingredient	Drug brand / proprietary name	n	Possible ocular and / or related side effects
Diuretics Thiazides and Related Diuretics	Bendrofluazide	Bendrofluazide	7	Photosensitivity
	Hydro-chlorothiazide	Hydrosaluric	1	Photosensitivity
	Indapamide	Indapamide	1	Headache Photosensitivity Reversible acute myopia
		Natrilix	1	
Diuretics Loop	Frusemide	Frusemide	1	Photosensitivity
Diuretics Potassium-Sparing	Co-Amilofruse	Co-Amilofruse	3	-
	Navispare	Navispare	1	-
Beta-Adrenoceptor Blockers	Acebutolol	Sectral	1	Dry eyes Peripheral vasoconstriction
	Atenolol	Atenolol	4	Dry eyes Peripheral vasoconstriction
		Tenoretic	1	
	Sotalol Hydrochloride	Sotalol	1	Dry eyes Peripheral vasoconstriction
Angiotensin-Converting Enzyme Inhibitors	Captopril	Captopril	1	Headache Maculopapular rash Photosensitivity Sinusitis
	Enalapril Maleate	Enalapril Maleate	1	Blurred vision Headache Photosensitivity Sinusitis
	Lisinopril	Zestril	4	Headache Photosensitivity Sinusitis
	Ramipril	Tritace	1	Conjunctivitis Headache Photosensitivity Sinusitis

Table 5.02a: Anti-hypertensive and cardiovascular medication prescribed and possible ocular / or related side effects (summarized from B.N.F., 2000).

Drug mode of action	Drug active ingredient	Drug brand / proprietary name	n	Possible ocular and / or related side effects
Calcium-Channel Blockers	Amlodipine Besilate	Istin	3	Dizziness Headache Visual disturbances
	Diltiazem Hydrochloride	Diltiazem	2	Dizziness Headache Photosensitivity
		Tildiem LA	1	
	Felodipine	Plendil	1	Dizziness Headache
	Lacidipine	Motens	1	Dizziness Headache
	Nicorandil Hydrochloride	Cardene	1	Dizziness Headache
	Nifedipine	Adalat	2	Dizziness Eye pain Headache Visual disturbances
	Verapamil Hydrochloride	Securon	1	Dizziness Headache
Nitrates	Glyceryl Trinitrate	GTN 300-mcg	1	Dizziness Throbbing headache
		Nitrolingual Pumpspray	1	
	Isosorbide Dinitrate	Isosorbide Dinitrate	2	Dizziness Headache
	Isosorbide Mononitrate	Imdur	2	Dizziness Headache
Angiotensin II Antagonists	Losartan Potassium	Cozaar	2	Dizziness
	Valsartan	Diovan	3	-
Cardiac Glycosides	Digoxin	Digoxin	1	Hallucinations Headache Visual disturbance
Oral Anticoagulants	Warfarin Sodium	Warfarin	2	Haemorrhage
Antiplatelet Drugs	Aspirin	Aspirin	10	Haemorrhage
Lipid-Regulating Drugs	Cerivastatin Sodium	Lipobay	2	Headache
	Simvastatin	Zocor	2	Dizziness Headache

Table 5.02b: Anti-hypertensive and cardiovascular medication prescribed and possible ocular / or related side effects (summarized from B.N.F., 2000).

5.34 - General Practitioner Opinion on Measurement of Blood Pressure in Optometric Practice

The GPs sampled were generally in favour of optometrists measuring BP (+1.42, n = 59); Figure 5.06. The views of the optometrist in relation to BP measurement (chapter 2) revealed that they felt that GPs would be only slightly in favour (+0.40) of them measuring BP. GPs were in favour (+1.29, n = 49) of the incorporation of systemic hypertensives in optometric Shared Care schemes in the future. They were also in favour (+1.13, n = 53) of a fundus photograph accompanying the optometrist's referral letter.

Over half of the GPs who expressed a neutral to positive response to optometric use of BP monitors stated that the BP of all patients should be monitored (53.6%, n = 30; Figure 5.07). Over two thirds of GPs stated that diabetics should have their BP measured as part of the sight test (67.9%, n = 38), closely followed by those patients who are already known to have high BP or symptoms of systemic hypertension (64.3%, n = 36). Additional patient categories that would require BP measurement were stated as: at the optometrist's discretion (2); following a fall (1), patients over 35 years (1); over 40 years (1), over 60 years (1); non-systemic hypertensives (1), and patients who do not see their GP regularly (4).

The average BP reading recorded for the research was higher than that in the GP surgery: (difference 2.7 ± 14.5mmHg for systolic (t test - two tailed; $p = 0.14$) and 3.0 ± 9.4mmHg for diastolic (t test - two tailed; $p < 0.01$); n = 65). The range of differences is shown in Figure 5.08. All of the GPs, who responded, stated that they would find it useful to be notified of a patient's BP if it was above 160/100mmHg (n = 50), with some indicating referral at lower pressures (Figure 5.09). In the case of patients with co-existing medical conditions, notification of BP was requested at lower levels: chronic heart disease; >140/90mmHg (1), diabetes mellitus >120/80mmHg (1) and >140/90mmHg (2).

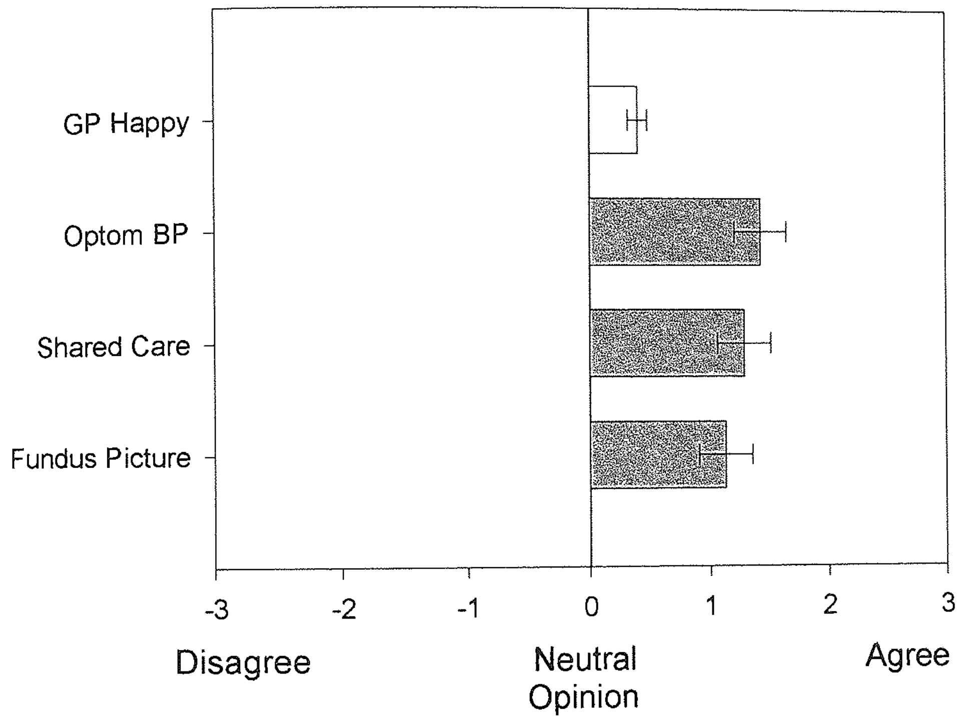


Figure 5.06: GP opinion on optometric involvement in detection and monitoring of systemic hypertension, (Error bars ± 1 S.E.M.).

Key - ▩ GP Opinion

Optom BP = Optometric BP measurement.

Shared Care = Shared Care incorporating systemic hypertension.

Fundus Picture = Fundus photograph to be included with referral letter.

☐ Optometric Opinion - (chapter 2).

GP Happy = GP happy with optometric BP monitoring.

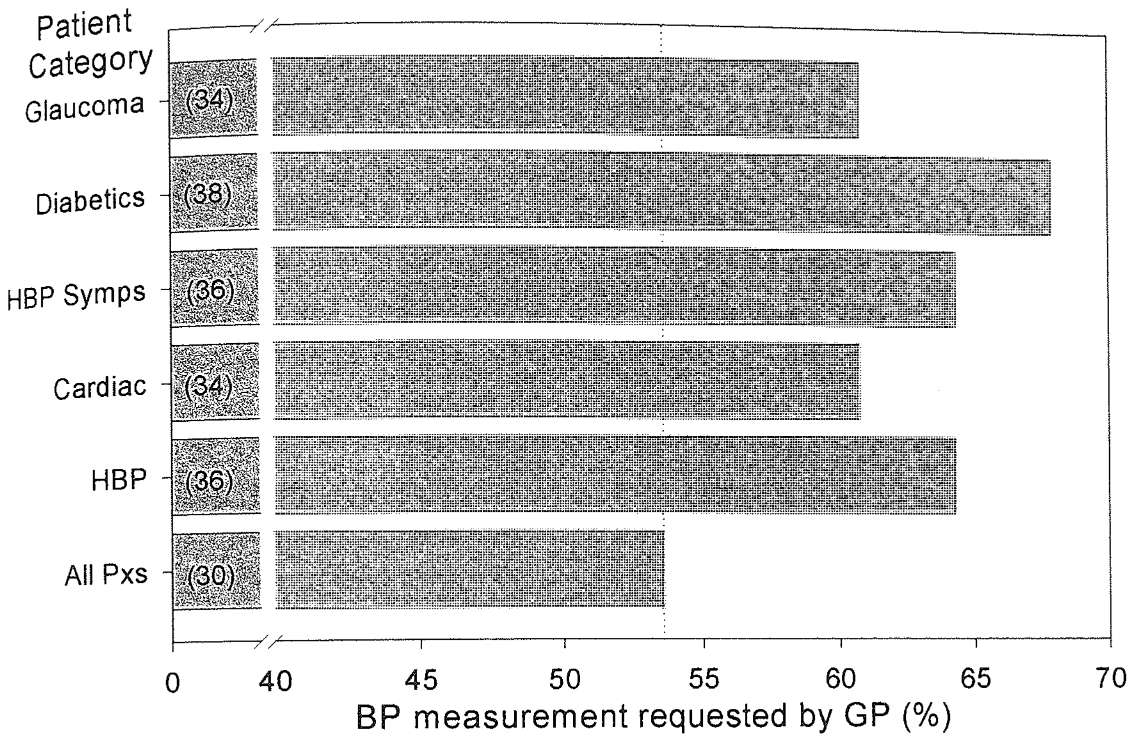


Figure 5.07: Patient type recommended Blood Pressure reading in optometric practice.

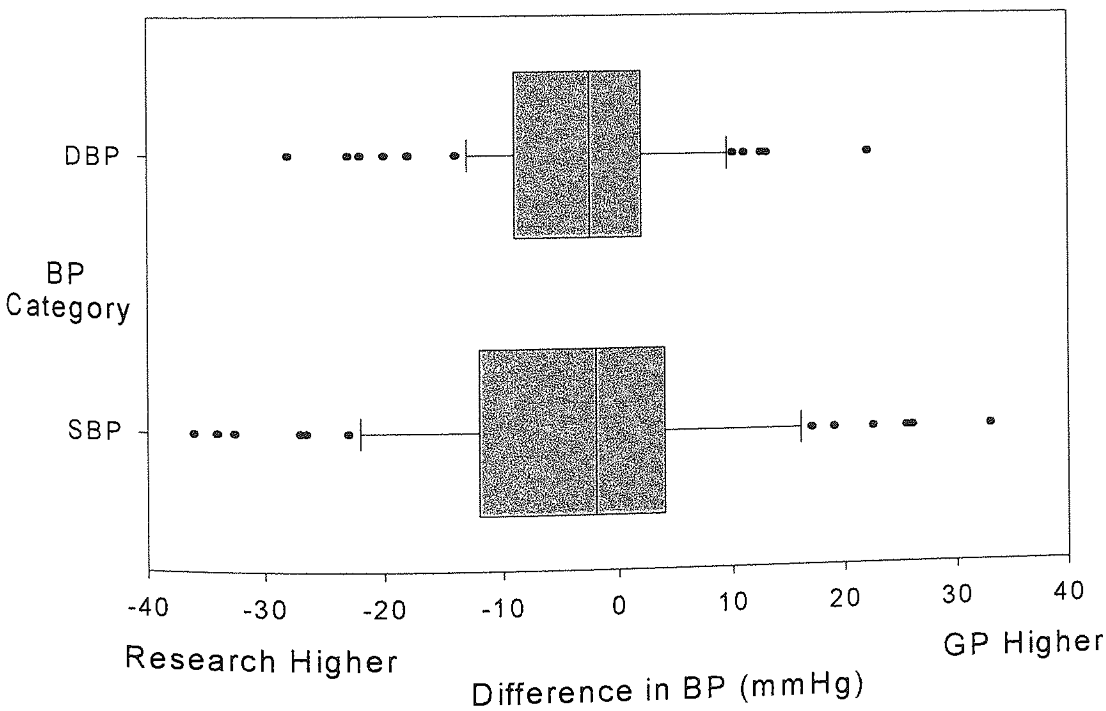


Figure 5.08: Difference in Blood Pressure reading; research versus General Practice.

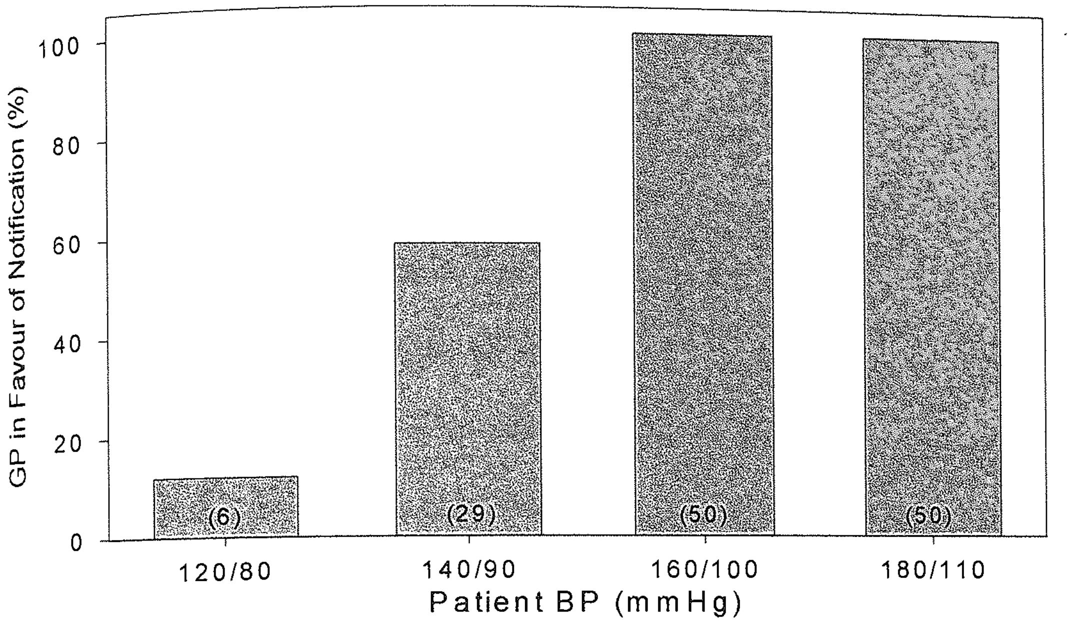


Figure 5.09: Blood Pressure level requiring notification to General Practitioner

(on pressure alone; n = 50).

5.40 - Discussion

5.41 - General Practice Attendance

From the population sampled, patient attendance at the GP surgery (7.8 ± 14.0 months) was more often than to optometric practice (15.5 ± 24.2 months). However, attendance at the optometrists will tend to be on a more regular basis, rather than on the presence of symptoms. BP measurement at the GP clinic (by GP or nurse), on average, occurred every third visit (33.3%; n = 23). The frequency of the BP measurement will be determined by the patient's medical status and presenting symptoms. The systemic hypertensive will tend to be asymptomatic in the early stages of the condition and, therefore, may not present with symptoms warranting a BP measurement, remaining undetected without the introduction of regular routine screening. The elderly patient attended the GP surgery on a more frequent basis, which is to be expected with the increase in medical conditions requiring regular monitoring and/or issuing of prescriptions (chapter 4).

5.42 - Patient History and Symptoms / Accuracy of Reporting

All patients were able to supply the researcher with their GP's name (or part name when they were unsure of the spelling). Eighty-five percent of the patients were able to supply correctly at least three further details of their GP's contact address. The name and the additional information permitted confirmation of the GP's name and address from the GP lists supplied by the local health authorities. Comparing these findings with the Australian study (Wolffsohn *et al.*, 2001), where post code was not requested, more than twice as many patients were able to correctly supply contact details of their GP (name, street number and name and suburb): 19.8% versus 9.4%. The higher prevalence of full correct answers in the Australian study could be due to the fact that 5% of the patients were able to confirm their answers from a business card supplied by their GP, whereas none of the patients in the UK study had on their persons their GP's business card. The patient's ability to recollect the street number of the practice was not significantly different between the two samples (31.3% versus 30.7%), indicating a general problem with remembering numbers, as indicated in recalling of the BP measurement. The patient's ability to supply the primary health care provider with these details facilitates correspondence, if warranted, concerning the findings of the examination.

Optometric patients are occasionally surprised by the questions asked by the optometrist about their general health, as they are generally unaware of the interactions between systemic health and the eye. The optometrist, or any health care provider, who asks general questions about their patients' general health will fail to discover their full medical status in over half of their patients. The patient who takes systemic hypertensive medication is likely to assume that as he/she is taking the prescribed medication, his/her general health is good, particularly if asymptomatic. Patients who have a heart condition will in most occurrences inform their optometrist of the condition in response to non-specific questioning, possibly because it is, in the patient's opinion, more serious than systemic hypertension and the patient may experience more prominent symptoms (e.g. pains in their chest).

The accurate reporting of medical status by these patients, through both general and direct questioning was much higher than that previously reported. The use of direct questioning revealed the correct medical status in all of the systemic hypertensive and cardiovascular patients, whereas in a previous study this was only the case in 69% and

74% of the patients respectively (Wolffsohn *et al.*, 2001). The poorer reporting of medical status to direct questioning in the Australian study could be due to the combined effect of an older patient basis and a lower socio-economic group. The improved patient reporting to direct questioning would indicate the benefit to all health care providers of the need to ask their patients specific questions.

Asking the optometric patients if they take medication is another approach to discovering their medical status. Patients' ability to recall their medication was poor, with less than half being able to correctly name their systemic hypertensive medication (active ingredient or proprietary name) and state the dosage. The accuracy of reporting of the medication name and dosage (39.3%) was nearly twice that of a similar study carried out in Australia (21%; Wolffsohn *et al.*, 2001). The underlying medical condition of the patient can be determined by the optometrist through application of previous knowledge, literature (e.g. B.N.F.) or computer software (e.g. David Thompson, City University). The list of the patient's current medication will steer the optometrist into relevant direct questioning to gain information into the duration, medical status and the date of the last check up by a medical professional.

The ocular structure may show the initial signs of drug toxicity, which if detected in the early stages are generally reversible (Edgar and Gilmartin, 1997). Therefore, knowledge of medication can give insight into the patient's medical status and avoid prescribed drug interactions, e.g. the rapid elevation of BP in a patient through inappropriate use of phenylephrine hydrochloride (Garston, 1975). These considerations are particularly important with the proposed introduction of independent prescribing rights to UK optometrists, as is the case in many US and Australian States. Patients should be encouraged to list their medications prior to an optometric appointment to maximise information dissemination.

5.43 - Optometric Blood Pressure Measurement

The ability of the optometric patients to recollect precisely their previous BP measurement was poor, only occurring in one case when the patient had written it down. For the patient with normal BP the date of their last BP reading is of little importance compared with the patient with systemic hypertension, resulting in a five times higher error in recollection of dates.

Over half of the patients were only able to state their last BP reading with a verbal comment. On being informed of their BP the patient's first response is to ask the health care provider what the figures represent. It is easier for the patient to remember a phrase which they can relay to their general health care provider rather than two figures which they have a limited understanding of and are more likely to forget over time. Testing the agreement of the verbal BP measure between the patient and the GP did depend on the definition of BP used by the GP which would have been influenced by the co-existing medical status of the patient. The wider range over which systolic BP can fluctuate compared with diastolic BP may account for the higher prevalence of disagreement over the former reading. A universally agreed category of verbal comments on BP measurements would benefit the optometrists in determining the relevance of observed retinal vasculature changes in their patients. Informing the patients of the BP categories used by GPs and optometrists would assist in referral and not worry the patients unnecessarily with conflicting opinions from two or more health care providers.

The scheduled review of the average patient's BP was less than three months, well within the guidelines (J.N.C., 1997). However, nearly half of the patients did not have a review planned for BP measurement. The incorporation of routine BP measurement in optometric practice could detect those patients who do not have their BP measured regularly at the GP surgery (one patient was four years outstanding for a BP check at the surgery) and give additional BP measurements to those patients at risk of complications of systemic hypertension. The benefit of widespread screening of BP was summed up by one GP who stated "regular BP checks are of value particularly in asymptomatic disease-free patients". The optometrist, with nationwide coverage, is ideally placed to pick up the asymptomatic systemic hypertensive patient.

5.44 - General Practitioner Opinions

The GPs were more in favour than optometrists thought they would be on the possible future incorporation of BP measurement in optometric practice (chapter 2). BP measurement would not be seen as "poaching patients from the GP", but would assist them in identifying high BP in patients who may otherwise go undetected. Optometric BP measurement could potentially reduce the burden of systemic hypertension on the health service, by detecting cases earlier when treatment and lifestyle changes are more effective and the patient can be managed in the community.

The BP monitors used in optometric practice must conform to the guidelines of the British Hypertensive Society (www.hyp.ac.uk/bhs/bp_monitors/resources.htm). Electronic BP measurement devices would appear to be appropriate to the optometric setting due to the high repeatability, objective measurement, low skill requirement and relative inexpense.

Six (8.7%) GPs stated reasons why the measurement of BP measurement should remain in the GP surgery. The measurement of BP was stated as a medical procedure which should be left to trained professionals (with detailed knowledge of the anatomy and physiology of the cardiovascular system) using well-maintained reliable equipment, with the automatic BP monitor frowned upon in favour of the mercury column sphygmomanometer. Another issue raised was that measurement of BP in optometric practice would create more work for the optometrist. The optometrist's opinion (chapter 2) indicated that the measurement of BP would not be a constraint financially or on time spent with each patient. The time taken to measure a patient's BP, even if done by the optometrist, would be similar to the time required to write a referral letter to the patient's GP requesting a BP measurement.

One GP raised the concern that optometric measurement of BP would produce more referrals to the GP. This is not a negative result as long as the measurement of BP is appropriate (2 readings at least 5 minutes apart in a relaxed patient, to minimise WCH) and that a referral level(s) for BP is agreed, following consultation between the General Optical and Medical Councils or, perhaps more likely in the short term, between Local Optometric and Medical Committees. The BP referral criteria should depend on the patient's current medical status, for example, the diabetic patient would be referred at a lower BP measurement than a non-diabetic with a similar BP level.

Concern was voiced over causing the patient undue stress by referring them for high BP following an elevated BP reading. Referring too many patients to their GP could cause undue stress in more patients while awaiting their appointment. Therefore, referrals using previously agreed referral criterion, should ensure the GPs only see appropriate patients, minimising patient stress levels. The notification of all BP readings, as requested by one GP, would increase the workload of the optometrist and GP. In a profession that is taking on greater management responsibilities of their patients and only notifying the GP when treatment is required outside of the practice, this would appear to be a retrograde step.

Two GPs were against optometric BP checks in those patients with: diabetes, heart disease and systemic hypertension, as these patients were already being monitored. However, as long as the patient reliably informed the optometrist of this during the history and symptoms, no additional workload need be created. Patients in this sample, with systemic hypertension, had on average had their BP measured at the surgery within the last 2 months, whereas those for heart disease had last seen their GP 6 months previously.

5.45 - Systemic Hypertensive Shared Care

The shared care management of systemic hypertensives, which GPs are in favour of, can only come about with the profession advancing their position as primary health care professionals who routinely measure BP. Financial reward for such services is likely to be in the form of patient and GP confidence and practice loyalty, but may be fully realised if optometrists become an integral part of public health care as well as specialised private eye care.

The present shared care management of the patient with diabetes mellitus, glaucoma or cataracts requires an increase in the chair time spent with each patient by the optometrist. Research in America has shown this resulted in a drop in practice income and 56% of optometrists had to increase their patient numbers to maintain their standard of living (Eisenberg, 1995). The screening of hypertensive retinopathy in the diagnosed patient would require an increase chair time whereas the incorporation of a BP screening of patients through sphygmomanometry, which could be delegated to an assistant to be performed as part of the battery of the pre-screening tests, should not have a negative influence on practice profitability.

5.46 - Fundus Photography

The inclusion of a fundus photograph in correspondence with the GP adds weight to the referral and quantifies the extent of damage to the retinal circulation. Those GPs who were not in favour of the photograph, indicated that it is of little use to them and that they had limited understanding of the features shown. A report highlighting the relevant features of the fundus picture was also requested by three GPs. This information would normally be provided on the referral letter, although provision of training for GPs in this area may be beneficial. The research photographs supplied to the GPs were not part of a sight examination and, therefore, correspondence to the GP could only state the findings from the research. There is a large financial implication for having the facility for taking fundus images in optometric practice, but they can help to detect and monitor eye disease, are an integral part of recently introduced diabetic screening schemes and can help to educate patients and general practitioners alike in the importance and relevance of eye care.

5.50 - The Future

The possible future public health role for optometrists in the measurement of BP would appear to be a screening role in those not already being monitored for systemic hypertension. Optometrists who measured BP would save the GPs' and the patients' time, potentially detect undiagnosed systemic hypertension and the knowledge of the patient's BP would assist the optometrist in the monitoring of eye disease, such as diabetes and glaucoma. The availability of literature in the health care centre educating the patient in a broad range of health matters may improve their understanding, interest and ability to recall their health status when asked by future health care practitioners. The use of smart cards stating the patient's GP contact details, health status, medication and BP reading would be of benefit to the optometrist in completing a thorough history and symptoms and determining the most appropriate procedures to be performed in the sight test.

CHAPTER 6 - SUBJECTIVE GRADING OF SYSTEMIC HYPERTENSIVE RETINOPATHY

6.10 - Introduction

The use of grading scales assists the primary health care practitioner in detecting, determining the severity, progression and proposed management of the clinical feature under examination (Reeves *et al.*, 1987; Bailey *et al.*, 1991). Grading scales designed for optometric applications can be classified by their construction: verbal descriptor scale (e.g. systemic hypertensive retinopathy; Keith *et al.*, 1939), photographic (e.g. crystalline lens opacity; Chylack *et al.*, 1989), pictorial (e.g. contact lens complications; Efron, 1999) and computer generated grading morphs (e.g. contact lens complications; Efron and Morgan, 2001).

6.11 - Systemic Hypertensive Retinopathy

The most commonly used grading scale for systemic hypertensive retinopathy is the Keith, Wagener and Barker classification system (1939). With advances in the detection and management of the disease over the intervening years a further seven grading scales have been published. These have been based to varying degrees on the 1930s scale, differing from each other in the weighting assigned to each retinopathic change. These scales, discussed in length in chapter 1, are hindered and thus limited in their widespread use by various factors: complexity and time requirement to undertake (Wagener *et al.*, 1947; Leishman, 1957; and Evelyn *et al.*, 1958); assumptions such as vasculature change is independent of age and just systemic hypertensive in origin (Scheie, 1953 and Cogan, 1974); and that arteriolar constriction is the only important indicator of systemic hypertensive retinopathy (Cogan, 1974). Dodson and co-workers

(1986) simplified the classification into two categories: pre-malignant and malignant. All these scales for systemic hypertensive retinopathy are descriptive in design and require input (judgement from previous experience / knowledge) from the health care professional to classify the retinal changes according to their interpretation of the wording of the grade. Classification alone also results in a loss of clinical information (Svardsudd *et al.*, 1978; Hayreh, 1989). Future grading scales for systemic hypertensive retinopathy would, therefore, require the grading to reflect in adequate detail (avoiding loss of information), over a short space of time, a description of the vascular appearance of the fundus to assist the clinician in monitoring the patient.

6.12 - Pictorial Hypertensive Retinopathy Grading Scale

Wolffsohn and colleagues (2001) proposed a pictorial grading scale for systemic hypertensive retinopathy that combined photographic and computer generated morphs. The findings from the first trial of this scale (101 patients – 192 fundi) indicated that it assisted observers in the description of retinal vasculature and improved intra- and inter-observer agreement of grading retinal changes (Wolffsohn *et al.*, 2001). Those patients with elevated BP (systolic >160mmHg and diastolic >95mmHg) and pulse pressure (>70mmHg) were found to have a significant greater degree of arteriolar tortuosity and focal arteriolar calibre changes than those with normal BP. The subjective grading scores were compared with the results of the vasculature analysed with a purpose written image analysis program. For the two features examined, A/V ratio and arteriolar reflex, only a poor relationship existed between the subjective and objective grading (Wolffsohn *et al.*, 2001). However, this poor correlation could be due to the fact that these features were only examined at two locations per fundus in the objective measure, whereas the subjective analysis was over an area one and a half disc diameters around the optic nerve head.

The patient base of the Australian study comprised disadvantaged and limited income patients attending a national health vision clinic (Wolffsohn *et al.*, 2001). The prevalence of medical conditions is influenced by the patient's socio-economic status, which could account for the higher prevalence rate of diagnosed systemic hypertension (45%) in this population. There is, therefore, a requirement to repeat the Australian study with a wider patient basis that reflects the general population of the UK to determine the clinical significance and application of the scale to the management of systemic hypertensive retinopathy in UK optometric practice.

6.20 - Method

This chapter examines the validity and clinical application of a pictorial grading scale through the following techniques:

1) Accuracy - Are the grading scores assigned by qualified optometrists and non-optometrists clinically comparable?

2) Interpolation - Does the optometric experience / knowledge of the grader determine the range of grading scores assigned?

3) Reliability - Would repeat grading of the fundus produce clinically similar findings?

4) Sensitivity - Does the grading score correlate to the patient's medical status?

5) Subjective versus Objective - Are the subjective scores comparable to the findings from objective image analysis?

6) Optometric practice - Are the grading scores from ophthalmoscopy comparable to fundus photographs?

7) Systemic influences - Which patient factors have the greatest influence upon the retinal vasculature appearance?

6.21 - Accuracy and Repeatability of the Pictorial Grading Scale

Forty fundus photographs were selected from the database of 272 retinal pictures taken as part of the initial baseline examination of the longitudinal study. The photographs (45° field of view) were selected to illustrate the full range and severity of the retinal features in the systemic hypertensive pictorial grading scale. Photograph selection secondarily took into account the patients' BP and medication for systemic hypertension. All photographs were sharply in focus and free of media opacities (e.g. cataract). To reduce the influence of variations in fundus pigment upon the grading of the retinal features, the ethnic background of all the subjects was white European (race code 1). The photographs (140 mm in diameter) were printed on photographic paper.

The photographs were supplied to 20 undergraduate final year optometry students and 20 qualified optometrists. The grading scale (Figure 6.01), reprinted with permission of the authors from their paper (Wolffsohn *et al.*, 2001), and the recording of each retinal feature (Table 6.01), was explained to each examiner prior to data collection. They were asked to grade independently each picture (the full 45° to allow comparison with the findings from image analysis) with reference to the pictorial grading scale (held next to the fundus picture for comparison).

As the pictorial grading scale was being assessed for its accuracy, repeatability and future clinical application, examiners were not limited to integer grades (e.g. 1, 2 or 3), as shown in Figure 6.01, but asked to interpolate (e.g. 3.25, 3.50 or 3.75) or extrapolate (e.g. 0.50 or 5.50) their grading if it was felt a retinal feature was in-between/beyond the illustrated scale. In the instance of one quadrant of an eye having more pronounced vasculature changes associated with systemic hypertensive retinopathy, the grading of the more severely involved quadrant was recorded.

The presence of any retinal lesions was also recorded. To assess the inter- and intra-observer repeatability of the scale the optometry students repeated the grading of the retinal photographs, in the same order and independent of their first results at least two months later. The graders were unaware of the identity and medical status of each photograph.

Each optometric examiner was requested to grade 240 hypertensive retinal features (40 images x 6 conditions) and the optometry student examiner 480 hypertensive retinal features (40 images x 6 conditions x 2 trials) resulting in a possible 14,400 grades from the 40 examiners. The results were double entered into the spreadsheet by the two researchers (P.H. and A.P.) and any discrepancies (<1.0%) were corrected. Any additional comments on the photographs or the grading scale were recorded to avoid the loss of any information. The research was approved by Aston University ethics committee and conforms to the declaration of Helsinki. All data collected maintained the patient's anonymity.

Retinal Feature	Scale	Description	Image Type
Artery/Vein Ratio (A/V)	120% - 40% (1) - (5)	-	Computer Morph
Arteriolar Reflex	0% (1) - 100% (5)	-	Computer Morph
Tortuosity	1 - 5	-	Retinal Photograph
Focal Arteriolar Calibre	1 - 3	None / Slight / Marked	Retinal Photograph
Crossing Change	1 - 3	None / Slight / Marked	Computer Morph
Lesion	0 - 1	Absent / Present	*None*

Table 6.01: Grading scale score (from Wolffsohn *et al.*, 2001).

6.22 - Application of Grading Scale to Optometric Practice

The pictorial grading scale was trial-run in four optometric practices in the UK during the summers of 2001 and 2002. This sample comprised three branches of two different multiple optometrists (Coventry, Gateshead and Newcastle-upon-Tyne), and one independent optometrist (Coventry). The patient's medical status and BP were recorded by two researchers (G.G. and P.H.), the method for which is detailed in chapter 4. Five optometrists graded the appearance of the retinal vasculature for signs associated with systemic hypertension, during the patient's eye examination, according to the pictorial grading scale (Figure 6.01). The optometrist was masked from the patient's BP reading at the time of the examination, but was, however, aware of the patient's general health status as displayed on the patient's record card.

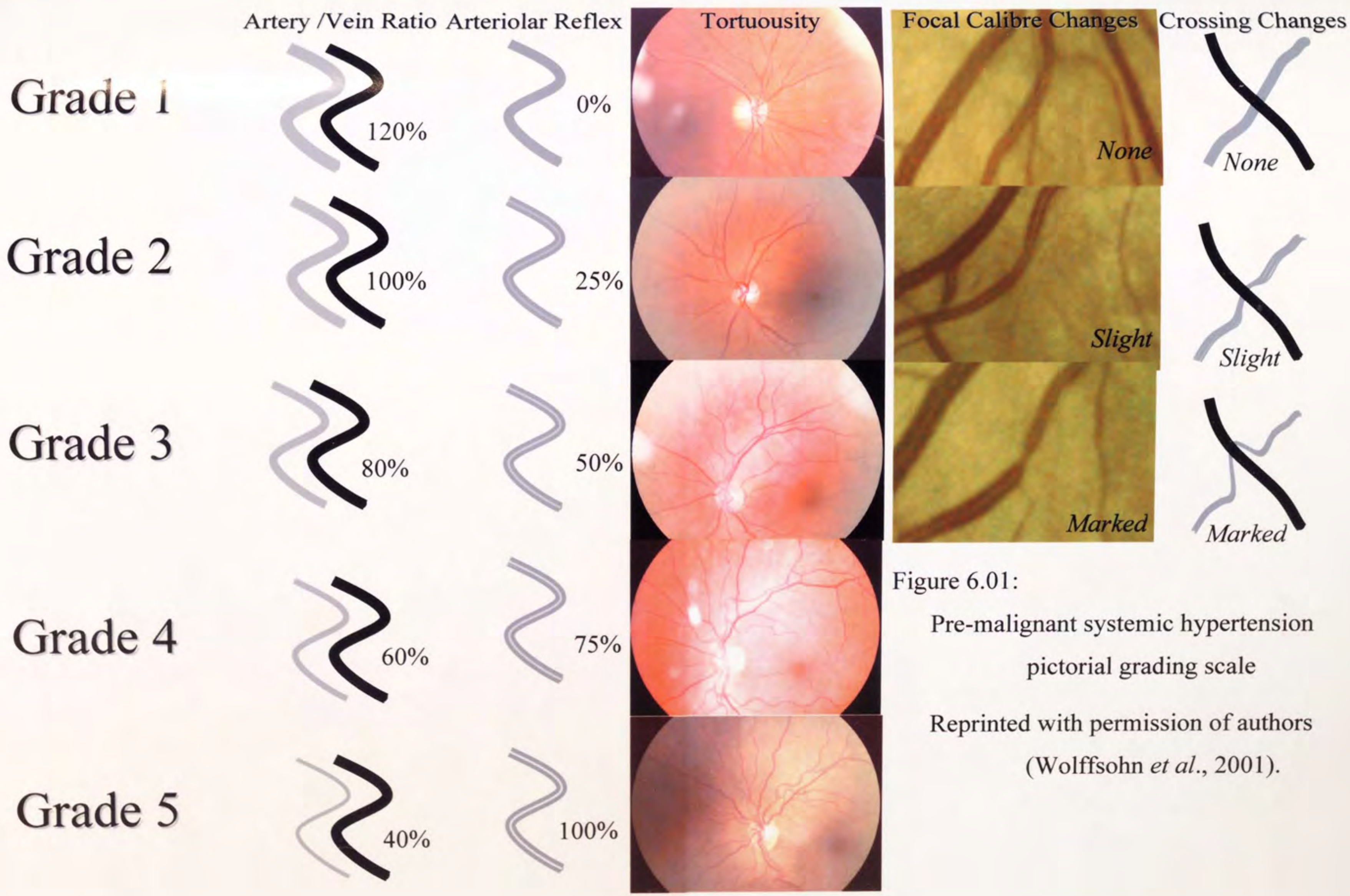


Figure 6.01:

Pre-malignant systemic hypertension pictorial grading scale

Reprinted with permission of authors (Wolffsohn *et al.*, 2001).

6.30 - Results

Subjective grading estimates on the vasculature of 40 retinal photographs were compiled from twenty optometrists (completed grading estimates 99.94%; n = 4797) and twenty final year optometry students (completed grading estimates 99.98%; n = 9598). The fundus was assessed and graded in 201 optometric patients (completed grading estimates 100%; n = 1005). Completed patient questionnaires and BP were recorded for the patients in optometric practice, but the presence of any type of retinal lesion was not recorded on the research sheet. The responses are calculated as percentages and the number of subjects included in the category given in brackets. Average findings are recorded as mean ± one standard deviation.

6.31 - Demographics

The optometrists who graded the retinal photographs had been qualified on average 8.88 ± 8.15 years (range 1.5 to 33.5 years). The optometrists who graded the fundi in practice had been qualified on average 6.80 ± 5.36 years (range 1.0 to 13.0 years).

The average age of the patients was 46.7 ± 21.6 years (range 18 to 85 years) for the retinal photographs and 50.7 ± 19.0 years (range 18 to 93 years) for the optometric practice sample. The gender split was 57.5% (23) male for the retinal photographs and 46.0% (93) male for the optometric sample. The prevalence of elevated BP (systolic >160mmHg and /or diastolic > 95mmHg and/or medication for BP) in the photographic sample was 57.5% (23) and 48.4% (107) in the optometric sample. The ethnic background of the subjects was 100% (n = 40) white European for the retinal photographs and 93.0% (n = 188) white European for the optometric practice sample.

6.32 - Accuracy of Grading

The average grade used by each examiner within the two groups, for the five pictorial scales, is illustrated in Figure 6.02. The average grade assigned by the optometrists (2.45 ± 0.24) was clinically the same as that assigned by the optometry students in both trials: 2.49 ± 0.07 (trial 1; t test - two tailed: $p = 0.38$) and 2.44 ± 0.08 (trial 2; t test -two tailed: $p = 0.93$). There was greater variation in the grades assigned by the optometrist (± 0.24) than by the optometry students in both trials (± 0.07 and ± 0.08). The difference between the two groups of examiners was not significant and, therefore, indicates that on average non-optometrists (final year optometry students – prior to lecture module on systemic hypertension) could grade systemic hypertensive retinopathy as accurately as optometrists with use of the pictorial grading scale.

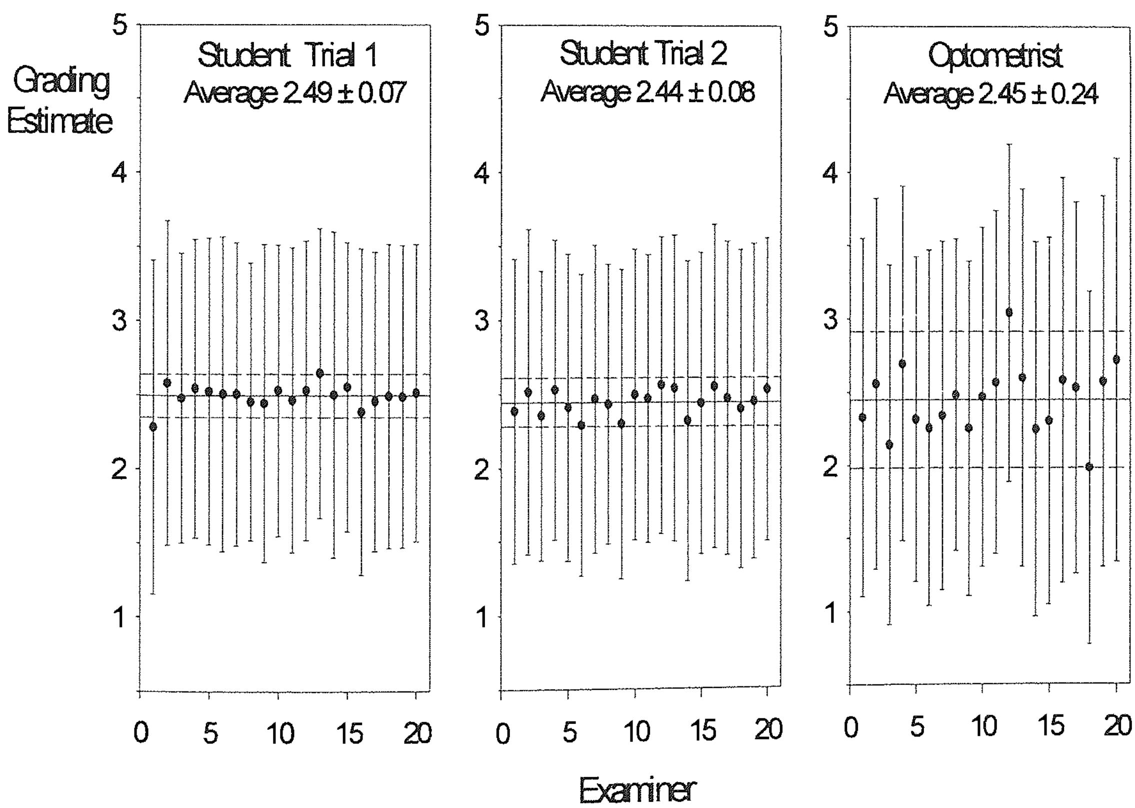


Figure 6.02: Mean grading estimate of each examiner (±1 S.D.) for pictorial grades.

All scales equal to 5 point recording. Dark line is the mean and the dotted lines represent the upper and lower 95% confidence limits.

6.33 - Interpolation of the Grading Scale

The breakdown of the grading estimates into the spread within each retinal feature is illustrated in Figure 6.03. The grading of lesions between the optometrist and optometry student (trial 1) shows no significant clinical difference (mean grade 0.18 ± 0.38 and 0.19 ± 0.39; t test - two tailed: $p = 0.43$). The grading of the arteriolar reflex shows the greatest spread across the scale in both examiner groups, with the standard deviation for both optometrists and optometry students greater than one grade boundary (± 29.27 and ± 26.41, respectively).

The grade categories used by the examiner groups is illustrated in Figure 6.04. The optometrists graded with a part digit (interpolated; e.g. 1.75) in 5.1% of the retinal features. The optometry students, in both trials, did not interpolate any feature with a part digit. Optometry students were more likely to interpolate their grading with a half digit than optometrists: 33.7% versus 6.6% respectively. The recording of retinal features by both examiner groups with whole digits was significantly higher than their occurrence (56.8%) in the range of possible full and half digit gradings permissible.

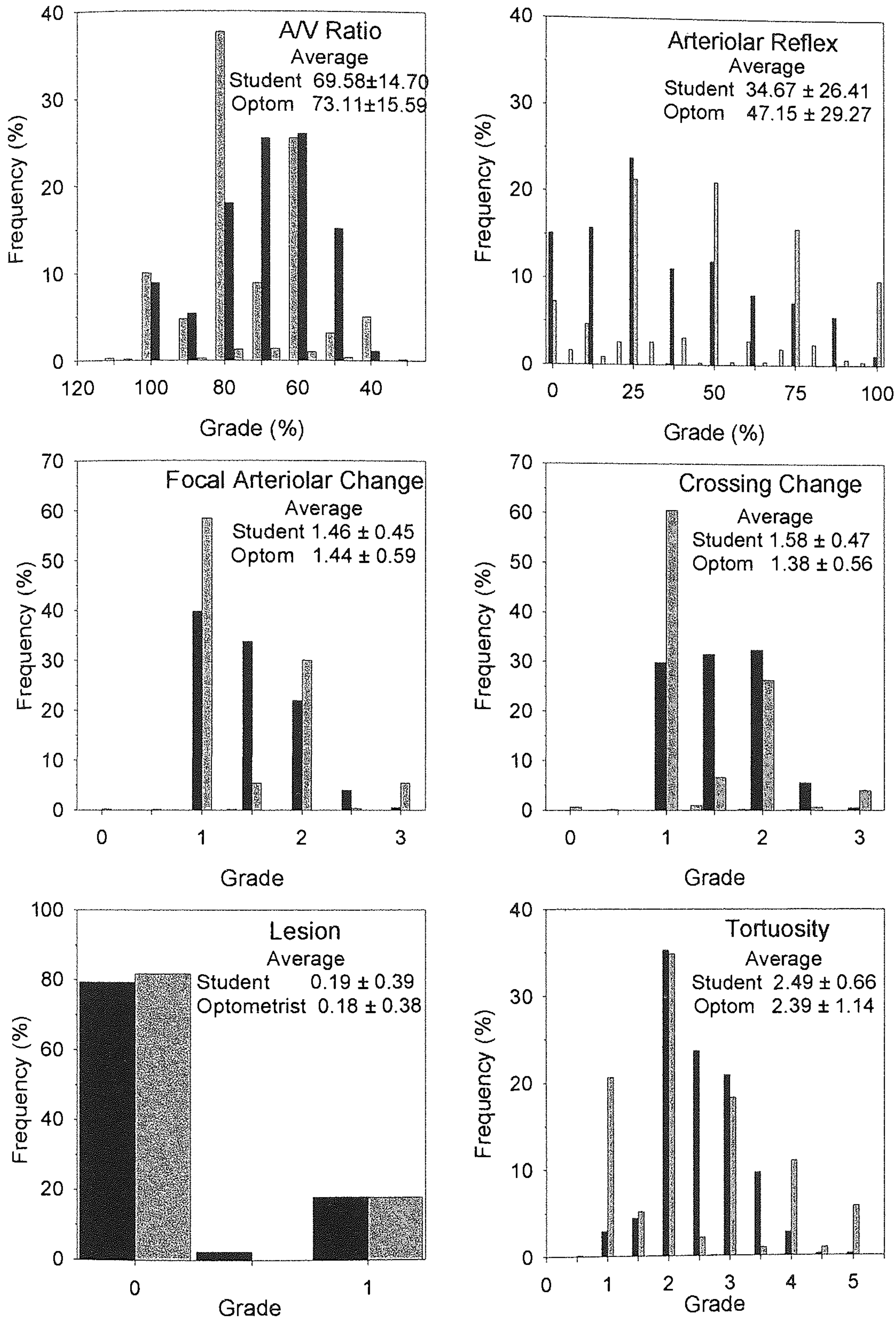


Figure 6.03: Frequency distribution of grading estimates:

Optometry students (■; trial 1) and optometrists (Optom; ▩).

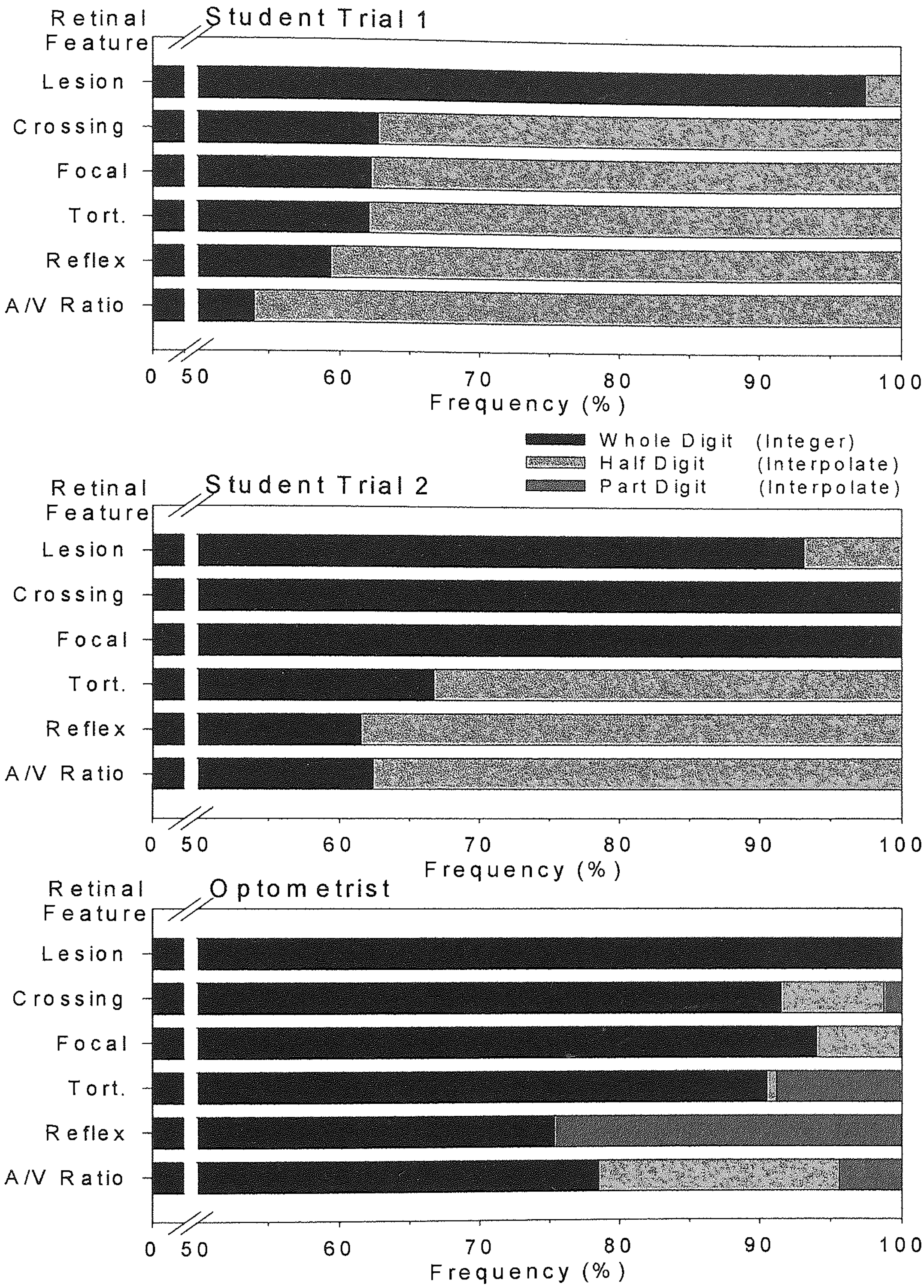


Figure 6.04: Grading bias of examiners for hypertensive retinopathy grading scale.

Key: Crossing = Crossing change; Focal = Focal calibre change,

Tort. = Tortuosity; Reflex = Arteriolar reflex;

A/V Ratio = Artery / Vein ratio.

6.34 - Reliability of Grading Scale

The reliability of the grading scale can be defined as the ability of the examiner to give similar findings on repeat recordings (Bullimore and Bailey, 1993). There was no clinical significance in the difference between the average optometry student grading score for the retinal photographs from trial 1 (2.49 ± 0.07) and trial 2 (2.44 ± 0.08; t test - two tailed: $p<0.05$). Figure 6.05 shows the histograms for the frequency of discrepancies in the optometry student gradings between trial 1 and 2 (intra-observer variation). The mean of the standard deviations (reliability) for the five pictorial scales (grading scores as proposed by Wolffsohn and colleagues; 2001) was ± 0.72 (range ± 0.51 to ± 0.92). The reliability of all five pictorial grading scales was within one grade (<1.00). Therefore, a change in assigned grade of at least one whole digit of a retinal feature would be indicative of a clinically significant change.

6.35 - Bias of Grading Scale

Figure 6.06 illustrates the test/retest differences plotted against the mean grade of the two trials for the optometry student observers (Bland and Altman, 1986). Of the five measures, the recording of focal calibre changes was found to be most reliable (± 0.51) and arteriolar reflex the least (± 0.92; grade scales as depicted on original pictorial grading scale). There was a slight positive bias in the grade for A/V ratio (+0.22) and crossing changes (+0.14) and a negative bias for the arteriolar reflex (-0.33) on repeat measurement. For all retinal changes there is stronger reliability between repeat grading estimates at the extremes of the grade (e.g. none and marked – ceiling and floor effect). This indicates that the reliability of the grading using the pictorial grading scale is influenced by the severity of the retinal feature under examination.

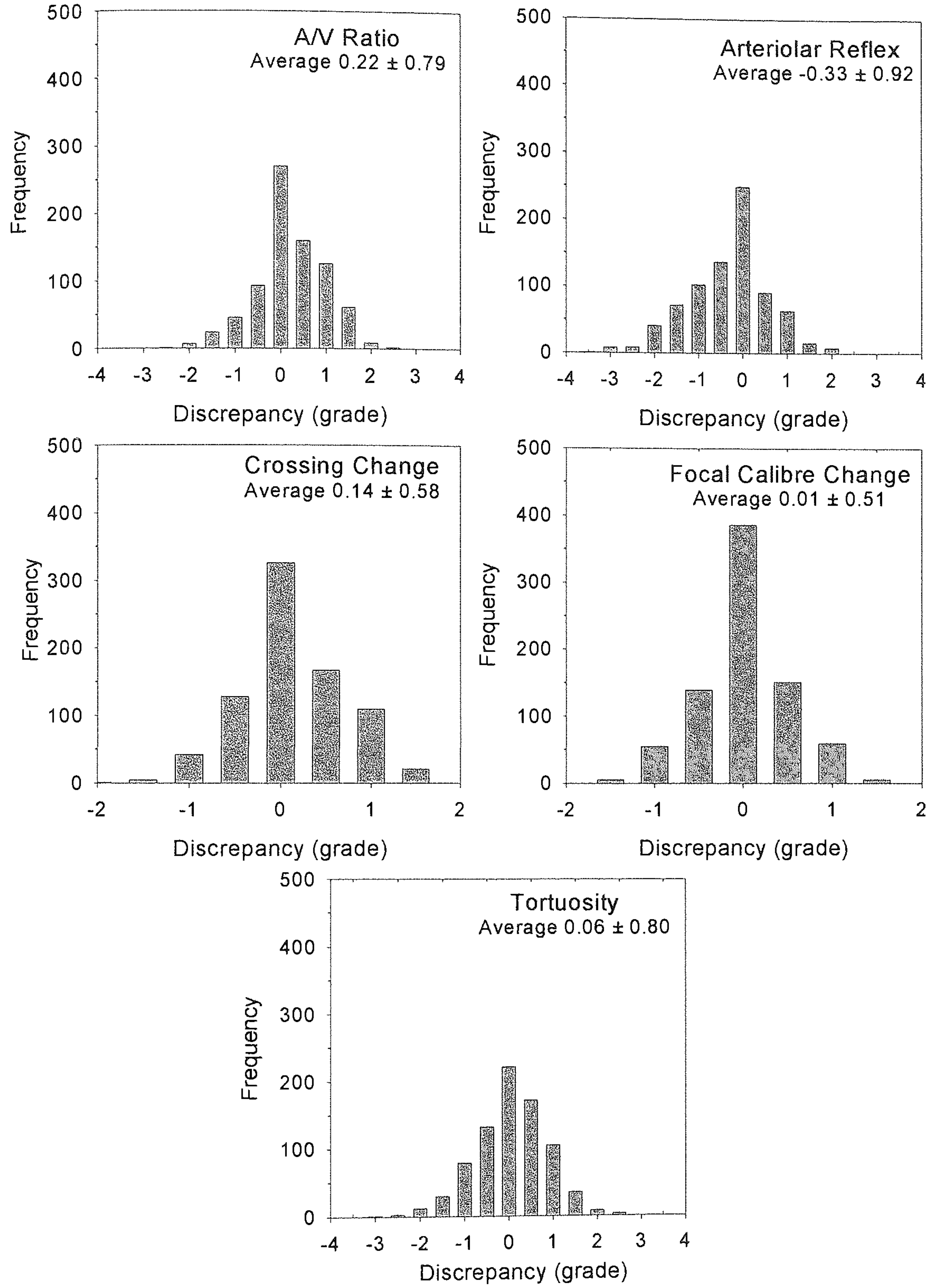


Figure 6.05: Frequency of optometry student test/retest discrepancies.

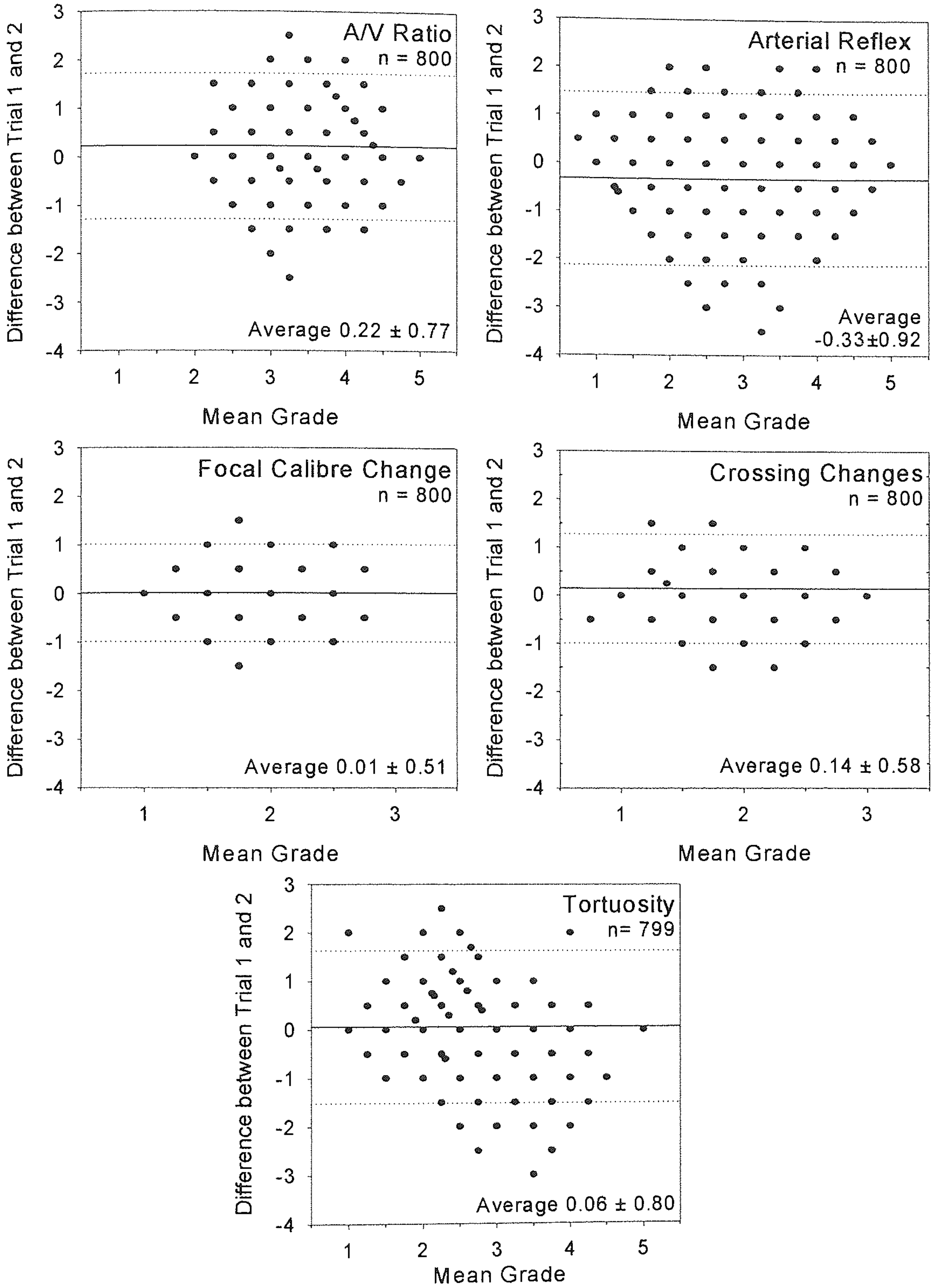


Figure 6.06: Test/retest discrepancies (y–axis) versus mean grading scale (x-axis).

Solid line =Mean test/retest discrepancy.

Dotted lines = Upper and lower 95% confidence limits of test/retest discrepancy.

6.36 - Sensitivity of the Grading Scale

Comparison of the optometrist grading scores for the retinal features in the normotensive, elevated BP (systolic >160mmHg and diastolic >95mmHg), medicated controlled BP and uncontrolled hypertensive patient is illustrated in Figure 6.07. The average BP of these four patient groups is shown in Table 6.02. Comparison of the grading estimates from the retinal photographs found that the only significant clinical difference between groups was for focal calibre changes (one-way ANOVA: $p < 0.05$). A Tukey test identified the difference was between those patients with BP under control with medication (BP Med; 1.58 ± 0.25) and those whose BP was poorly controlled with medication (High Med; 2.29 ± 0.86; Figure 6.07).

The variation in BP (systolic and diastolic) and pulse pressure against the five pictorial grades is illustrated in Figure 6.08. A wide spread of grading estimates for A/V ratio, arteriolar reflex and tortuosity permitted the plotting of regression lines. The A/V ratio was the only retinal change that showed a positive correlation between increasing grade and BP: systolic BP ($r^2 = 0.54$; $p < 0.001$), and PP ($r^2 = 0.82$; $p < 0.01$). The arteriolar reflex showed a negative correlation to BP: systolic ($r^2 = 0.78$; $p < 0.001$), diastolic BP ($r^2 = 0.70$; $p < 0.001$) and PP ($r^2 = 0.65$; $p < 0.01$).

BP Control Key to Figure 6.07	n =	Average Systolic BP (mmHg)	Average Diastolic BP (mmHg)	Average Pulse Pressure (mmHg)	Average Grade (1-5)
Normotensive (Normo)	23	121.4 ± 15.3	74.1 ± 9.1	47.7 ± 11.5	2.5 ± 0.9
Elevated BP (High BP)	5	138.6 ± 5.0	93.8 ± 2.2	44.8 ± 4.1	2.4 ± 0.9
BP Medication (BP Med)	6	133.7 ± 11.2	80.2 ± 6.6	53.5 ± 10.2	2.2 ± 0.9
High BP & BP Medication (High Med)	6	160.3 ± 24.3	104.0 ± 16.8	56.3 ± 33.6	2.6 ± 1.0

Table 6.02: Average BP and PP for photographic patient groups (± 1 S.D.).

All grades scaled up to five point scoring system

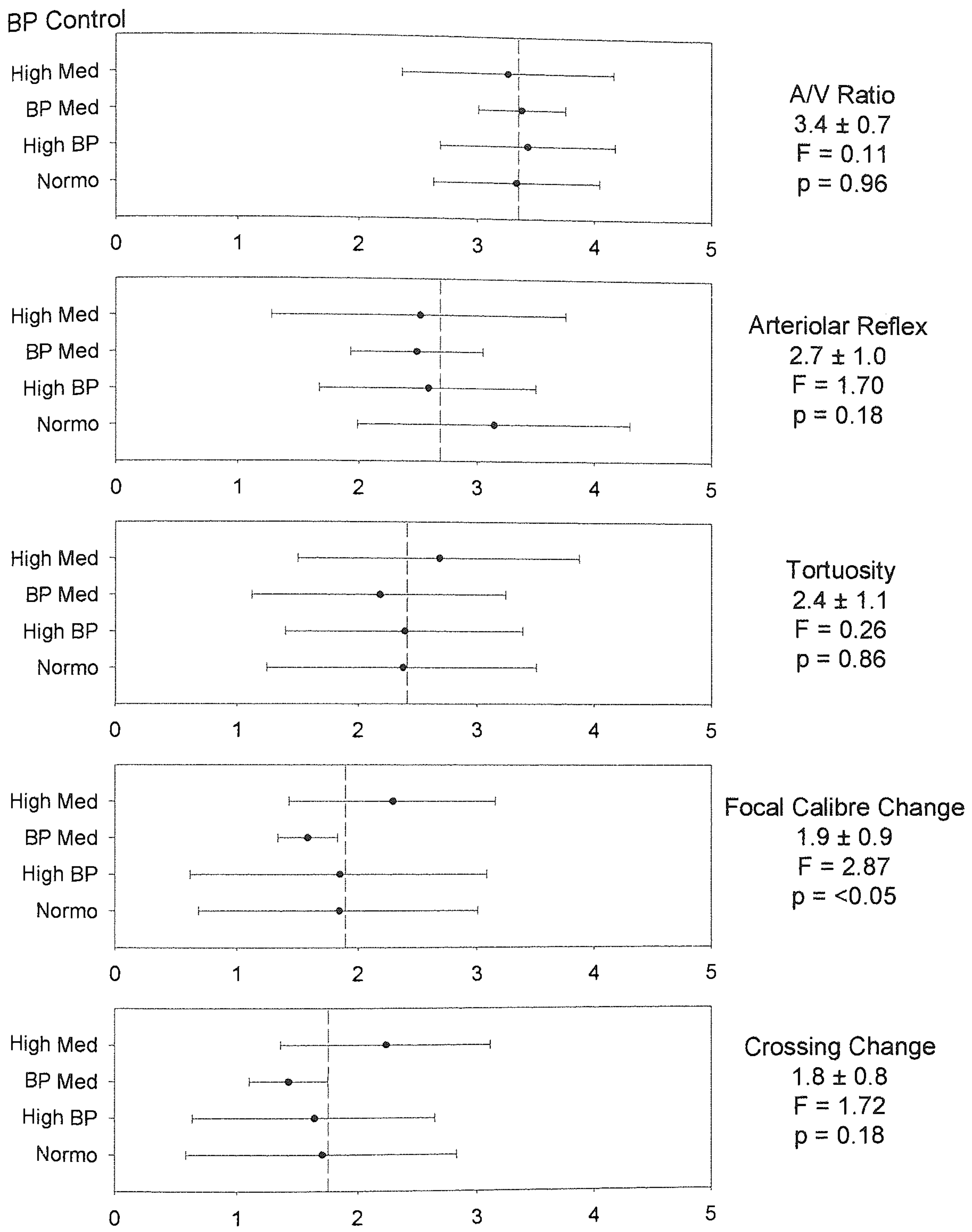


Figure 6.07: Mean grading estimates (± 1 S.D.) for pictorial grading scale.

All Retinal changes equal to a 5 point grading scale.

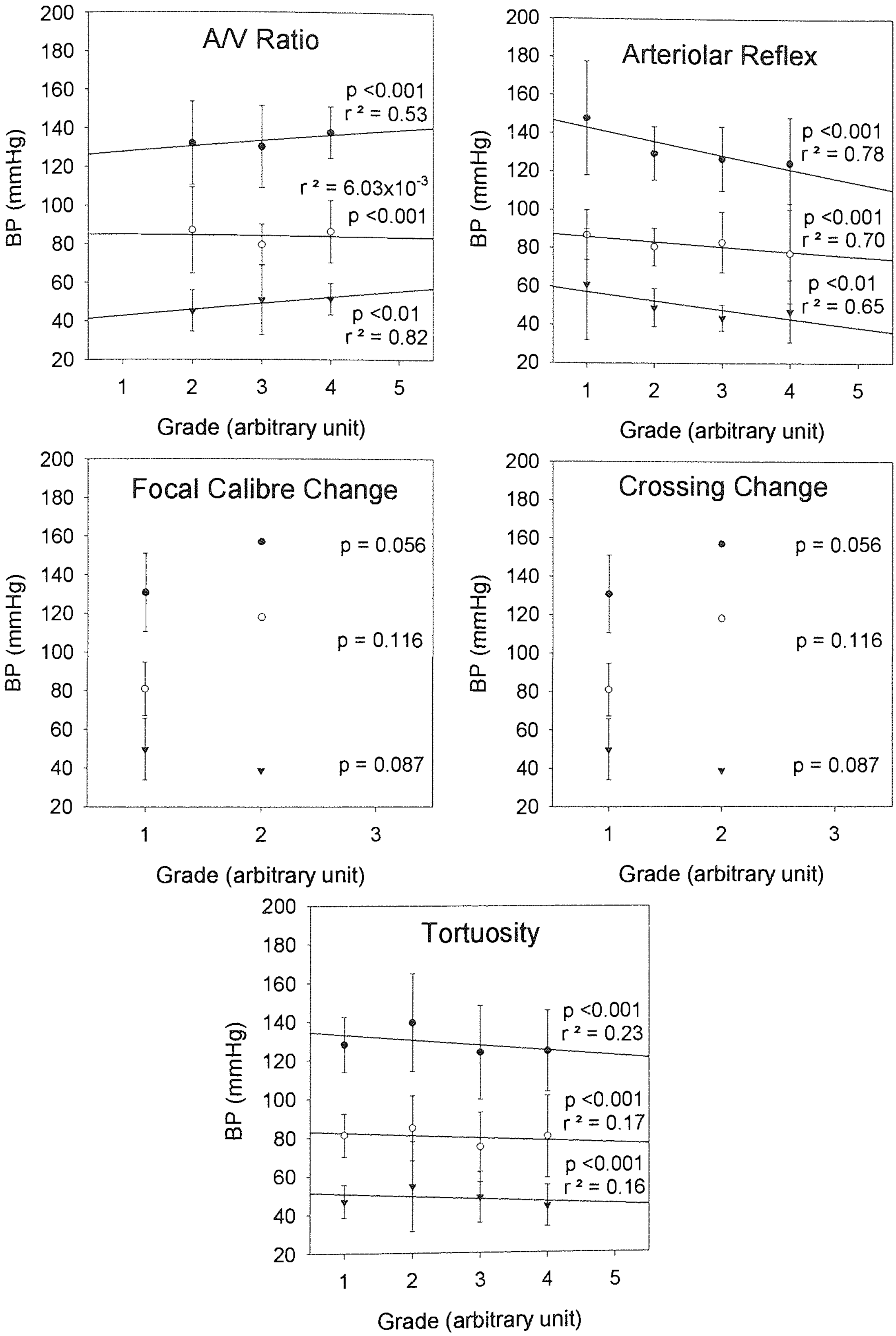


Figure 6.08: Retinal grade versus patient BP (retinal photographs).

Key - ● Systolic BP: ○ Diastolic BP: ▼ Pulse Pressure.

6.40 - Objective Analysis of Pictorial Grading Scale

The pictorial grading scale was analysed with the image analysis software (chapter 3) and the results illustrated in Table 6.03. The A/V ratio was calculated from the average arteriole width against the venule width. The arteriolar reflex was calculated from the manual analysis of the graph of luminance profile across the vessel every 4mm, along its course (five points). Vessel tortuosity was assessed through two measurements: firstly, the tortuosity index as calculated from comparison of the actual vessel length to the chord connecting the first and last points on the vessel; secondly, the displacement of the vessel from the chord, calculated as the average area contained between the vessel and its chord. To differentiate the three grades of focal calibre change two equations were applied. Marked changes were separated from slight changes with application of the equation that the segment must be no more than 2/3 the width of the pre or post vessel segment (University of Wisconsin Madison, 2002). The application of the arbitrary figure of 5/6 for slight change (half way between 2/3 and 3/3) permitted differentiation between none and slight focal calibre change. Image analysis identified a non-linear increase in vascular characteristic with scale grade, particularly for photographic rather than computer generated morphs.

The semi automated computer program, described in chapter 3, can perform the extraction of data and image analysis for the A/V ratio, tortuosity and focal calibre constriction. The measurement of arteriolar reflex (if too pronounced would indicate two vessels split by an area of light fundus), crossing changes (edges of the combination of the two most prominent vessel edges are returned) and lesions (program just returned co-ordinates of vessel edges from the location the examiner specifies and can not identify structures / anomalies) cannot yet be measured with the software program without increased supervision from the analyser. Therefore, the subjective grading estimates of the retinal photographs from the optometrist with respect only to the A/V ratio, tortuosity and focal constriction were compared with those found from the findings of the retinal photographs which had undergone image analysis.

Retinal Feature	Grade	Image Analysis	
A/V Ratio	1 / 2 : 1.67 (120%)	1 / 2 : 1.67 ± 0.13	
	2 / 2 : 2.00 (100%)	2 / 2 : 2.05 ± 0.13	
(Computer	3 / 2 : 2.50 (80%)	3 / 2 : 2.51 ± 0.18	
Morph)	4 / 2 : 3.33 (60%)	4 / 2 : 3.40 ± 0.29	
	5 / 2 : 5.00 (40%)	5 / 2 : 5.16 ± 0.33	
Arteriolar Reflex		Width (pixels)	Intensity (%)
	1 - 0%	5.31 ± 5.08	21.25
(Computer	2 - 25%	8.10 ± 2.12	22.50
Morph)	3 - 50%	5.05 ± 9.01	27.50
	4 - 75%	25.21 ± 7.66	27.50
	5 - 100%	32.29 ± 3.67	26.25
Tortuosity		Tortuosity Index	Displacement (pixels)
(Photograph)	1	1.03 ± 0.02	11.32
	2	1.11 ± 0.06	22.14
	3	1.07 ± 0.03	10.62
	4	1.19 ± 0.15	39.66
	5	1.14 ± 0.14	12.36
Focal Calibre		(2/3)	(5/6)
Change	1 - None	0	1
	2 - Slight	0	7
(Photograph)	3 - Marked	1	6

Table 6.03: Results from image analysis of the pictorial grading scale.

(Wolffsohn *et al.*, 2001).

The comparison of the subjective and objective A/V ratio is illustrated in Figure 6.09. There was a highly significant agreement between the image analysis results and the subjective grading by optometrists of the A/V ratio using the pictorial grading scale ($p < 0.001$). The regression line for the data points indicated that the subjective grading scale was more comparable, and therefore more reliable, with the image analysis at the higher grades. The tortuosity index showed a highly significant agreement between the objective and subjective measures ($p < 0.001$). The regression line for arteriolar tortuosity is not clinically significant from the proposed locus equating to an arbitrary grading scale for the image analysis results, Figure 6.10. Objective and subjective measures of focal calibre changes (marked and slight changes) showed a non-significant correlation ($p < 0.05$), Figure 6.11.

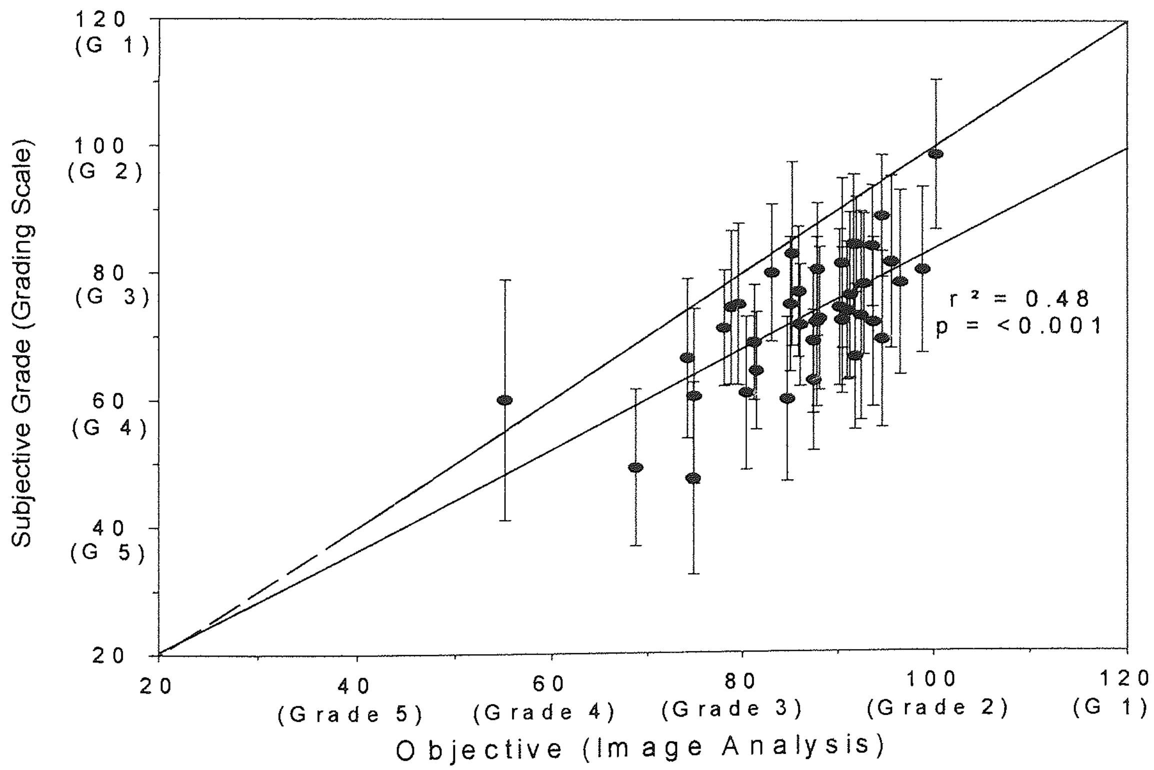


Figure 6.09: A/V ratio: objective versus subjective grading (n=40).

Solid line = regression; Dashed line = Proposed agreement (45° locus).

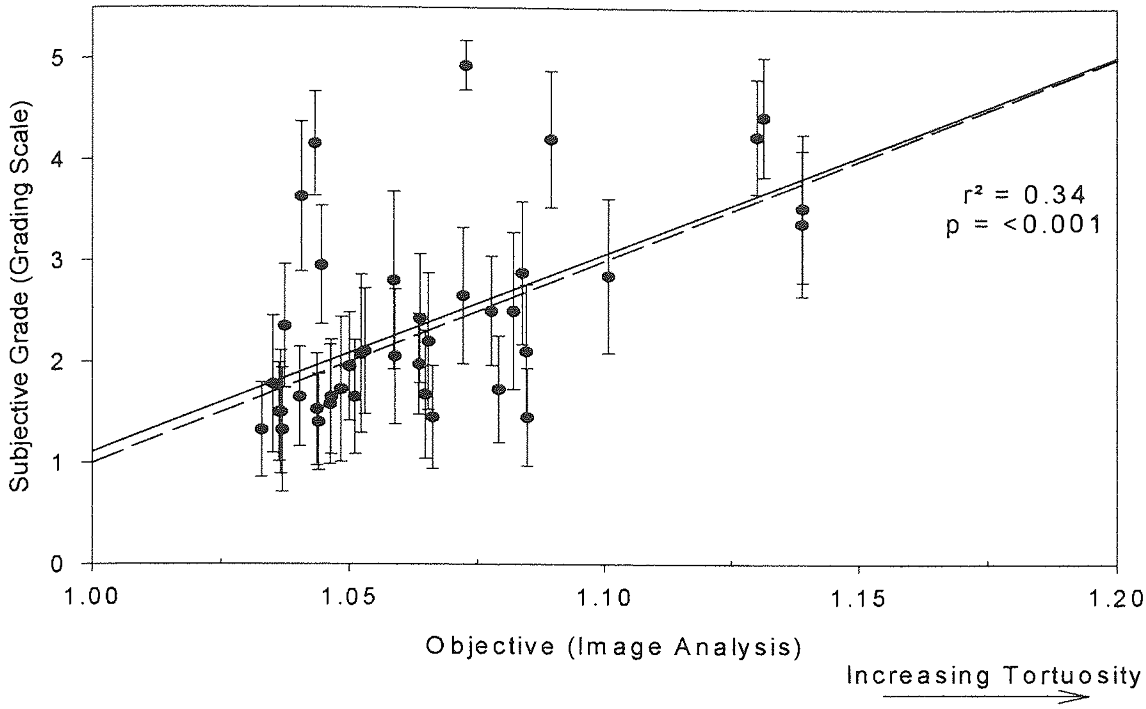


Figure 6.10: Objective versus subjective grading of tortuosity (n=40).

Solid line = regression; Dashed line = Proposed agreement.

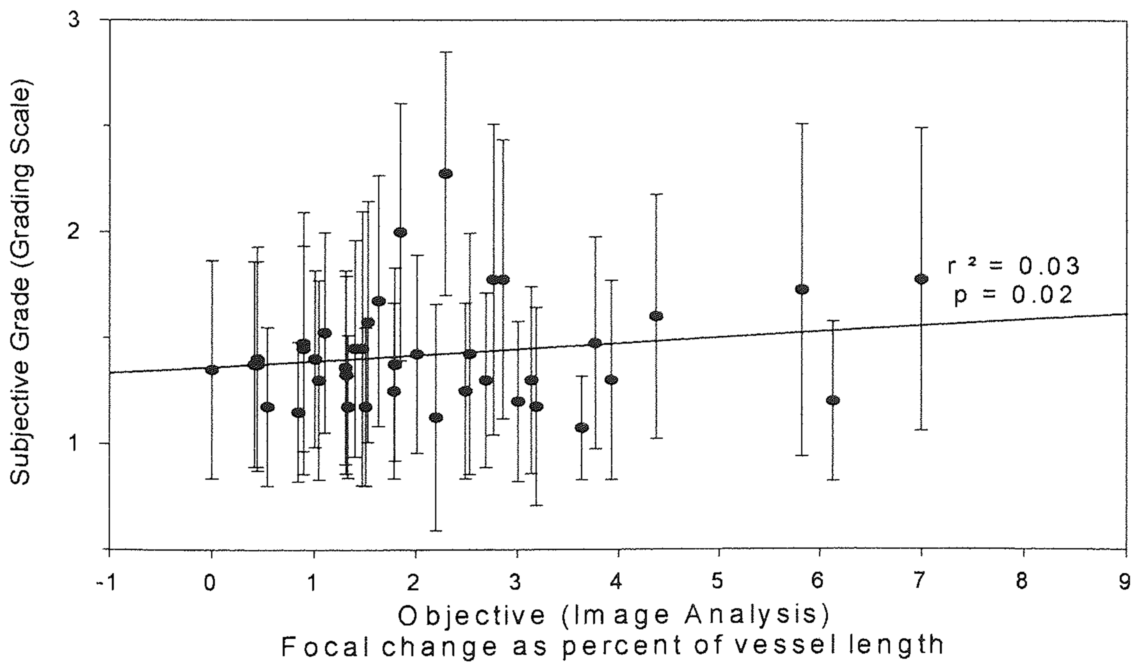


Figure 6.11: Objective versus subjective grading of focal calibre change (n=40)..

Solid line = regression.

6.50 - Pictorial Grading in Optometric Practice

The variation in BP (systolic and diastolic) and PP against the five pictorial grades in 201 patients is illustrated in Figure 6.12. The increase in arteriolar tortuosity and A/V ratio are highly correlated with increasing systolic BP, diastolic BP and PP (t test - two tailed: $p < 0.001$). The width of the arteriolar reflex showed a positive relationship to systolic and diastolic BP (t test - two tailed: $p < 0.001$) and a negative relationship to PP (t test - two tailed: $p < 0.001$).

The retinal grade for each pictorial retinopathic change within patient groups, determined by their BP level and control regime, is illustrated in Figure 6.13. Retinal vascular changes (A/V ratio, tortuosity, focal calibre and crossing changes) indicated a significant higher score for patients with elevated BP and/or presently taking hypertensive medication (HBP or med) compared with normotensives (t test - two tailed: $p < 0.0001$). Significant differences in pictorial grading of A/V ratio, arteriolar reflex, tortuosity and crossing changes was also illustrated between normotensives and patients with diastolic BP above 95mmHg (t test - two tailed: $p < 0.001$). The arteriolar reflex showed the least degree of clinical significance between the various BP levels / controls, with only a significant difference between the normotensive and patient with diastolic BP >95mmHg (t test - two tailed: $p < 0.001$). The significance of the pictorial grading scores to a patient's BP level / control is illustrated in Table 6.04.

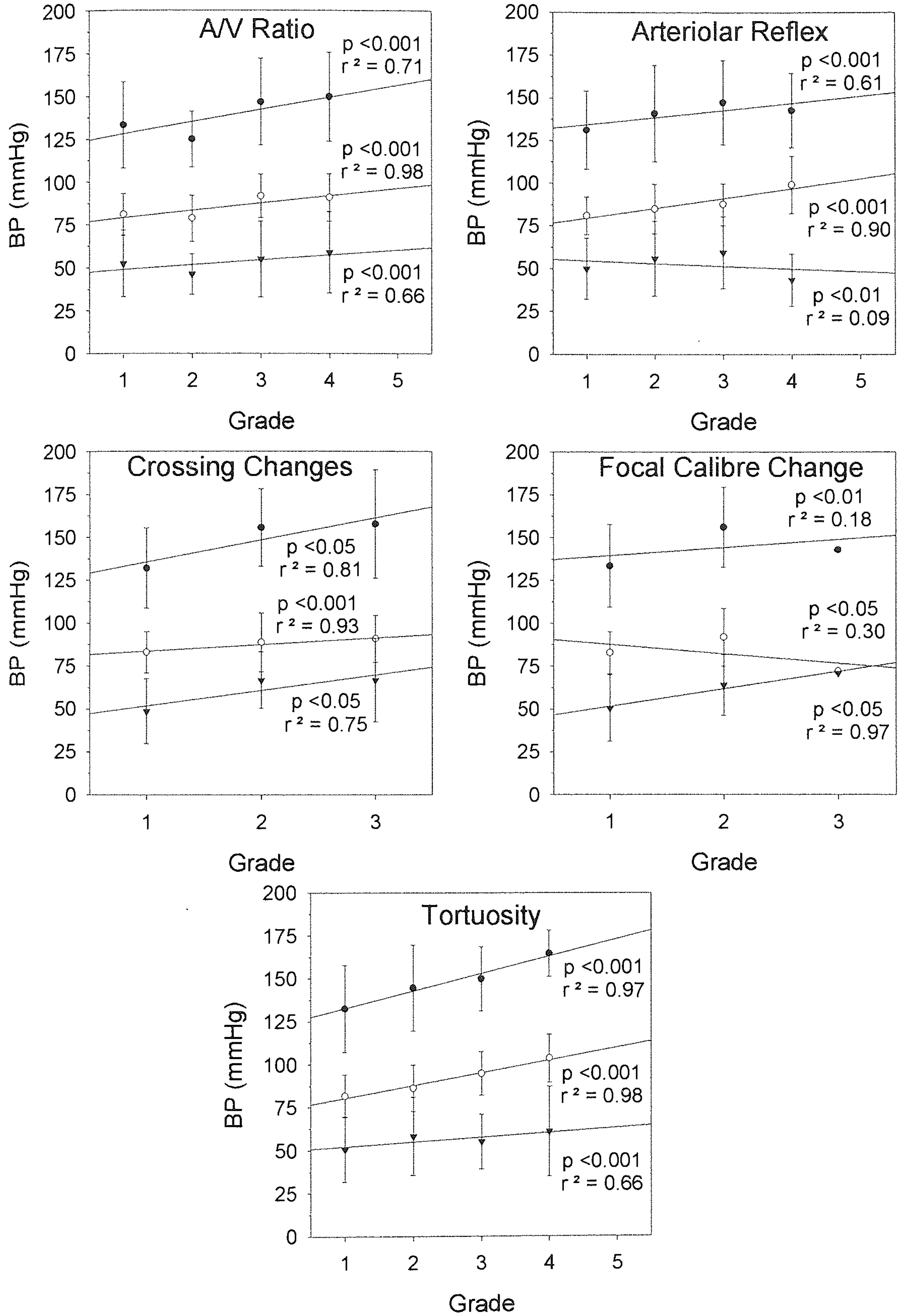


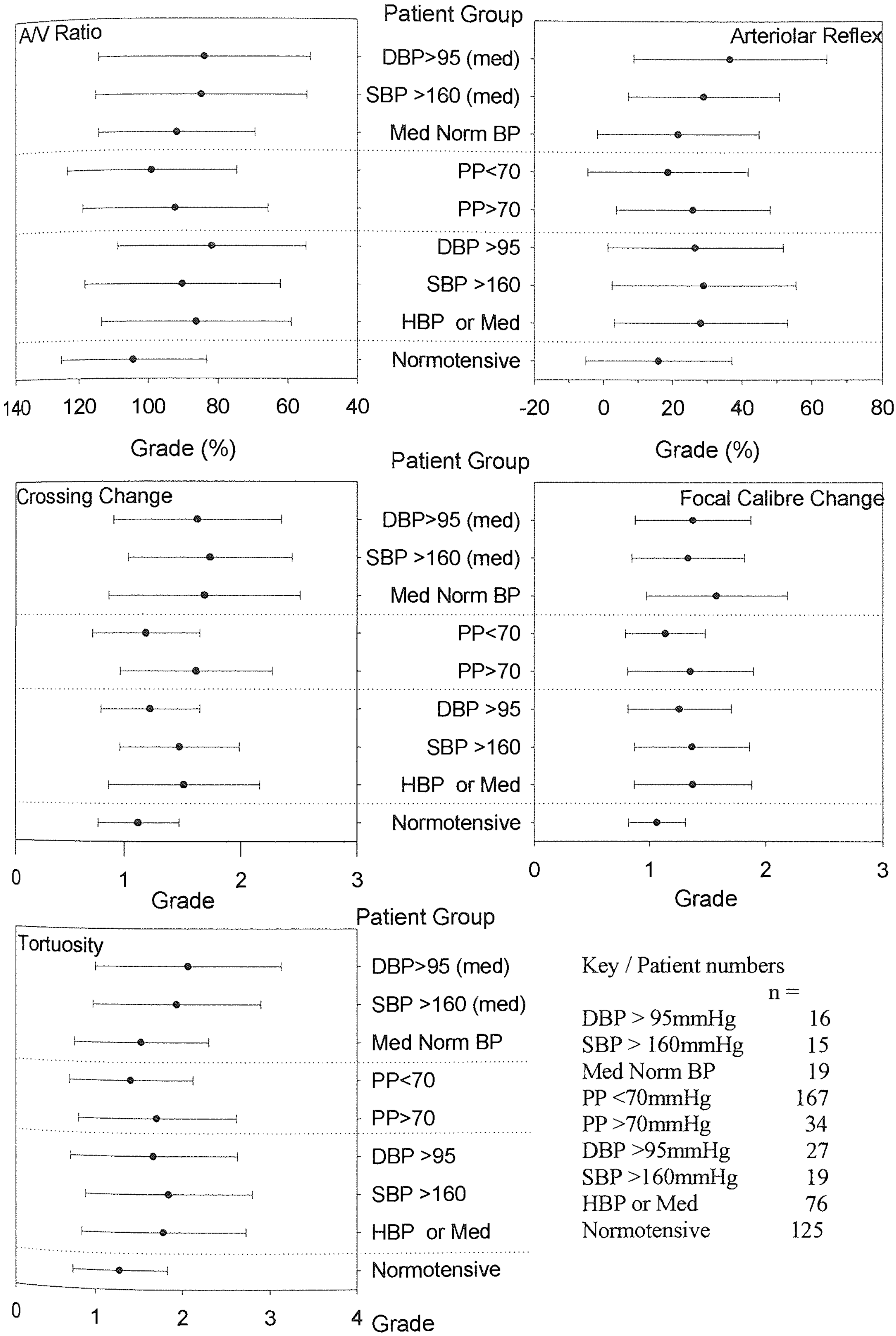
Figure 6.12 - Retinal grade versus patient BP (optometric patients).

Key - ● Systolic BP; ○ Diastolic BP; ▼ Pulse Pressure.

Retinal Feature	ANOVA (one-way)		Difference Between	Significance Level (Tukey)
	F	p		
A/V Ratio	5.43	<0.001	Normotensive vs. HBP or Medicated	0.01
			Normotensive vs. DBP >95mmHg	0.01
			PP <70mmHg vs. HBP or Medicated	0.05
Arteriolar Reflex	3.22	<0.001	Normotensive vs. DBP >95mmHg (med)	0.05
Tortuosity	5.03	<0.001	Normotensive vs. HBP or Medicated	0.01
			Normotensive vs. DBP >95mmHg (med)	0.01
			PP <70mmHg vs. HBP or Medicated	0.05
			PP <70mmHg vs. DBP >95mmHg (med)	0.05
Focal Calibre Change	7.39	<0.001	Normotensive vs. HBP or Medicated	0.01
			Normotensive vs. PP>70mmHg	0.01
			Normotensive vs. Med Norm BP	0.01
			HBP or Medicated vs. PP>70mmHg	0.01
			PP<70mmHg vs. Med norm BP	0.01
Crossing Changes	9.30	<0.001	Normotensive vs. HBP or Medicated	0.01
			Normotensive vs. PP>70mmHg	0.01
			Normotensive vs. Med Norm BP	0.01
			Normotensive vs. SBP>160mmHg (med)	0.01
			Normotensive vs. DBP>95mmHg (med)	0.01
			PP<70mmHg vs. HBP or Medicated	0.01
			PP<70mmHg vs. Med Norm BP	0.01
			PP<70mmHg vs. PP>70mmHg	0.01
			PP<70mmHg vs. SBP>160mmHg (med)	0.01
			PP<70mmHg vs. DBP >95mmHg (med)	0.05

Table 6.04: Significance of pictorial grading scores to a patient's BP level / control.

- Analysis of Figure 6.13 (optometric practice; n=201).



Key / Patient numbers

	n =
DBP > 95mmHg	16
SBP > 160mmHg	15
Med Norm BP	19
PP <70mmHg	167
PP >70mmHg	34
DBP >95mmHg	27
SBP >160mmHg	19
HBP or Med	76
Normotensive	125

Figure 6.13: Retinopathy grade with BP level/control - optometric practice (n=201).

6.60 - Retinal Photography versus Ophthalmoscopy

Comparison of the average grade for three hypertensive states (normotensive, controlled medicated hypertensive and elevated BP with/without medication) between the retinal photographs and optometric practice is illustrated in Figure 6.14. The grading scores for the retinal photographs were lower than that recorded for the fundi in optometric practice (average grade: 1.87 ± 0.48 versus 2.60 ± 0.63; t test - two tailed: $p < 0.001$). Those pictorial grades that use a five-point grading scale show a larger difference in grades between the two environments than the three-point grades.

6.70 - Influences on Retinal Vasculature Appearance

The medical status and lifestyle of the patient, as recorded on the questionnaire, was analysed (SPSS – linear stepwise regression) to determine the factors that influence the five retinal vasculature features. The influence of a patient's gender was found to be the largest single influence on the A/V ratio (18.9%; $p < 0.05$) and crossing changes (11.2%; $p < 0.01$) as determined by the subjective analysis of the photographs (Table 6.05). These predictors were not confirmed with image analysis of the retinal photographs (Table 6.06). Image analysis revealed that the important influences upon the retinal features were the occurrence of previous heart attacks and nose bleeds: A/V ratio 54.4% ($p < 0.001$) and 3.7% ($p < 0.05$) and focal calibre changes 11.6% ($p < 0.01$) and 5.9% ($p < 0.05$) respectively. The two main predictors of retinal vasculature features in optometric practice were: diastolic BP and age (Table 6.07). The influence of diastolic BP on the retina was: A/V ratio 14.4% ($p < 0.001$); arteriolar reflex 8.5% ($p < 0.001$) and tortuosity 15.3% ($p < 0.001$). The influence of age on tortuosity was 8.7% ($p < 0.001$), focal calibre change 19.8% ($p = 0.001$) and crossing changes 24.8% ($p = 0.001$).

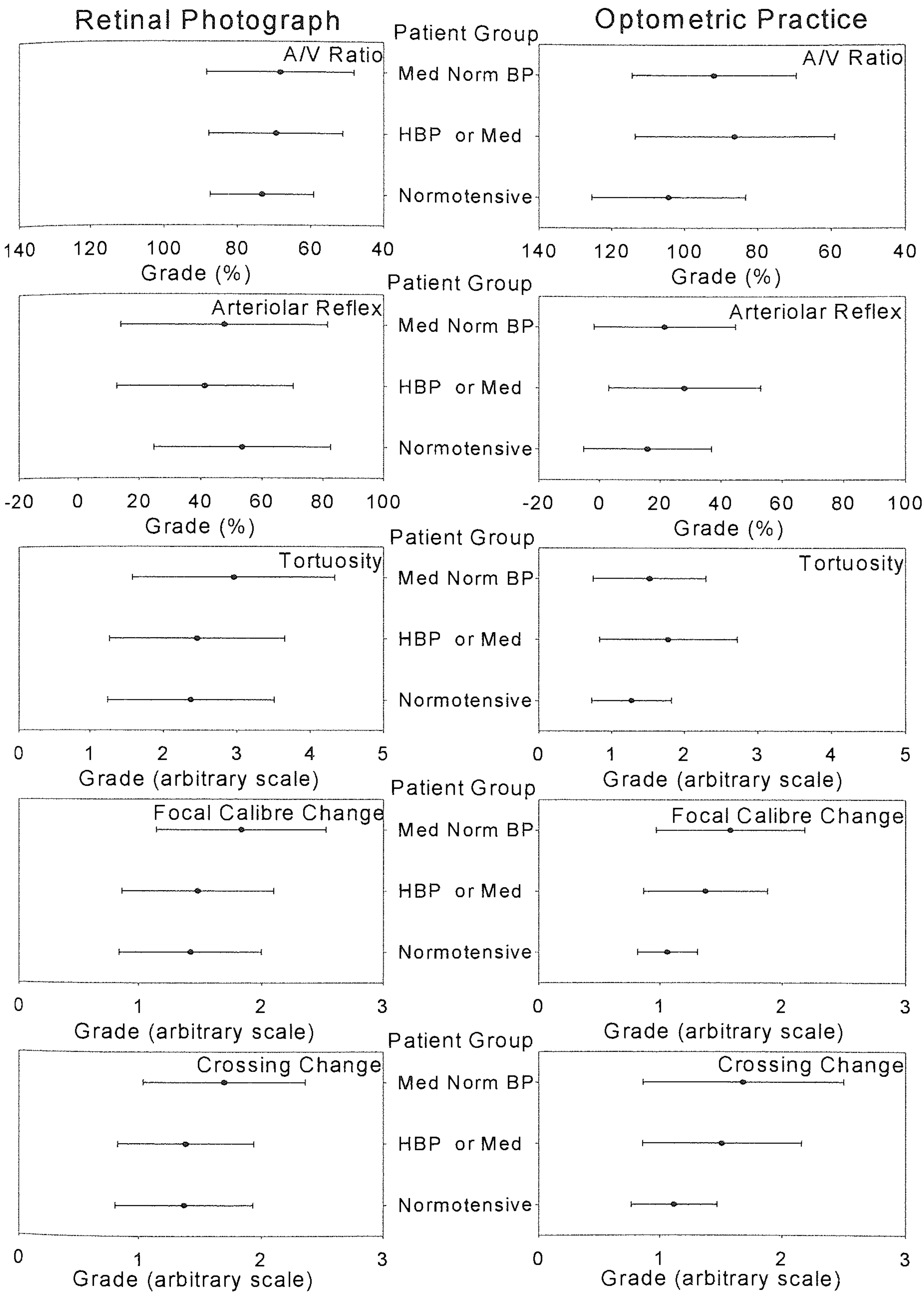


Figure 6.14: Average pictorial grade with BP level/control.

Photograph (optometrist) versus optometric practice.

Photograph - Normo (n=23); HBP/ Med (n=11); Med Norm BP (n=6).

Optometric practice - Normo (n=117); HBP/ Med (n=68); Med Norm BP (n=16).

Retinal Feature	Predictor	Adjusted R Square	p
A/V Ratio	Gender	0.189	<0.05
Arteriolar Reflex	Age	0.168	<0.01
Tortuosity	-	-	-
Focal Calibre	-	-	-
Crossing Change	Gender	0.112	<0.05
Lesions	Angina	0.203	<0.01
	Height	0.275	<0.05
	Overall Stress	0.365	<0.05

Table 6.05: Factors influencing retinal vasculature – Subjective.

Subjective grading of retinal photographs (n=37).

Complete data for comparison of all factors only available for 37 of the 40 retinal photographs.

Retinal Feature	Predictor	Adjusted R Square	p
A/V Ratio	Heart Attack	0.544	<0.001
	Angina	0.618	<0.01
	Nose Bleeds	0.655	<0.05
Arteriolar Reflex	-	-	-
Tortuosity	Work Stress	0.109	<0.05
Focal Calibre	Weight	0.208	<0.01
	Heart Attack	0.324	<0.01
	Nose Bleeds	0.383	<0.05
Crossing Change	-	-	-

Table 6.06: Factors influencing retinal vasculature - Objective.

Image Analysis of retinal photographs (n=37).

Retinal Feature	Predictor	Adjusted R Square	p
A/V Ratio	Diastolic BP	0.144	<0.001
	Work Stress	0.254	<0.001
	General Health	0.274	<0.05
	Ethnicity	0.288	<0.05
	Smoking	0.303	<0.05
Arteriolar Reflex	Work Stress	0.114	<0.001
	Diastolic BP	0.199	<0.001
	General Health	0.216	<0.05
	Diet	0.231	<0.05
Tortuosity	Diastolic BP	0.153	<0.001
	Age	0.240	<0.001
	Angina	0.259	<0.05
Focal Calibre	Age	0.198	<0.001
	Systemic Hypertension	0.233	<0.01
	Weight	0.264	<0.01
Crossing Change	Age	0.248	<0.001
	Systemic Hypertension	0.303	<0.001
	Cholesterol	0.324	<0.01
	Angina	0.346	<0.01
	Weight	0.357	<0.05

Table 6.07: Factors influencing retinal vasculature (optometric practice; n=163).

6.80 - Discussion

6.81 - Accuracy of Pictorial Grading Scale

The average grade assigned by the two groups of examiners (optometrists and students) was clinically the same and indicated that individuals with a minimum of technical knowledge could grade systemic hypertensive retinopathy as accurately as trained professionals with use of the pictorial grading scale. A limitation in the examiners' clinical knowledge of systemic hypertension does not clinically affect their grading accuracy. The grading of systemic hypertension with the pictorial grading scale is a straightforward visual matching task and therefore, does not require a high clinical knowledge and training (Efron, 2003). However, examiners with additional knowledge will apply this to the visual matching task permitting the ability to ignore artefacts and conflicting observations. The grading scale can be termed accurate as the results from non-optometrists compare favourably with those from experienced optometrists (ISO 5725-1, 1994 – Accuracy (trueness and precision) of measurement methods and results – part 1: general principles and definitions). Grading scales with widespread professional backing reduce classification errors due to variations in optometrists' opinion and assist in the comparison of results for audits (Chylack, *et al.*, 1989).

6.82 - Interpolation of the Grading Scale

Interpolation of the grading was undertaken to determine if the grading increments could be adjusted to make the scale more sensitive with finer increments (Bailey *et al.*, 1991). Examiners' reluctance to grade to the nearest decimal increment (inter / extrapolate) is initially high (94.9% of optometrists) as they are not confident in assigning the correct decimal score, consistent with the findings of Bailey and colleagues (1991) and Efron (2001).

6.83 - Reliability of Grading Scale

The repeat measurement by the optometry students produced a slight (non-significant) shift in the interpolation of grading estimates indicative of a possible increase in their experience of the grading scale and knowledge of systemic hypertensive retinopathy. These findings were similar to those of Quigley and colleagues (1993). The results from application of the pictorial grading scale will change after a brief training session and reduce the need for knowledge in interpreting the clinical signs.

The use of the pictorial grading scale assists the observers in giving a reliable repeat measurement (intra-observer variation). However, these results do not indicate the importance of each grade, which may have been assigned by subjective impressions or an arbitrary measure. The question, therefore raised is: are the arbitrary grade increments the same as clinical grade increments?

The variation between the grading estimates, as Bailey and co-workers (1991) stated, is to be expected as the examiner is grading a continuous variable. Subjective grading of the fundus vasculature has been found to have poor inter- and intra- observer repeatability (Michaelson *et al.*, 1967; Dimmitt *et al.*, 1989). The reduced repeatability of the pre-malignant changes is due to their subtle nature, as the human eye can only assess accurately changes in blood vessel width that are greater than 10um (Wolf *et al.*, 1998), and their overlap with physiological findings. The grading of retinal lesions was the most reliable of those examined, but even retinal lesions have a degree of continuous variability.

6.84 - Bias of the Grading Scale

Grading estimates which showed a degree of bias on repeat measurements, all less than one clinical grade, were those retinal features which show a vast range of subtle changes across the fundus: A/V ratio, crossing changes and arteriolar reflex. The grading of photographs and to a lesser extent the eyes in situ were open to bias by grading the fundus with reference to a previous grading estimate, rather than grading the fundus solely in relation to the pictorial grading scale.

A grading tutor has been shown to remove grading bias and permit comparison of data between examiners (Efron, 2001). The examiner grades the retinal features of the grading tutor and compares the grading estimates with the stated normative values to allow a correction factor to be applied to future readings. Examiners can also evaluate their own reliability to determine their own grading capabilities. Failure to adjust results with the correction factor would cause the inaccurate recording of the retinal features and potential mis-management of the patient.

6.85 - Objective versus Subjective Analysis

A poor relationship existed between the subjective and objective grading of the A/V ratio and arteriolar reflex, which has previously been reported (Wolffsohn *et al.*, 2001). With a non-uniform increase in scale grade increments there is to be expected a lack of accuracy between the subjective and objective measures of these features.

It has been demonstrated that the proposed pictorial grading scale images, with the exception of A/V ratio, are not evenly spaced in terms of increasing clinical severity. The use of drawings or computer morphs could be utilised to improve the linearity and progression of the grading scale. However, these images can lack the realism of a more variable retinal photographic scale.

The grading scale and the proposed comparison between the subjective and objective grades was determined by arbitrary boundaries. They, therefore, fail to take into account the importance of the variable change. Weighting of the grading scale is, therefore, required within each retinal vascular change and across the various retinal vasculature features to permit a scoring for the systemic hypertensive changes to assist in the management of the patient.

6.86 - Pictorial Grading in Optometric Practice

The increase in arteriolar tortuosity with increasing BP confirms previous research by Wolffsohn and colleagues (2001). Confirmation of the increase in severity of focal calibre changes with increasing BP (Svardsudd *et al.*, 1978; Wolffsohn *et al.*, 2001) was not possible as there was a lack of patients with marked changes. In most instances the retinal vascular appearance change was less marked in those patients with well controlled BP compared with those with uncontrolled BP (with/out medication). The variance of grading estimates was larger in those patients with elevated BP, confirming a previously published report indicating a wider variation in the defective population (Reeves *et al.*, 1987). The exception to this was focal calibre change. These findings would indicate that the control of BP is accompanied by a slight reverse in the damage of the vasculature, as has been previously reported (Klein, 1992; Wolffsohn *et al.*, 2001).

There were no malignant hypertensive changes in the optometric patients and no A/V ratio was less than 40%, which if the patient sample were recorded with the Keith Wagener and Barker scale (1939) would have resulted in all patients being recorded as grade I. Therefore, the recording of retinal vasculature, in particular the A/V ratio with the proposed pictorial grading scale permitted greater differentiation within the pre-malignant stage.

6.87 - Retinal Photography versus Ophthalmoscopy

There were two marked differences between the grading estimates: firstly the optometric practice grading estimates were lower than those recorded from the retinal photographs and secondly, the findings from the optometric practice showed a positive correlation with the patient's BP, not present with the photographs.

The grading of a retinal photograph (2-D) and the retina in situ (3-D) require from the observer two differing techniques to permit grading. The retinal photographs permitted multiple observations over 45° of the fundus without time constraints, but limited by the spatial and colour resolution of the photograph. The digital fundus photograph had approximately half the resolution of the natural image (Bradford, 2001).

The area under observation at one moment in time was 70mm in radius with the retinal photograph compared with approximately 2mm which an ophthalmoscope permits. The photographic score may, therefore, have been influenced by observation of a larger field permitting direct comparison between different sections and with the previous photograph. Differences in the findings could also be due to the retinal vasculature changes being beyond the area of the fundus photograph, which would otherwise have been detected with an ophthalmoscope. The grading estimates of the retina in situ may have been influenced by the optometrist's knowledge of the patient's medical status weighting the significance of the retinal feature and variations in illumination, magnification, viewing angles.

The optometric scores also are a combination of the grading estimates from two eyes, and even though they are served by the same vascular network, differences will exist meaning one eye should be compared with the other (Aspinall, 1974). In the instance where only one eye is affected it has not been determined whether this is less severe than when both eyes are affected. The difference between eyes could be similar to segmental tortuosity, which is indicative of a pathological state due to altered blood flow between the eyes and requiring a higher clinical weighting.

The in-depth analysis of data from the three data sources (subjective and objective grading of retinal photographs, and fundus examination) is not possible as they record the hypertensive changes differently. This, therefore, indicates that the influence of systemic hypertension on the retinal vasculature is subject to variations between the two eyes and also segmental changes within the eye. The comparison of these findings just examined the most severe degree of the systemic changes from the subjective analysis with the average from the objective analysis.

6.88 - Influences on Retinal Vasculature Appearance

The relationship between A/V ratio and focal calibre changes could be indicative of similar vascular changes occurring within the coronary circulation. Arteriolar narrowing has previously been shown to be related to risk of coronary heart disease in women but not in men (Wong *et al.*, 2002). Generalized arteriolar narrowing and A/V crossing change are irreversible long-term indicators of systemic hypertension, related to current and past BP levels (Wong *et al.*, 2001)

The relationship between arteriolar reflex and age could be the recording of vessels that have undergone arteriosclerosis; a diffuse hardening or stiffening of the arteries (Terry, 1976). These changes present in the normotensive vessel will lead to resistance to normal blood flow and subsequent raised BP.

6.89 - Proposed Changes

Grading scales that have gained acceptance and are used commonly in optometric practice (CCLRU, 1997; Efron, 1999) have a four step grading scale. The proposed pictorial grading scale (Wolffsohn *et al.*, 2001) incorporated two different scales: 1-5 (A/V ratio, arteriolar reflex and tortuosity) and 1-3 (focal calibre change and crossing change). Feedback from optometrists who graded the photographs reported that the two differing grading scores was a hindrance to the smooth grading of the photographs. The design of the scale was not discussed in the original paper (Wolffsohn *et al.*, 2001). It must, therefore, be assumed that the design was to enhance the sensitivity of grading in those features where there was a wide spread of variation in the population (e.g. tortuosity) and not expand those features which have a limited degree of variation (focal calibre change).

The grading scales with more grades are more sensitive to clinical measurement than those with fewer grades; the latter have been shown to reduce the clinician's ability to detect change within the grade (Bailey *et al.*, 1991). Design of a moderately sensitive grading scale would incorporate the grade steps to be less than one standard deviation of the discrepancy (Bailey *et al.*, 1991). Therefore, a proposed amendment of the pictorial scale would turn each vasculature change into a six point grading system. The present increments for focal calibre and crossing changes would be halved and those for A/V ratio, arteriolar reflex and tortuosity would have grades three-quarters that of their present. A fine scale, where grade increments are calculated from a third of the standard deviation of the discrepancy (Bailey *et al.*, 1991), would produce an 18-point grading scale hindering its clinical application.

The modification of the grade increments of the pictorial grading scale require both the cross-sectional and longitudinal assessment of the normative retinal vasculature, for one day, to take account of variations over time and determine their significance; these are assessed in chapters 3 and 7. It has previously been reported that the variation in appearance of the patient's fundus with time is important when determining the management to be followed (Spaeth and Varma, 1987).

6.90 - Conclusion

To incorporate the amended systemic hypertensive pictorial grade into practice it needs to be advertised on its benefits of enhancing the repeatability of measures and clinical recording of change (Dundas *et al.*, 2001). Educating the optometrists in the precision and relevance of the test would increase its widespread application in optometric practice (Reeves *et al.*, 1987). Retinal examination encompassing the pictorial grading scale and information recorded during history and symptoms assists the optometrist in making decisions on the management of his/her patient in relation to systemic hypertension. Patient management in relation to differentiating systemic hypertension from arteriolosclerosis could be further improved with accompaniment of the measurement of the patient's blood pressure.

CHAPTER 7 - OBJECTIVE GRADING OF THE RETINAL VASCULATURE - LONGITUDINAL STUDY

7.10 - Introduction

BP readings determined through sphygmomanometry indicate to the health care professional the level of the patient's BP, but not the patient's response in terms of target organ damage. The alteration in the appearance of the target organ arterioles in response to systemic hypertension can only be visualized in the eye (Keith *et al.*, 1939). These arterioles will reveal information on the state of the body's vasculature in response to elevations in BP through variation in the vessel diameter (radial stretching), colour and tortuosity (longitudinal stretching; Gang *et al.*, 2002; Heneghan *et al.*, 2002).

The prognosis of the systemic hypertensive patient through fundus examination of the vasculature and retinopathy, rather than BP measurement, has been examined through several large scale longitudinal studies on the prevalence and mortality of systemic hypertension (Keith *et al.*, 1939; Svardsudd *et al.*, 1978; Leibowitz *et al.*, 1980 and Klein *et al.*, 1997). The methods used in each of these studies differ (equipment used for fundus examination, patient grouping and follow up), hindering direct comparison of the findings. Three of these were based within the medical environment, whereas the Beaver Dam study was population based (Klein *et al.*, 1997). The patient basis influences the prevalence and longitudinal variations of systemic hypertension and hypertensive retinopathy.

7.11 - Longitudinal Retinopathy Studies

The examination of retinal vasculature (n = 200) and muscle biopsies (n =138) over a nine-year period permitted the construction of a four point grading scale for systemic hypertensive retinopathy based on the patient prognosis by Keith and co-workers (1939). An increase in the group number was associated with an increase in the symptoms of systemic hypertension and a worsening of the prognosis for the patient, Table 7.01. This grading scale and patient prognosis has been outdated as it has not been amended to take account of advances in the medical treatment of systemic hypertension and knowledge on the pathophysiology of arterial hypertension (Dodson *et al.*, 1996).

The prevalence of retinal haemorrhages, arteriolar narrowing and crossing changes was found to be 0.4%, 6.0% and 8.9%, respectively, in a male middle-aged population (Svardsudd *et al.*, 1978). The mean systolic and diastolic BP was higher in those patients with these retinal changes. At a four-year follow up there was found to be no significant change in the frequency of these lesions. At the eight-year follow up arteriolar narrowing and crossing changes were associated with increased mortality rates. After 12 years the presence of focal arteriolar calibre changes was found to be the important prognostic retinal indicator for mortality (Svardsudd *et al.*, 1978).

The prevalence of retinopathy in the non-diabetic Beaver Dam population was found to be 7.8%; which comprised 6.0% of the normotensives and 10.7% of the systemic hypertensives (Klein, 1992). The highest prevalence and increase in the severity of retinopathy was associated with those individuals whose BP was not controlled. An elevation in diastolic BP of 10mmHg was found to be associated with a 12% increase in microaneurysms for the general population and 49% in those with systemic hypertension.

Group	Retinal Change	General Health	Patient Prognosis Survival
1	Minimal retinal vasculature change	No symptoms Adequate cardiac and renal function	60% (6/10) after 7-9 yrs
2	Greater degree of retinal vasculature change	Higher level of BP Adequate cardiac and renal function	35% (9/26) after 7-9 yrs
3	Marked arteriolar changes Cotton wool spots Oedema Haemorrhages	Symptoms of systemic hypertension Possible cardiac and renal involvement Proteinuria Microscopic haematuria	8% (3/37) after 7-9 yrs
4	Grade 3 + Elevated discs	Persistent elevated BP Headaches Visual disturbances	22% (32/149) after 1 yr

Table 7.01: Prognosis of patient groups in the Keith, Wagener and Barker scale (1939).

At the five-year follow up retinopathy was found to have developed in 6.0%, arteriolar narrowing in 9.9% and arteriovenous crossing changes in 6.5% of the non-diabetic population. The incidence of retinopathy and arteriolar narrowing was greater in those people with poorly controlled BP compared with normotensives; 9.2% versus 4.6% and 15.2% versus 7.7%, respectively, (Klein and Klein, 1997). The risk of developing arteriolar narrowing and arteriovenous crossing changes after five years was influenced by the baseline systolic BP; there was a 21% and 16% respective increase in the odds ratio with every 10mmHg elevation (Klein and Klein, 1997). The influence of uncontrolled systemic hypertension upon the incidence of retinopathy, focal arteriolar narrowing and arteriovenous crossing changes was found to be 60%, 49% and 37% respectively.

The longitudinal studies previously carried out have all been based on subjective analysis of the retinal vasculature. This chapter examines the retinal vasculature through objective measurement to determine if the subtle variations in the vasculature with time can be monitored with image analysis. The general health of the patients is also examined over the two year time frame to examine changes in the general health of the patient basis.

7.20 - Method

Subjects who had previously taken part in the initial data collection session (January-March 2001; n=103) were invited back on two further occasions for repeat measurements. Data point two was November - January 2002 (n=95) and data point three October – December 2002 (n=87). The research was approved by the university ethics committee and conforms to the declaration of Helsinki. Patients were asked to confirm that the information on their initial consent form was still appropriate at each attendance, and no patients subsequently asked for a change in the communication links between the researcher and their GP from their previous session.

A sub group of patients for assessment of longitudinal variation in retinal vasculature was divided into three according to age: group 1; 18-40 years (n = 10, average age 25.9 ± 8.8 years); group 2; 40-60 years (n = 10, average age 48.8 ± 5.2 years); and group 3; over 60 years (n = 20, average age 72.1 ± 6.3 years). Group 3 was subdivided into normotensive patients (n = 10, average age 70.9 ± 6.1 years); and systemic hypertensive patients (n = 10, average age 73.4 ± 6.6 years).

7.21 - Blood Pressure Measurement

The patient's BP was recorded on each occasion with the OMRON 705 CP automatic BP monitor. The method for BP measurements has been described in detail in chapters 1 and 3. All patient BP measurements were taken from the left arm with an appropriately selected size inflatable bladder (cuff). At least two readings were taken per patient, with an interval of at least two minutes between readings, until two readings within 5mmHg of each were recorded (J.N.C., 1997).

7.22 - Patient Questionnaire

The subjects completed a questionnaire on each visit about their general health, medication and life style (appendix 2). The questionnaire was amended between visits, to remove questions whose answers would remain the same between visits (e.g. birth history) and additional questions were inserted (e.g. patient opinion on BP measurement). A single examiner (P.H.) completed the questionnaires with all the subjects to ensure consistency. Interviewing the subject, rather than requiring them to self-complete the questionnaire allowed the order of questioning to be fixed and prevent revision of answers in the light of subsequent questions.

7.23 - Fundus Photographs

Non-mydriatic 45° colour fundus photographs, centered on the optic disc, were taken using a Topcon TRC-NW5S Fundus Camera. The background illumination within the fundus camera was set at 3.5, the flash intensity at medium and the gain setting at 12 for all patients. At least one photograph per eye was taken of each subject to ensure the image analysis was performed on the best quality image available for the individual.

All the retinal photographs were taken at the same part of the cardiac cycle, immediately following the closure of the aortic and pulmonic valves (second heart sound), as detected through a stethoscope with the diaphragm held in place by the patient over the aortic area. Additional details of retinal photography and the influence of the cardiac cycle on the retinal circulation is discussed in chapter 3. All the retinal photographs were taken by one examiner (P.H.).

7.24 - Image Analysis

Ten patients' (five male and five female) photographs from each patient sub-group, having previously been selected for their image clarity, were analyzed in a random order independent of any information on the patients' medical status and BP to reduce possible bias. The four main pairs of retinal arterioles and venules in each photograph were analyzed from each of the data collection points with a purpose written computer edge detection program (Labview and Vision Software, National Instruments, USA), appendix 3. The design of the computer algorithm for detecting the vessel edges is discussed in chapter 3.

The vessel width of the major arterioles and venules was determined at the edge of the optic disc and then every two millimetres (on the computer monitor - determined by a hand held calibre) until the margin of the photograph was reached or the vessel became indistinct from the background. Where the vessel branched, crossed or was crossed by another vessel a reading of "0" was scored. The results (co-ordinates of the vessel edges) from the edge detection program were automatically fed into an excel spreadsheet. Vessel edges which were absent (e.g. due to vessel branching) were calculated by the assumption that the missing value would lie half way between the pre and post segment edge points. The length of each vessel analyzed was the same for each of the three years to avoid any scaling factor by analyzing a vessel differing in length from the previous year. The calculation used in analyzing the vessel edge data is described in chapter 3.

7.30 - Results

Fundus photographs, questionnaires and BP measurements were completed for 87 patients over the two-year time frame. Fifty five percent of the patients were male (n = 48) and 29.9% (n = 26) were taking medication for systemic hypertension. Reasons for patients not being followed through the research period were: failure to attend a follow up session (5.7%; n = 6), poor quality fundus photograph which could not be analysed with the image analysis software (4.8%; n = 5), ill health (1.9%; n = 2) and failure to record BP at a previous session due to the size of their arm (even with the largest cuff; 2.9%; n = 3). One of the patients, with diagnosed systemic hypertension, who did not complete the follow up due to ill health, had three strokes between session 2 and 3.

The retinal fundi of both eyes of the sub group of 40 patients underwent image analysis over the two-year period. These patients were selected on the basis of an optimum retinal photograph and group characteristics based on age, gender and BP status. Despite all photographs being optimised for clarity, 1.8% (84) of vessels could not be measured and analysed due to poor contrast. Average findings are shown as the mean ± 1 standard deviation.

7.31 - General Health

Completed health questionnaires and BP measurements were compiled from 87 patients at each of the data collection points. The changes in the general health of the 85 white European patients over the two-year period are presented in Table 7.02. Diabetes mellitus (type II) was the most common systemic condition to be diagnosed over the two-year time frame; 4.6% (n = 4) of the population sample. The average B.M.I. of the diabetic patient was 30.89 ± 5.43 compared to 27.83 ± 7.52 for age-matched non-diabetic patient (t test - two tailed: p = 0.55). The occurrence of previously undiagnosed conditions was more prevalent in group 3 than group 2 (1 in 4.3 versus 1 in 10.0) and in those with diagnosed systemic hypertension compared with normotensives (1 in 2.4 versus 1 in 8.7).

The average systolic and diastolic BP measurements for these patients from the three data collection points are plotted in Figure 7.01. Male BP (both systolic and diastolic) was significantly higher than female BP over the two-year period (one-way ANOVA: $F = 5.78$; $p < 0.05$). The average BP for the group 2 female systemic hypertensive was comparable to the group 2 normotensive male (t test - two tailed: $p = 0.10$). There was no significant change in BP between the data collection points (one-way ANOVA: $F = 0.55$; $p = 0.58$).

Patient Group	n	Change in BP Yr1 → Yr3 (%)		Health Changes (n)				
		SBP	DBP	Diabetes	Angina	BP	Cholesterol	Stroke
Gp1 M bp	11	-1.26	+0.62	-	-	-	-	-
Gp1 F bp	11	-0.70	+1.84	-	-	-	-	-
Gp2 M bp	7	+4.48	+3.24	-	1	-	-	-
Gp2 M BP	2	-4.68	-2.05	-	-	x	-	-
Gp2 F bp	6	-3.35	-3.59	-	-	-	-	-
Gp2 F BP	5	+5.15	+2.47	1	-	x	-	-
Gp3 M bp	18	-1.93	-6.08	-	1	1	-	-
Gp3 M BP	9	+0.63	-2.29	-	-	x	1	1
Gp3 F bp	8	+2.65	-0.25	-	-	1	-	-
Gp3 F BP	8	+3.48	-0.85	3	-	x-	2	-

Table 7.02: General health changes over two years - white European (n = 85).
Key: Gp = Group (1/2/3); M = Male; F = Female; bp = normotensive,
BP = Diagnosed systemic hypertensive (with medication).

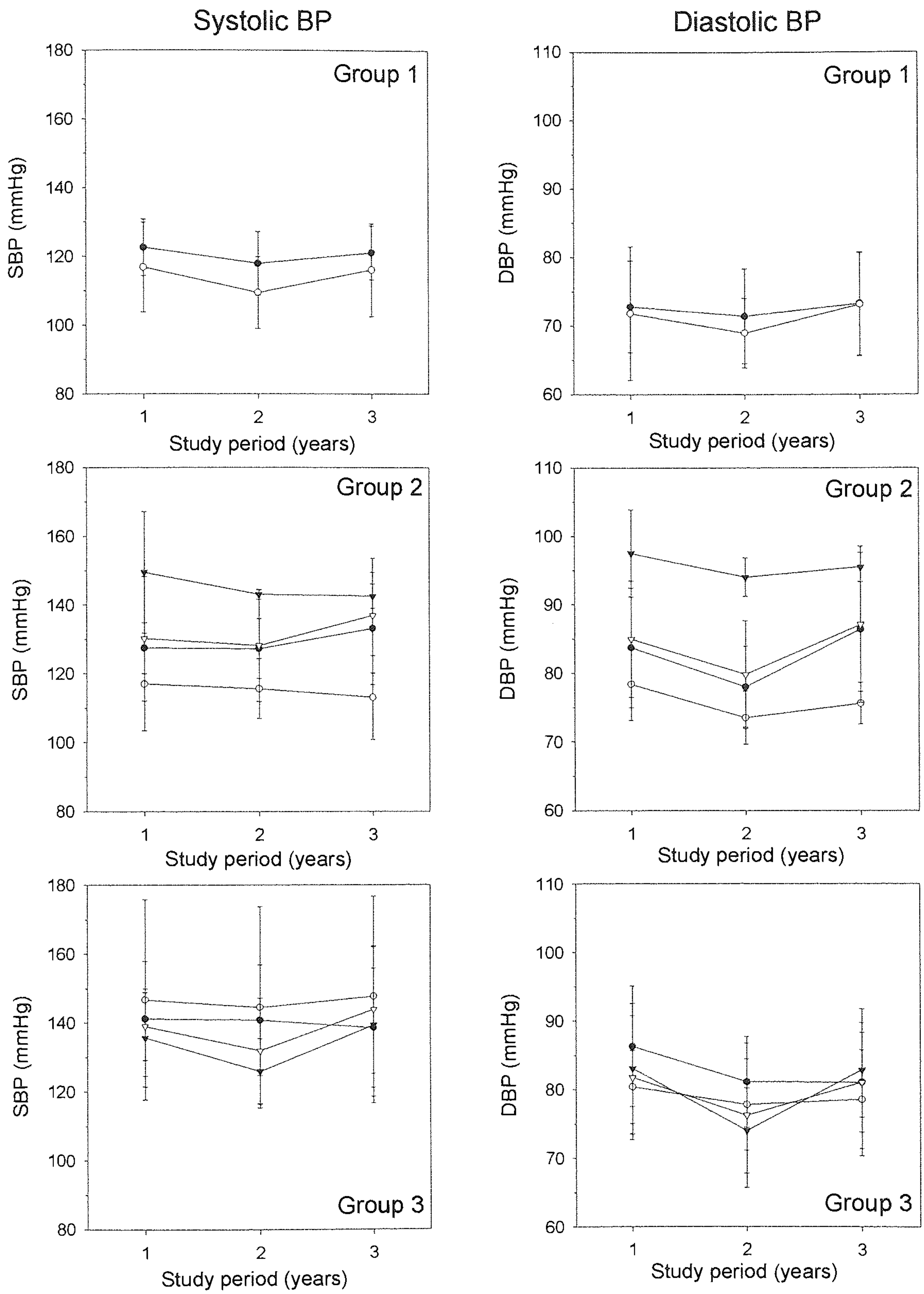


Figure 7.01: Longitudinal Blood Pressure measurements, key Table 7.01 (n = 85).

Key: Male; ● Normotensive; ▼ Systemic Hypertensive

Female: ○ Normotensive; ▽ Systemic Hypertensive

7.32 - Vasculature Change

The retinal features of ten patients from each sub-group were followed over the two-year period (Figures 7.02 to 7.05), the demographics of which are displayed in Table 7.03. All four groups showed no significant change in the A/V ratio over the two-year period; average change +0.40 ± 2.46%. The patient's gender had a significant influence upon the variation of the A/V ratio over this time period (one-way ANOVA: $F = 4.24$; $p < 0.05$). The tortuosity index was also stable over this period (-0.03 ± 0.31%) and not influenced by the patient's BP (one-way ANOVA: $F = 1.12$; $p = 0.30$), gender (one-way ANOVA: $F = 0.01$; $p = 0.97$) or time (one-way ANOVA: $F = 0.19$; $p = 0.83$). The average change in displacement of the vessel from the chord was –11.32 ± 7.14%, indicating a straighter vessel after two years. Displacement was related to the patient's BP (one-way ANOVA: $F = 7.60$; $p < 0.01$) and time (one-way ANOVA: $F = 4.28$; $p < 0.05$). The highest degree of vasculature change for all patients over the two-year period was that of focal calibre changes; marked –50.1 ± 42.20% (one-way ANOVA: $F = 8.10$; $p < 0.01$) and slight –28.5 ± 26.85% (one-way ANOVA: $F = 6.83$; $p < 0.001$).

Patient Group	n	Average BP (mmHg)		Medical Status (n = yr1, yr2, yr3)			
		SBP	DBP	BP	Diabetes	Cholesterol	Stroke
Gp 1 M	5	125.3 ± 8.4	75.1 ± 5.8	-	-	-	-
Gp 1 F	5	112.6 ± 8.1	72.6 ± 6.3	-	-	-	-
Gp 2 M	5	128.9 ± 10.7	81.7 ± 7.5	-	-	-	-
Gp 2 F	5	114.5 ± 12.2	75.3 ± 5.1	-	-	-	-
Gp 3 M	5	132.1 ± 20.6	79.1 ± 8.4	-	-	-	-
Gp 3 M BP	5	139.5 ± 27.6	82.8 ± 11.3	5,5,5	-	1,1,1	2,2,2
Gp 3 F	5	135.5 ± 19.0	81.5 ± 7.7		-	-	-
Gp 3 F BP	5	137.5 ± 15.3	80.1 ± 6.4	5,5,5	0,0,2	1,1,1	-

Table 7.03: Medical status of patients in the longitudinal study of vasculature (n = 40).

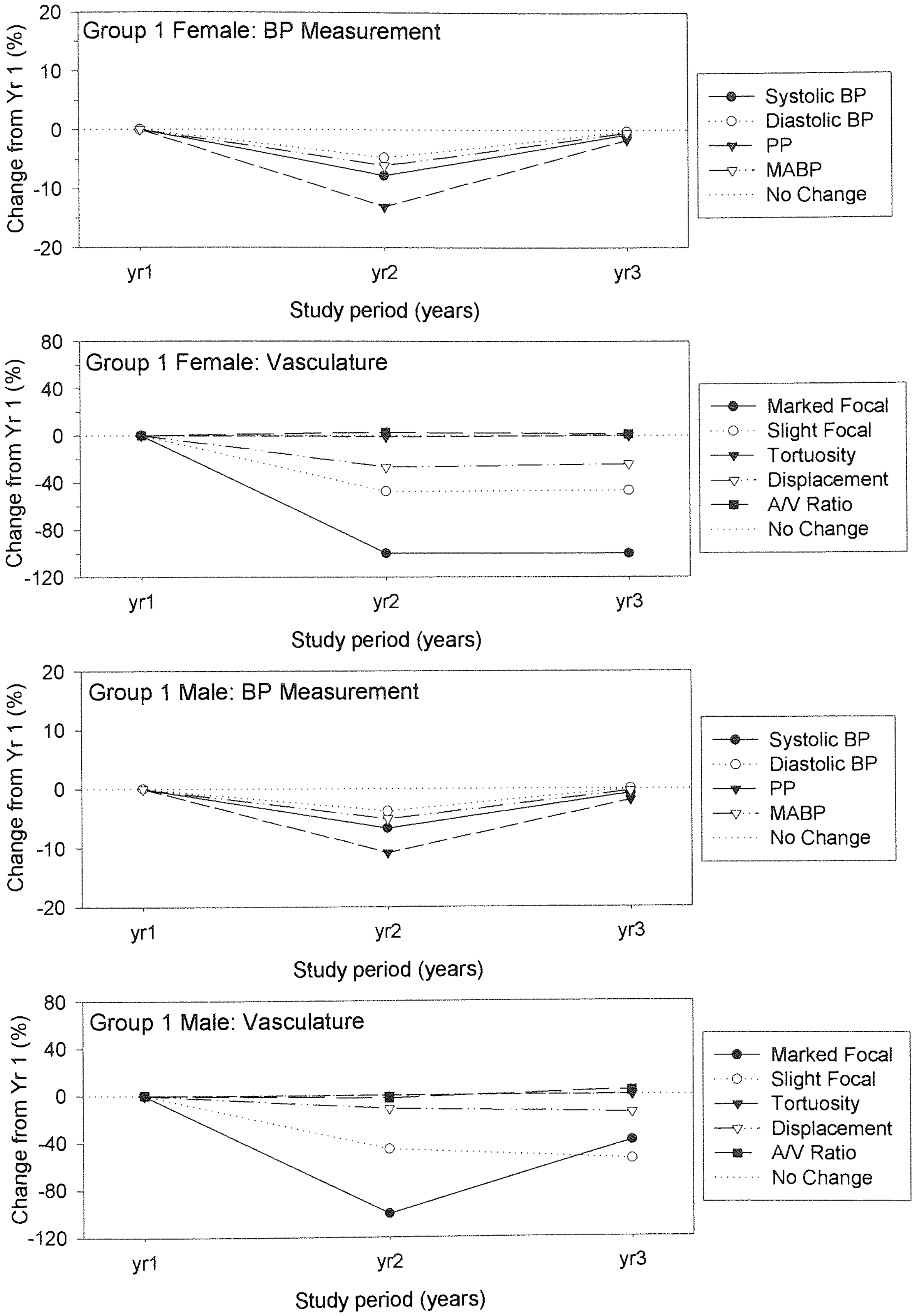


Figure 7.02: Average Blood Pressure and retinal vasculature variation over two years

– Group 1 normotensive.

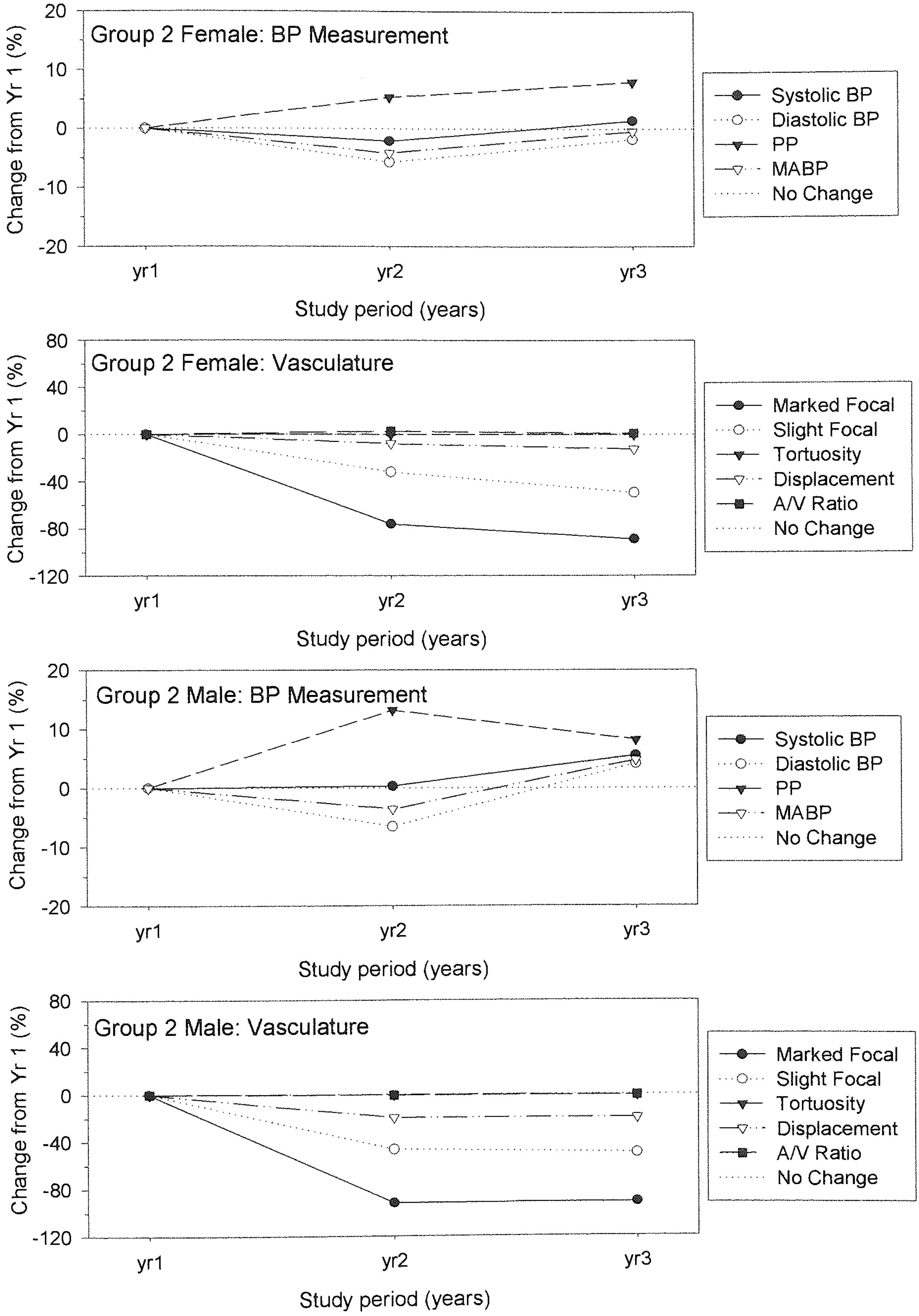


Figure 7.03: Average Blood Pressure and retinal vasculature variation over two years – Group 2 normotensive.

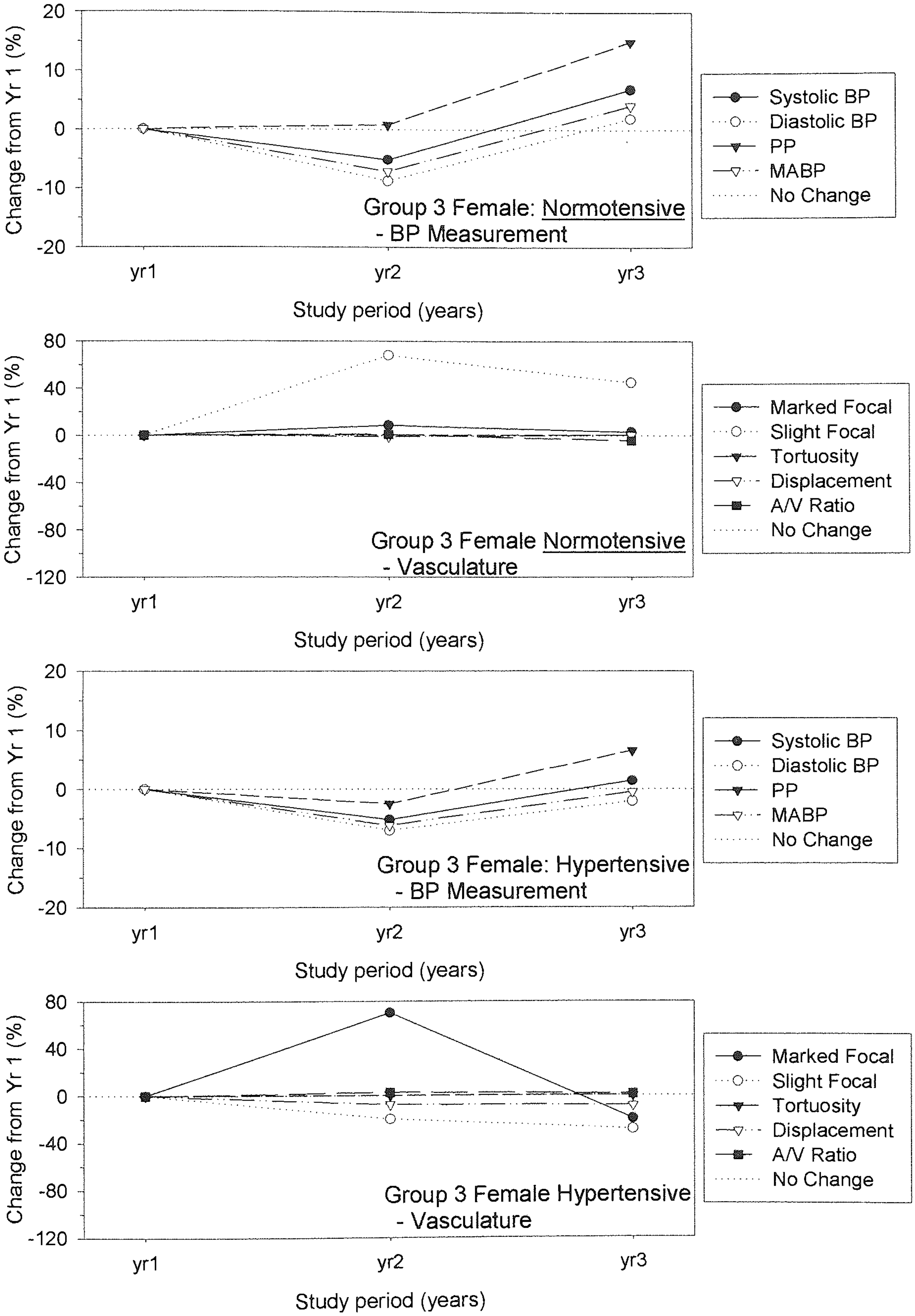


Figure 7.04: Average Blood Pressure and retinal vasculature variation over two years

– Group 3 female normotensive versus systemic hypertensive.

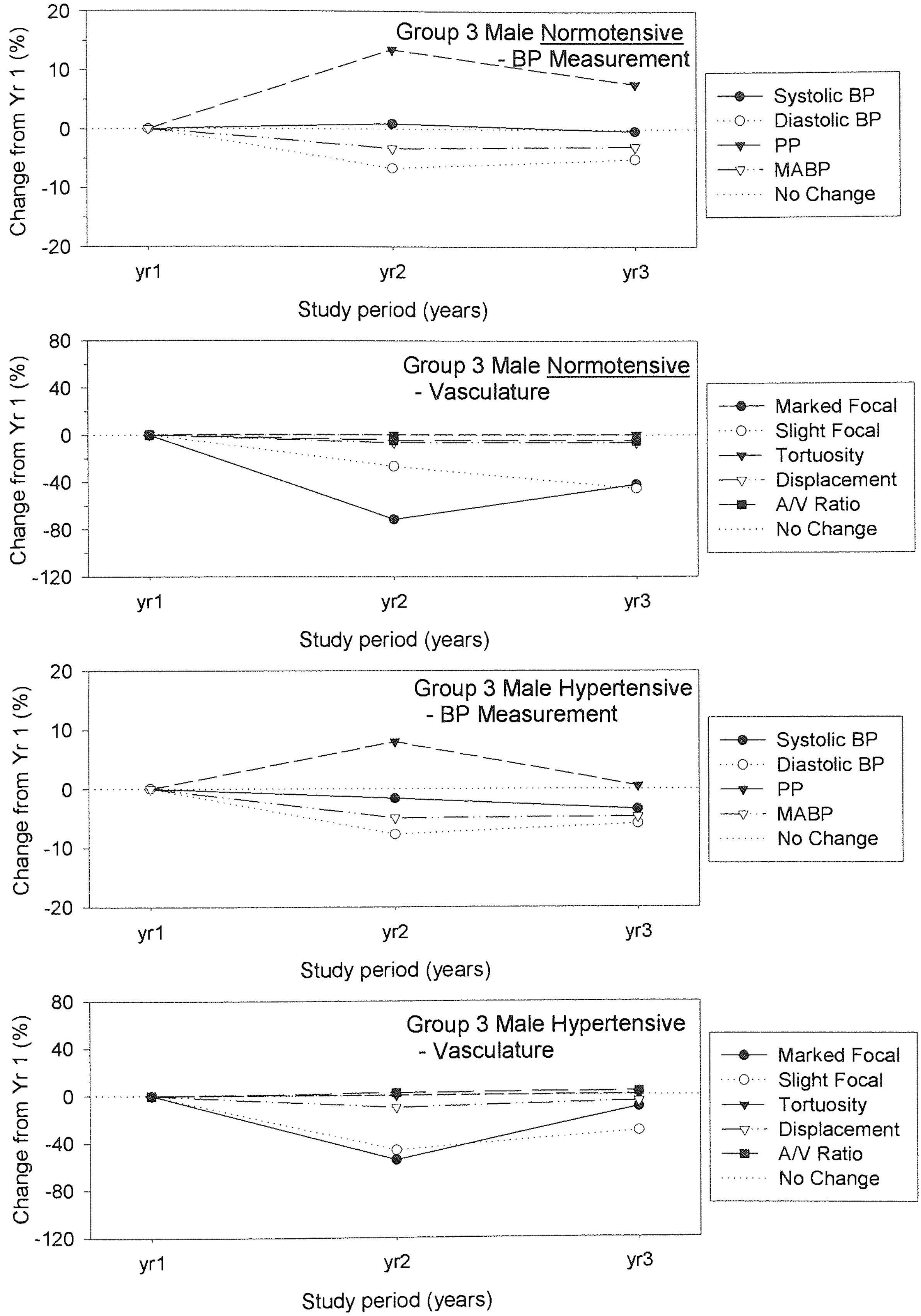


Figure 7.05: Average Blood Pressure and retinal vasculature variation over two years

– Group 3 male normotensive versus systemic hypertensive.

7.40 - Discussion

7.41 - General Health

The larger increase in medical conditions over the two years in the group 3 patients is to be expected as medical conditions increase with increasing age and BP (chapter 4). Research has shown that on average the elderly patient will be suffering from at least two chronic diseases (Rumsey, 1988). The increase in diabetes mellitus, in just the systemic hypertensives could be because they are more susceptible to disease states as their body system is compromised and that the two conditions have a common pathological pathway (Rumsey, 1988; Messerli *et al.*, 1997). The frequency of systemic hypertension amongst type II diabetics has been recorded at 40%, rising to 60% by the age of 75 (Gillow *et al.*, 1999). Diabetes affects the same target organs (brain, retina, heart and kidneys) as essential hypertension (Messerli, *et al.*, 1997). Diabetic retinopathy is accelerated in patients with co-existing systemic hypertension (Messerli *et al.*, 1997, Gillow *et al.*, 1999).

All patients were followed up over the two years, of which two developed health problems associated with systemic hypertension. Patient 1, with systemic hypertension of twenty years duration (BP at session 1: 134 / 70mmHg) had experienced a stroke 5 months before the start of research and withdrew before session 2 due to hospital tests for angina. Patient 2, had systemic hypertension for 7 years (BP at session 1: 166 / 85mmHg and session 2: 163 / 70mmHg), unfortunately experienced three strokes between session 2 and 3. Trends in the progression of systemic hypertensive retinopathy will, therefore, be reduced, as those with a more severe form are unable to attend follow up sessions.

The long term follow up of the patients indicates that even with advances in the treatment of systemic hypertension those with accelerated hypertension have a reduced survival rate. This has been calculated as 80% over 5 years (Eames *et al.,* 1995) and 48% over ten years (McGregor *et al.,* 1986). A possible explanation for this could be that the damage caused by accelerated hypertension is reduced by treatment, but not all is reversed; e.g. the retinal and optic nerve function is altered due to infarction (Talks *et al.*, 1996).

7.42 - Blood Pressure Variation

There was no significant change in the BP over the two-year session. The average BP fluctuation which would be expected over this time frame would be +0.77mmHg for systolic and +0.18mmHg for diastolic BP (Duthie, 1982). The subtle changes between years could be due to the influence of recording the BP at differing times during the day.

7.43 - Vasculature Change

The longitudinal study did not indicate any positive correlation between BP and the retinal vasculature changes, as has been previously reported (Keith *et al.*, 1939, Dodson *et al.*, 1996; Klein and Klein, 1997). In all of the patients over the two-year period no one had any malignant changes of systemic hypertension. This would, therefore, have graded all patients within group 1 and 2 of the Keith, Barker and Wagener scale (1939), even when the variation in BP between the patients indicated a wider spread of cardiovascular status: systolic BP range 96 to 208mmHg and diastolic BP 56 to 108mmHg.

The greatest vasculature variation was that of focal calibre change, with a reduction in the degree of vessel involvement. Research of subjective images over a longer time span have indicated that, arteriolar narrowing developed in 6.0% of the non-diabetic population (Klein and Klein, 1997). Data from this research finding would indicate that marked focal calibre changes were present in 55% of the eyes and slight changes present in all. There was no difference between those with systemic hypertension compared to an aged matched group of normotensives. Previous research has shown that the incidence of arteriolar narrowing was greater in those individuals with poorly controlled BP compared with normotensives; 15.2% versus 7.7% (Klein and Klein, 1997).

The longitudinal trends were influenced by the treatment of the patient with systemic hypertension. Half of those systemic hypertensive patients whose vasculature was analysed had their medication altered between years 1 and 3. One patient, who had been diagnosed with systemic hypertension (without any prescribed medication) two years before the first session was prescribed medication following correspondence with the GP after the first study visit (BP: 175/84mmHg), and subsequently had his medication adjusted again after year 2 (BP: 205/84mmHg). There were no major changes in diastolic BP over the study. Previous research has shown a reduction in hypertension related complications by treating those with a diastolic BP above 104mmHg (Veterans Administration Cooperative Study, 1967; 1970).

The retinal features examined were from a series of photographs taken over a period of two years, therefore, retinopathy associated with systemic hypertension could have been missed due to its variable progression and transient nature of appearance (Chasis, 1974;

Stokoe, 1975). Keith and co-workers (1939) acknowledged that the retina of the patient may have to be examined over several months to assign a grading and that the retinal features could be transitory (Keith *et al.*, 1939).

The poor relationship between the pre-malignant systemic hypertensive retinal changes and BP could be due to the small sample size followed over the two-year period. Research by Bechgaard and colleagues (1950) found that 33.0% (n = 485) of patients examined with systemic hypertension of more than 10 years showed no vascular changes.

7.44 - Future

Developments to the image analysis were discussed in length in chapter 3. In relation to the longitudinal follow up it is important that the software design records not only the values of vasculature changes, but also a skeletonal representation (image which only illustrates the retinal vessels), if not the actual picture to allow over-lay of the two images. This would allow differentiation of not only the vasculature, but also of any lesions. To permit overlay, comparison anchor points would have to be identified within the fundus (e.g. optic disc margin) to allow subsequent images to be laid directly on top.

Future advances in the analysis of the retinal vasculature (subjective and objective) would incorporate calculations to allow the examiner to predict the probability level that the patient is / is not suffering from systemic hypertension. Such calculations would draw on the individual grading scores from each of the retinal vasculature features examined and through previously determined weightings of each feature (dependent upon the patient's BP measurement, gender, ethnicity, medical status, etc.) to calculate the overall grade for the retinal vasculature examined.

7.50 - Conclusion

The variable progression and transient nature of the appearance of hypertensive retinopathy indicates the importance of utilizing all the available information to the primary health care practitioner in managing the systemic hypertensive patient (Chasis, 1974 and Stokoe, 1975). The progression of hypertensive retinopathy and finding associations between duration and retinal changes is similar to that of diabetic for the patient may have the condition for several years before the symptoms force the patient to seek medical help (Frant and Groen, 1950).

The retinal vasculature is relatively stable longitudinally with only minor changes in response to early disease states. This facilitates longitudinal objective studies to identify and monitor the vasculature on a yearly basis and detect subtle changes. Therefore, patient loyalty is important to allow comparison with data from the previous year's sight examination, for variation in the appearance of the patient's fundus with time is important when determining the management to be followed (Spaeth and Varma, 1987).

CHAPTER 8 - CONCLUSION

8.10 - Purpose of Research

This thesis set out to examine in detail the condition of systemic hypertension in relation to optometric practice. The methods undertaken to achieve these goals combined a literature search to discover what is already known in the area; field research examining professionals' views; measurement of BP and recording of patient demographics to determine prevalence and lifestyle influences; and analysis of the retinal vasculature to quantify the effects of systemic hypertension using subjective grading (with a new pictorial grading scale) and objective image analysis with digital funduscopy and computer algorithms.

8.20 - Background Reading

Systemic hypertension, which is asymptomatic in the early stages, is diagnosed from the BP measurement recorded by a sphygmomanometer and/or from the complications that have developed in target organs. The BP measurement does not give insight into the duration of systemic hypertension or condition of the arterial walls in the patient. The diagnosis, when based on the BP measurement alone, is determined by which side a patient lies of an arbitrary level, which is set dependent upon the treatment available and the patient's co-existing cardiovascular risk factors.

The early diagnosis and treatment of systemic hypertension is necessary to reduce the mortality from cardiovascular disease and stroke. Optometric involvement in systemic hypertension has the potential to improve detection and BP medication compliance rates, but may increase the number of patients examined suffering with retinal complications in response to arterial hypotension.

8.30 - Optometric Patient

The most frequent patient group in optometric practice was the early presbyope. The older patient, as well as being supplied with a prescription, needs to be screened for systemic medical conditions, which are more prevalent with increasing age.

Diagnosed systemic hypertension was found to be the most prevalent cardiovascular medical condition in optometric practice. The occurrence of systemic hypertension increased with age and was also found to accompany an increasing prevalence of co-existing systemic medical conditions. The inclusion of sphygmomanometry into optometric practice would see the prevalence of diagnosed systemic hypertensives rise as at least one patient each full working day would be referred for suspect systemic hypertension.

The optometrist needs to be aware of the geographic location, ethnic make up and socio-economic factors of the practice's patient basis. These demographics will influence the prevalence of medical and ocular conditions which are seen in the practice. The optometrist needs to promote a healthy lifestyle in all patients to reduce the risk of premature death from cardiovascular disease and cancer.

The optometric patient is advised to have regular eye examinations once every one to two years, whereas they tend to visit their GP on an irregular basis when they feel unwell, and will have on average a BP measurement every third visit. The wide variation between the dates of the last BP measurement (one fifth of the patients had not had a measurement in the last two years) could be reduced by the widespread use of BP monitors in the primary health care sector. The potential benefit of BP monitoring in the optometric practice is illustrated in those patients presenting with symptoms of temporary ischaemic attacks, for if left untreated one sixth of them will experience a fatal stroke at a later date.

8.40 - Optometric Opinion

The patient basis would indicate a strong requirement for BP monitoring in optometric practice, but there was a wide spread of opinion on BP measurement in optometric practice. The measurement of BP would advance the profession, being appreciated by both patients and GPs, but was felt to be an unnecessary routine procedure. One in every 8.5 optometrists stated they had a BP monitor available to use. However, even when the optometrist knew of a BP monitoring device in his/her practice, it was rarely used.

The present sight examination for the systemic hypertensive is similar to that of the normotensive patient, but may involve, when the patient informs the optometrist of his/her medical status, an altered fundus examination and a visual field test. It is, therefore, important that the optometrist is aware of the patient's full medical condition. The optometrist needs to specifically ask each patient if he/she suffers from precise medical conditions (e.g. systemic hypertension, angina) to guarantee that a complete medical history is recorded.

The finding of haemorrhages, a malignant change, was the most important criterion in determining a practitioner's referral. The pre-malignant retinal features of focal calibre changes and A/V crossings were also found to have a high bearing on the decision to refer a patient.

If BP was to be measured in practice, it was felt to be the role of the optometrist. This is surprising when optical assistants in many practices perform other additional screening tests as part of the sight examination. However, patients were happy for any member of the practice to record their BP.

Thorough training in the use and interpretation of the BP measurement in relation to the patient's medical status is warranted if optometrists are to take a more active role in BP monitoring. Continuing education in the anatomy and physiology, which is required for the clinical advancement of therapeutic drugs in optometric practice, could also encompass the cardiovascular system.

8.50 - General Practitioner Opinion

The GPs were more in favour than optometrists thought they would be on the possible future incorporation of BP measurement in optometric practice. However, discussion between the two professions is required to determine the most appropriate equipment to be used and to establish BP level referral and notification criteria. GPs were also in favour of shared care management of systemic hypertensives.

GP records indicated that those patients who have their BP monitored at the GP's surgery, mainly systemic hypertensives, are seen on a regular basis. However, nearly half of the patients, patients who are presently normotensive, did not have a review planned for BP measurement and, therefore, would benefit from the availability of additional BP measurement in optometric practice.

Patients' memory of medical data was generally poor (e.g. medication, BP measurement). Best practice should include the writing down of medical information for patients, which could then be passed onto subsequent health care practitioners.

8.60 - Subjective Grading

The present detection of systemic hypertension in optometric practice is mainly through subjective fundus examination. The incorporation of pictorial grading scale turned this task of recording the systemic hypertensive vascular changes from verbal description into a matching one. The pictorial grading scale permitted a greater differentiation of pre-malignant retinal features, than would have been possible with the Keith, Wagener and Barker scale (1939). The pictorial grading scale was shown to be accurate and reliable in the recording of a continuous variable.

The grading estimates from the fundus photographs showed that only A/V ratio had a significant correlation with systolic BP and PP. Grading estimates from fundus examination in optometric practice revealed higher grading estimates in those patients with elevated BP (with/out medication). The variation in grading was also larger in those patients with elevated BP. Normotensive patients had a lower average grading score. It was recommended that the grading scale should be redesigned into a six-point linear scale, based on computer morph images before entering optometric practice.

Comparison of the subjective with the objective grading results was hindered as the techniques varied in their methodology. Subjective gradings made in optometric practice were on average higher and had stronger correlations with BP, than those from the objective fundus photography. This could imply that it's the smaller arterioles in the macular area and the far periphery which are of importance when deciding on referring a patient for suspect systemic hypertension.

8.70 - Image Analysis

The possible future automation of the detection and monitoring of fundus vasculature change was examined through image analysis software. Vessel width was shown to decrease with increasing age. The reduction in vessel width was constant between the arterioles and venules meaning there was no significant change in the average A/V ratio. A healthy vessel was recorded as having an A/V ratio of 1:1.14 ± 0.11 (pictorial grade: 87.7%), which is less than the commonly stated value on the record card from the sight examination of 1:1.50 (pictorial grade: 66.6%). In comparison the average A/V ratio from the subjective pictorial grading was 1:1.37 (73.3 ± 14.2%). The retinal features examined through objective analysis all showed a strong correlation with BP. The temporal vessels were more tortuous and wider than their nasal counterparts.

The findings from the image analysis were not as positive as previous subjective research had shown. The subtle pre-malignant vascular changes require reliable accurate detection and analysis to assist in the management of the systemic hypertensive patient. Advances in camera resolution (both single and multiple frame photography) and associated software have the potential to surpass subjective gradings and ensure that image analysis of retinal photographs becomes an integral part of the routine sight test in the future.

The two-year longitudinal study did not indicate any positive correlation between BP and changes in the retinal vasculature with time. The advantage of image analysis over current subjective descriptive recording is the ability to precisely compare the pre-malignant hypertensive changes with previous data. The retinal vasculature is relatively stable longitudinally with only minor changes in response to early disease states. This facilitates longitudinal objective analysis to identify and monitor the vasculature to detect subtle changes.

8.80 - Conclusion

The optometrist has training in funduscopy, which can give an indication into the duration of the systemic hypertension and with additional training could take on board sphygmomanometry to determine the actual BP level. The incorporation of sphygmomanometry into the battery of pre-screening tests would assist in the screening for systemic hypertension as individually these two techniques may not reveal the true extent of the patient's medical status.

The subjective recording of retinal vasculature features associated with systemic hypertension can be improved by the application of a pictorial grading scale. The increased usage of digital funduscopy over the next few years will open the way for image analysis software in monitoring eye conditions, and will make optometrists more effective in monitoring their patients longitudinally.

The importance of an optometric role in the screening for systemic hypertension can be summed up by one 77 year-old patient's comment after being told that his BP reading was a little on the high side (179 / 89mmHg): "I haven't seen my GP for four and half years, as I did not want to waste his time".

REFERENCES

Akita, K. and Kuga, H. (1982). A computer method of understanding ocular fundus images. *Patt. Recog. Soc.* **15**, 431-443.

Anderson, J. S., Davies, I. P., Kruse, A., Lofstom, T. and Ringmann, L. A. (1996). Handbook of contact lens management, Vistakon, Jacksonville, Fl, USA.

Andreoli, K. G., Fowkes, V. K., Zipes, D. P. and Wallace, A. G. (1983). Comprehensive Cardiac Care. 5th Edition. *C. V. Mosby Co.* 53-65.

Artigao, L. M., Llavador, J. J., Puras, A., Lopez, A. J., Rubio, M. M., Torres, C., Vidal, A., Sanchis, C., Divison, J. A., Naharro, F., Caldevilla, D. and Fuentes, G. (2000). Evaluation and validation of Omron Hem 705CP and Hem 706/711 monitors for self measurement of blood pressure. *Aten. Primaria.* **25**, 96-102.

Ashton, N. (1972). The eye in malignant hypertension. *Trans. Am. Acad. Ophthal. Otolar.* **76**, 17-40.

Aspinall, P. A. (1974). Inter-eye comparison on the 100 hue test. *Acta Ophthalmologica..* **52**, 307-316.

Aurell, E. and Tibblin, G. (1965). Hypertensive eye-ground changes in a Swedish population of middle-aged men. *Acta Ophthalmologica..* **43**, 355-361.

Augsburger, A. R. and Good, G. W. (1986). Hypertension: an optometric problem for the 80s. *J. Am. Optom. Assoc.* **57**, 355-359.

Avetisov, E. S. and Savitskaya, M. B. (1977). Some features of ocular microcirculation in myopia. *Ann Ophthalmol.* **9**, 1261-1264.

Aylett, M., Marples, G. and Jones, K. (1999). Home blood pressure monitoring: its effect on the management of hypertension in general practice. *Br. J. Gen. Pract.* **49,** 725-728.

Azen, S. P., Irvine, A. R., Davis, M. D., Stern, W., Lonn, L., Hilton, G., Schwartz, A., Boone, D., Quillen-Thomas, B., Lyons, M., Lean, J. S. (1989). The validity and reliability of photographic documentation of proliferative vitreoretinopathy. *Ophthalmol.* **96**, 352-357.

Bailey, I. L., Bullimore, M. A., Raasch, T. W. and Taylor, H. R. (1991). Clinical grading and the effects of scaling. *Invest Ophthalmol. Vis. Sci.* **32**, 422-432.

Bailey, K. V. and Ferro-Luzzi, A. (1995). Use of body mass index of adults in assessing individual and community based nutritional status. *Bull. W.H.O.* **73**, 673-680.

Barnard, N. A. S., Allen, R. J. and Field, A. F. (1991). Referrals for vascular hypertension in a group of 45-64 year old patients. *Ophthal. Physiol. Opt.* **11,** 201-205.

Barnes, J., Bartley, D., Hallstrom, C., Hodgkinson, M., Jolly, H., Millington, H. and de Wardener, H. (1989) Family Healthy Encyclopaedia. 1st Edition. Quarto Publishing. London. 316-319, 322-331.

Bartlett, W. J. and Price, J. (1983). Familial retinal arteriolar tortuosity with retinal haemorrhage. *Am. J. Ophthalmol.* **95**, 556-558.

Bechgaard, P., Porsaa, K. and Vogelius, H. (1950). Ophthalmological investigations of 500 persons with hypertension of long duration. *Br. J. Ophthalmol.* **34**, 409-424.

Becker, R. A. (1981). Hypertension and arteriosclerosis. In Jaeger, E.A. and Benson, W. E., Eds. *Clinical Ophthalmology*. Philadelphia. *Harper and Row*. 1-26.

Behrendt, T. and Duane, T. D. (1966). Investigation of fundus oculi with spectral reflectance photography. *Arch. Ophthalmol.* **75**, 375-379.

Behrendt, T. and Wilson, L. A. (1965). Spectral reflectance photography of the retina. *Am. J. Ophthalmol.* **59,** 1079-1088.

Bell, E. T. (1944). *A text book of pathology*. 5th Edition. Lea and Febiger. 594-600.

Bennett, A. G. and Rabbetts, R. B. (1994). Clinical Visual Optics. 2nd Edition. Butterworth-Heinemann Ltd. Oxford. 16-19.

Black, H. R., Kuller, L. H., O'Rourke, M. F., Weber, M. A., Alderman, M. H., Benetos, A., Burnett, J., Cohn, J. N., Franklin, S. S., Mancia, G., Safar, M. and Zanchetti, A. (1999). The first report of the systolic and pulse pressure (SYPP) working group. *J. Hypertens.* **17**, (suppl 5), S3-S14.

Bland, J. M. and Altman, D.J. (1986). Regression analysis. *Lancet.* **19,** 908-909.

B. N. F. (2000). British Nuclear Formulary. 40th Edition. British Medical Association and the Royal Pharmaceutical Society of Great Britain. Cardiovascular System. 61-128.

Bracher, D. (1982) Changes in peripapillary tortuosity of the central retinal arteries in newborns *Graefe's Arch. Clin. Exp. Ophthalmol.* 218, 211-217.

Bracher, D., Dozzi, M. and Lotmar, W. (1979). Measurement of vessel width on fundus photographs. *Albrecht v. Graefes Arch. Klin. Exp. Ophthal.* **211,** 35-48.

Bradford. (2001). Digital imaging of the anterior segment. MSc Anterior eye segment – Digital image capture. 1-10.

Breslin, D. J., Gifford, R. W., Fairbairn, J. F. and Kearns, T. P. (1966). Prognostic importance of ophthalmoscopic findings in essential hypertension. *J.A.M.A.* **195**, 335-338.

Brin, B. N. and Griffin, J. R. (1995). Referrals by optometrists to ophthalmologists and other providers. *J. Am. Optom. Assoc.* **66**, 154-159.

Brinchmann-Hansen, O., Christensen, C. C. and Myhre, K. (1990). The response of the light reflex of retinal vessels to reduce blood pressure in hypertensive patients. *Acta Ophthalmologica.*. **68**, 155-161.

Brinchmann-Hansen, O. and Engvold[a], O. (1986). Microphotometry of the blood column and the light streak on retinal vessels in fundus photographs. *Acta Ophthalmologica.*. **64**, Suppl. 179, 9-19.

Brinchmann-Hansen, O. and Engvold[b], O. (1986). The light streak on retinal vessels II. A theoretical modelling of the reflex intensity. *Acta Ophthalmologica.ogica.* **64**, Suppl. 179, 46-51.

Brinchmann-Hansen, O. and Heier, H. (1986). The apparent and true width of the blood column in retinal vessels. *Acta Ophthalmologica.*. **64**, Suppl. 179, 29-132.

Brinchmann-Hansen, O., Heier, H. and Myhre, K. (1986) Fundus photography of width and intensity profiles of the blood column and the light reflex in retinal vessels. *Acta Ophthalmologica.*. **64**, Suppl. 192, 20-28.

Brinchmann-Hansen, O., Myhre, K. and Sandvik, L. (1987). The light reflex in retinal vessels and its relation to age and systemic blood pressure *Acta Ophthalmologica* **65,** 206 –212.

Brinchmann-Hansen, O. and Sandvik[a] L. (1986). The intensity of the light reflex on retinal arteries and veins. *Acta Ophthalmologica* **64**, 547-552.

Brinchmann-Hansen, O. and Sandvik[b] L. (1986). The width of the light reflex on retinal arteries and veins. *Acta Ophthalmologica* **64**, 433-438.

Broadway, D. C., Drance, S. M., Parfitt, C. M., and Mikelberg, F. S. (1998). The ability of scanning laser ophthalmoscopy to identify various glaucomatous optic disk appearances. *Am. J. Ophthalmol.* **125**, 593-604.

Bullimore, M. A. and Bailey, I. L. (1993). Considerations in the subjective assessment of cataract. *Optom. Vis. Sci.* **70**, 880-885.

Chasis, H. (1974). Appreciation of the Keith, Wagener and Barker classification of hypertensive disease. *Am. J. Med. Sci.* **268**, 347-351.

Chen, H. C., Patel, V., Wiek, J., Rassam, S. M. and Kohner, E. M. (1994). Vessel diameter changes during the cardiac cycle. *Eye.* **8**, 97-103.

Chylack, L. T., Leske, M. C., McCarthy, D., Khu, P., Kashiwagi, T. and Sperduto, R. (1989) Lens opacities classification system II (LOCS II). *Arch Ophthalmol.* **107,** 991-997.

Cogan, D. G. (1974). Ophthalmic manifestations of systemic vascular diseases. *W. B. Saunder Corp.* 74–80.

College of Optometrists (2001). Practitioner Survey results. DOCET Update. **15**, 1, 3.

Collins, R. (1994). Hypertension treatment trials: update metanalysis. *Br. Med. Bull.* **52**, 272-90.

Cornea and Contact Lens Research Unit (1997). CCLRU grading scales (appendix D). *Contact Lenses*. Eds. Philips A. J. and Speedwell, L. Butterworth-Heinemann, Oxford, UK, 863-867.

Couper, D. J., Klein, R., Hubbard, L., Wong, T. Y., Sorlie, P. D., Cooper, L. S., Brothers, R. J. and Neito, F. J. (2002). Reliability of retinal photography in the assessment of retinal microvascular characteristics: the atherosclerosis risk in communities study. *Am. J. Ophthalmol.* **133**, 78-88.

Couper, I. D. and Henbest, R. J. (1996). The quality of relationship of referral and reply letters – the effect of introducing a pro forma letter. *S. Afr. Med. J.* **86**, 1540-1542.

Crombie. M. and Button, N. F. (1995). Sphygmomanometry within optometry part 1. *Br. J. Optom. Dispens.* **3**, 124-127.

Crombie. M. and Button, N. F. (1995). Sphygmomanometry within optometry part 2. *Br. J. Optom. Dispens.* **3**, 151-154.

Crombie. M. and Button, N. F. (1995). Sphygmomanometry within optometry part 3. *Br. J. Optom. Dispens.* **4**, 20-25.

Daniels, S. R., Lipman, M. J., Burke, M. J. and Loggie, J. M. (1991). The prevalence of retinal vascular abnormalities in children and adolescents with essential hypertension. *Am. J. Ophthalmol.* **111**, 205-208.

Daubs, J. (1972). Funduscopy in the assessment of cardiovascular risk. *Opt. J. Rev. Optom.* **109,** 29-31.

Daubs, J. G. (1974). Cost efficiency of optometric screening. *Opt. J. Rev. Optom.* **111**, 9-18.

Davies, G., Sullivan, P. M., Morris, A. H., Caldwell, G. and Kohner, E. M. (1991). Retinal blood flow following a tyramine-induced increase in blood pressure. *J. Hypertens.* **9**, 425-430.

Davis, J. O., Laragh, J. H. and Selwyn, A. (1977). *Hypertension - mechanisms, diagnosis and management.* H.P. Publishing Co. Inc.

Davis, M., Hubbard, L., Trautman, J. and Klein, R. (1985). Studies of retinopathy methodology for assessment and classification with fundus photographs. *Diabetes.* **34,** Suppl. 3, 42-49.

Delori, F. C., Gragouddas, E. S., Francisco, R. and Pruett, R. C. (1977). Monochromatic ophthalmoscopy and fundus photography. I. The normal fundus. *Arch. Ophthalmol.* **95**, 861-868.

Deupree, D. M., DeLori, F. C., Feke, G. T. and Weiter, J. J. (1985). Measurement of retinal blood vessel diameter. ARVO Abstracts. *Ophthalmol. Vis. Sci.* **26** (Suppl.), 37.

Dimmitt, S. B., Eames, S. M., Goslin, P., West, J. N. W., Gibson, J. M. and Littler, W. A. (1989). Usefulness of ophthalmoscopy in mild to moderate hypertension. *Lancet.* **1**, 1103-1106.

DOCET. (2001). Practitioner Survey Results. *Update.* **15,** 1.

Dodson, P. M. and Kritzinger, E. E. (1987). Management of retinal vein occlusion. *B. M. J.* **295**, 1434-1435.

Dodson, P. M. and Kritzinger, E. E. (1997). Medical cardiovascular treatment trials: relevant to medical ophthalmology in 1997. *Eye.* **11**, 3-11.

Dodson, P. M., Lip, S. M., Gibson, J. M. and Beevers, D. G. (1996). Hypertensive retinopathy: a review of existing classification systems and a suggestion for a simplified grading system. *J. Hum. Hypertens.* **10**, 93-98.

Drance, S. M. (1977). Is ischaemia the villain in glaucomatous cupping and atrophy? In Brockhurst, R. J., Boruchoff, S. A., Hutchinson, B. T. and Lessell, S. Eds. Controversy in ophthalmology. Philadelphia. Saunders. 292-300.

Duerey, N. M., Delori, F. C. and Gragoudas, E. S. (1979). Monochromatic ophthalmoscopy and fundus photography. II. The pathological fundus. *Arch. Ophthalmol.* **97**, 288-293.

Duke-Elder, S. (1967). System of ophthalmology. *Kimpton (London).* **10**.

Dundas, M., Walker, A., and Woods, R. L. (2001). Clinical grading of corneal staining of non-contact lens wearers. *Ophthal. Physiol. Opt.* **21**, 30-35.

Eames, S. M., Beevers, D. G., and Dodson, P. M. (1995). Hypertension and the retina. In: Clinical retinopathies. Editors: Dodson, P. M., Gibson, J. M., Kritzinger E. E. London. Chapman Hall.

Eaton, A. M. and Hatchell, D. L. (1988). Measurement of retinal blood vessel width using computerized image analysis. *Invest. Ophthalmol. Vis. Sci.* **29**, 1258-1264.

Edgar, D. F. and Gilmartin, B. (1997). Ocular reactions to systemic medication. *Ophthal. Physiol. Opt.* **17**, Suppl. 2, S2-S8.

Efron, N (1999). Grading scales and morphs. *Contact Lens Complications*. Butterworth-Heinemann, Oxford, UK, 161-167.

Eger, M. J. (1982). Survey results "delegation". *J. Am. Optom. Assoc.* **53**, 367-368.

Eisenberg, J. S. (1995). Can your practice pass the six-point checkup? *Rev. Optom.* **132**, 51-54.

Elliot, R. H. (1921). The retinal pulse. *Br. J. Ophthalmol.* **5**, 481–500.

Elton, M. (2000). Central retinal vein occlusion. *Optometry Today.* **40**, 28-29.

Elwyn, H. (1954). *Diseases of the retina.* 2nd Edition. Blakiston, New York. 17.

Evelyn, K., Nicholls, J. V. V. and Turnbull, W. (1958). A method of grading and recording the retinal changes in essential hypertension. *Am. J. Ophthalmol.* **45**, 165-178.

Farnett, L., Mulrow, C. D., Linn, W. D., Lucey, C. R. and Tuley, M. R. (1991). The J-curve phenomenon and the treatment of hypertension. *J.A.M.A.* **265**, 489-495.

Field, A. E., Coakley, E. H., Must, A., Spadano, J. L., Laird, N., Dietz, W. H., Rimm, E., Colditiz, G. A. (2001). Impact of overweight on the risk of developing common chronic diseases during a 10-year period. *Arch. Intern. Med.* **161**, 1581-1586.

Fletcher, A. E. and Bulpitt, C. J., (1992), How far should blood pressure be lowered. *New Eng. J. Med.* **326**. 251-254.

Folkow, B. (1982). Physiological aspects of primary hypertension. *Physiol. Rev.* **62**, 347-504.

Frant, R.; Groen, J. (1950). Prognosis of vascular hypertension. *Arch. Intern. Med.* **85**. 727-750.

Friedman, E., Smith, T. R., Kuwabara, T. and Beyer, C. K. (1964). Choroidal vascular patterns in hypertension. *Arch. Ophthalmol.* **71**, 842-850.

Fuchs, F. D., Maestri, M. K., Bredemeier, M., Cardozo, S. E., Moreira, F. C., Wainstein, M. V., Moreira, W. D. and Moreira, L. B. (1995). Study of the usefulness of optic fundi examination of patients with hypertension in a clinic setting. *J. Hum. Hypertens.* **9**, 547-551.

Gang, L., Chutatape, O. and Krishnan, S. M. (2002). Detection and measurement of retinal vessel in fundus images using amplitude modified second-order gaussian filter. *IEEE Trans. Biomed. Eng.* **49**, 168-172.

Garston, M. J. (1975). A closer look at diagnostic drugs for optometric use. *J. Am. Optom. Assoc.* **46**, 39-43.

Geddes, L. A. and Whistler, S. J. (1978). The error in indirect blood pressure measurement with the incorrect size of cuff. *Am. Heart J.* **96**, 4-8.

General Optical Council (2002). Opticians Act 1989. The Opticians Register 2002. Antony Rowe Limited, London. xxxvi, lxxiii.

General Optical Council (2002). Report of the General Optical Council January 2001 / March 2002. General Optical Council, London. 3.

Gilchrist[a], J. (1987). Computer processing of ocular photographs – a review. *Ophthal. Physiol. Opt.* **7**, 379-386.

Gilchrist[b], J. (1987). Analysis of early diabetic retinopathy by computer processing of fundus images – a preliminary study. *Ophthal. Physiol. Opt.* **7**, 393-399.

Gillow, J. T., Gibson, J. M. and Dodson, P. M. (1999) Hypertension and diabetic retinopathy - what's the story? *Br. J. Ophthalmol.* **83**, 1083-1087.

Goldberg, I., Hollows, F. C., Kass, M. A. and Becker, B. (1981). Systemic factors in patients with low-tension glaucoma. *Br. J. Ophthalmol.* **65**, 56-62.

Goldberg, M. F., Pollack, I. P. and Green, W. R. (1972). Familial retinal arteriolar tortuosity with retinal hemorrhage. *Am. J. Ophthalmol.* **73**, 183-191.

Goldring, W. and Chasis, H., (1944). Hypertension and hypertensive disease. *Oxford University Press.*

Good, G. W. and Augsburger, A. R. (1989). Role of optometrists in combating high blood pressure. *J. Am. Optom. Assoc.* **60**, 352–355.

Gowers, W. R. (1876). The state of the arteries in bright's disease. *B. M. J.* **2**, 743-745.

Groh, M. J. M., Michelson, G., Langhans, M. J. and Harazny, J. (1995). Influence of age on retinal and optic nerve head blood circulation. *Ophthalmol.* **103**, 529-534.

Grundy, J. W. (1990), Hypertension – the facts. *Optometry Today.* **30**, 7th May, 10-14.

Guthauser, U., Flammer, J. and Mahler, F. (1988). The relationship between digital and ocular vasospasm. *Graefe's. Arch. Clin. Exp. Ophthalmol.* **226**, 224-226.

Hall, N. F., Lempert, P., Shier, R. P., Zakir, R. and Philips, D. (1999). Grading nuclear cataract: reproducibility and validity of a new method. *Br. J. Ophthalmol.* **83**, 1159-1163.

Hankey, G. J., Slattery, J. M. and Warlow, C. P. (1991). Prognosis and prognostic factors of retinal infarction: a prospective cohort study. *B. M. J.* **302**, 499-504.

Harnish, A. and Pearce, M. L. (1973). Evolution of hypertensive retinal vascular disease: correlation between clinical and post-mortem observations. *Medicine.* **52**, 483-533.

Harper, R. (1990). Optometric screening for systemic hypertension. *Optician.* 17-23.

Harris, M. G., Gan, C. M., Revelli, E. J., Imamura, C. and Kinoshita, B. (1994). Blood pressure measurement by eye care practitioners. *J. Am. Optom. Assoc.* **65**, 512-516.

Hart, W. E., Goldbaum, M., Cote, B., Kube, P. and Nelson, M. R. (1999). Measurement and classification of retinal vascular tortuosity. *Int. J. Med. Inf.* **53**, 239-252.

Hayreh, S. S. (1989). Classification of hypertensive fundus changes and their order of appearance. *Ophthalmologica* **198**, 247-260.

Hayreh, S. S. (1996). Duke-Elder Lecture: Systemic arterial blood pressure and the eye. *Eye.* **10**, 5-28.

Hayreh, S. S., Servais, G. E. and Virdi, P. S. (1989). Cotton wool spots (inner retinal ischaemic spots) in malignant hypertension. *Ophthalmologica.* **198**, 197-215.

Hayreh, S. S., Servais, G. E. and Virdi, P. S. (1986). Fundus lesions in malignant hypertension IV. Focal intraretinal periarteriolar transudates. *Ophthalmol.* **93**, 60-73.

Hayreh, S. S., Servais, G. E. and Virdi, P. S. (1986). Fundus lesions in malignant hypertension V. Hypertensive optic neuropathy. *Ophthalmol.* **93**, 74-87.

Hayreh, S. S., Servais, G. E. and Virdi, P. S. (1986). Fundus lesions in malignant hypertension VI. Hypertensive choroidopathy. *Ophthalmol.* **93**, 1383-1400.

Hayreh, S. S., Servais, G. E. and Virdi, P. S. (1989). Macular lesions in malignant arterial hypertension. *Ophthalmologica.* **198**, 230-246.

Hayreh, S. S., Zimmermann, M. B. and Podhajsky, P. (1994). Incidence of various types of retinal vein occlusion and their recurrence and demographic characteristics. *Am J. Ophthalmol.* **103**, 429-441.

Hickey, N. and Graham, I. M. (1988). Hypertension. Croom Helm, London.

Hill, D. W. and Crabtree, A. (1984). Vascular calibres. *Trans. Ophthalmol. Soc. UK.* **104**, 107.

Hill, D. W. and Dollery, C. T. (1963). Calibre changes in retinal arterioles. *Trans. Ophthalmol. Soc. UK.* **83**, 61-70.

Hodge, J. V. and Dollery, C. T. (1964). Retinal soft exudates: a clinical study by color and fluorescene photography. *Quart. J. Med.* **33**, 117-131.

Hodge, J. V., Parr, J. C. and Spears, G. F. S. (1969). Comparison of methods of measuring vessel width on retinal photographs and the effect of fluorescein injection on apparent retinal vessel calibers. *Am. J. Ophthalmol.* **68**, 1060-1069.

Hobley, A. J., Woodward, E. G. and Port, M. J. A. (1992). Retrospective study of optometric referrals. *Ophthal. Physiol. Opt.* **12**, 395-399.

Henegham, C., Flynn, J., O'Keefe, M. and Cahill, M. (2002). Characterization of changes in blood vessel width and tortuosity in retinopathy of prematurity using image analysis. *Medical Image Analysis.* **6**, 407-429.

Houben, A. J., Canoy, M. C., Paling, H. A., Derhaag, P. J. and de Leeuw, P. W. (1995). Quantitative analysis of retinal vascular changes in essential and renovascular hypertension. *J. Hypertens.* **13**, 1729-1733.

Hubbard, L. D., Brothers, R. J., King, W. N., Clegg, L. X., Klein, R., Cooper, L. S., Sharrett, A. R., Davis, M. D. and Cai, J. (1999). Methods for evaluation of retinal microvascular abnormalities associated with hypertension/sclerosis in the atherosclerosis risk in communities study. *Ophthalmol.* **106**, 2269-2280.

Hurst, J. W. (1978). The Heart - arteries and veins. *McGraw-Hill Book Co.* 226-255, 1435-1453.

Hypertension - Drug Cooperative Study Group, (1974). Effect of antihypertensive treatment on stroke recurrence. *J.A.M.A.* **229**, 409.

Kagan, A., Aurell, E., Dobree, J., Hara, K., McKendrick, C., Michaelson, I., Shaper, G., Sundaresan, T. and Tibblin, G. (1966). A note on signs in the fundus oculi and arterial hypertension: conventional assessment and significance. *Bull. W.H.O.* **34**, 955-960.

Kannel, W. B., Drawber, T. R., Kagan, A., Revotskie, N. and Stokes, J. (1961). Factors of risk in the development of coronary heart disease, six year follow-up experience. *Ann. Int. Med.* **55**, 33.

Kannel, W. B, and Sorlie, P. (1975). Hypertension in Framingham. In: Epidemiology and control of hypertension. *New York Stratton.* 553–592.

Kanski, J. J. (1995). *Clinical Ophthalmology.* 3rd Edition. Butterworth-Heinemann, Oxford, 367-370.

Kaplan, L. J. (1982). Statistics on a routine "optometric" practice. Incidence of suspected ocular disease. *Ophthalmol.*. **89**, 41A-43A.

Keith, N. M., Wagener, H. P. and Barker, N. W. (1939). Some different types of essential hypertension: their course and prognosis. *Am. J. Med. Sci.* **191**, 332-343.

Kergoat, H. and Lovaski, J. V. (1995). Response of parapapillary retinal vessels to exercise. *Optom. Vis. Sci.* **72**, 249-257.

Kirkendall, W. M., Feinleib, M., Freis, E. D. and Mark A. L. (1980). Recommendations for human blood pressure determination by sphygmomanometers. *Circulation.* **62**, 1146A-1155A.

Kishi, S., Tso, M. O. M. and Hayreh, S. S. (1985). Fundus lesions in malignant hypertension. 1. A pathologic study of experimental hypertensive choroidopathy. *Arch. Ophthalmol.* **103**, 1189-1197.

Klein, B. A. (1968). Ischemic infarcts of the choroid (elschnig spots). *Am. J. Ophthalmol.* **66**, 1069-1074.

Klein, B. E. K., Davis, M. D., Segal, P., Long, J. A., Harris, A., Haug, G. A., Magli, Y. L. and Syrjala, S. (1984). Diabetic retinopathy - assessment of severity and progression *Ophthalmol.* **91**, 10-17.

Klein, R. (1992). Retinopathy in a population-based study. *Trans. Am. Ophthalmol. Soc.* **90**, 561-594.

Klein, R., Klein, B. E. K., Moss, S. E. and Wang, Q. (1993). Blood pressure, hypertension and retinopathy in a population. *Trans. Am. Ophthalmol. Soc.* **91**, 207-222.

Klein, R., Klein, B. E. K., Moss, S. E. and Wang, Q. (1994). Hypertension and retinopathy, arteriolar narrowing, and arteriovenous nicking in a population. *Arch. Ophthalmol.* **112**, 92-98.

Klein, R., Klein, B. E. K. and Moss, S. E. (1997). The relation of systemic hypertension to changes in the retinal vasculature: the Beaver Dam Eye Study. *Trans. Am. Ophthalmol. Soc.* **95**, 329-350.

Klein, R., Klein, B. E. K., Neider, M. W., Hubbard, L. D., Meuer, S. M. and Brothers, R. J. (1985). Diabetic retinopathy as detected using ophthalmoscopy, a non-mydriatic camera and a standard fundus camera. *Ophthalmol.* **92**, 485-491.

Keinstein, R. N., Maxwell, L., Wayne, J. B. and Charles, E. D. (1982). Screening for hypertension. *J. Am. Optom. Assoc.* **53**, 379-381.

Korb, D. R. (2000). Survey of preferred tests for diagnosis of the tear film and dry eye. *Cornea* **19**, 483-6.

Krogsaa, B., Lund-Anderson, H., Parving, H-H, and Bjældager, P. (1983). The blood-retinal barrier permeability in essential hypertension. *Acta Ophthalmologica.* **61**, 541-544.

Kylstra, J. A., Wierzbicki, T., Wolbarsht, M. L., Landers III, M. B., and Stefansson, E. (1986). The relationship between retinal vessel tortuosity, diameter, and transmural pressure. *Graefe's Arch. Clin. Exp. Ophthalmol.* **224,** 477-480.

Landau, J. and Davis, E. (1957). Capillary thinning and high capillary blood pressure in hypertension. *Lancet.* **6983,** 1327-1330.

Lapuerta, P. and L'Italien, G. J. (1999). Awareness, treatment and control of systolic blood pressure in the United States. *Am. J. Hypertens.* **12**, 92A.

Lee, E. T., Rehkopf, P. G., Warnicki, J. W., Friberg, T., Finegold, D. N. and Cape, E. G. (1997). A new method for assessment of changes in retinal blood flow. *Med. Eng. Phys.* **19,** 125-130.

Lee, V. S., Kingsley, R. M., Lee, E. T., Lu, M., Russell, D., Asal, N. R., Bradford Jr, R. H. and Wilkinson, C. P. (1993). The diagnosis of diabetic retinopathy. *Ophthalmol.* **100,** 1504-1512.

Leibowitz, H. M., Krueger, D. E., Maunder, L. R., Milton, R. C., Kini, M. M., Kahn, H. A., Nickerson, R. J., Pool, J., Colton, T. L., Ganley, G. L., Loewenstein, J. I. and Dawber, T. R. (1980). The Framingham eye study monograph: An ophthalmological and epidemiological study of cataract, glaucoma, diabetic retinopathy, macular degeneration, and visual acuity in a general population of 2631 adults, 1973-1975. *Surv. Ophthalmol.* **24.** (Suppl.), 335-610.

Leishman, R. (1957). The eye in general vascular disease: hypertension and arteriosclerosis. *Br. J. Ophthalmol.* **41**, 641-701.

Lieberman, E. (1994). Paediatric hypertension: clinical perspective. *Mayo. Clin. Proc.* **69**, 1098-1107.

Linton, K. L. P., Klein, B. E. K. and Klein, R. (1991). The validity of self-reported and surrogate-reported ocular disease in the Beaver Dam Eye Study. *Am. J. Epidemiol.* **134**, 1438-1446.

Lorentzen, S. E. (1970). Incidence of spontaneous venous pulsation in the retina. *Acta Ophthalmologica.* **48**, 765-770.

Lotmar, W., Freiburghaus, A. and Bracher, D. (1979). Measurement of vessel tortuosity on fundus photographs. *Albrecht v. Graefes Arch. Klin Exp. Ophthalmol.* **211**, 49-57.

Lubianca, N. J. F, Fuchs, F. D., Gus, M., Fasolo, L., Mafessoni, R and Gleissner, A. L. (1999). Is epistaxis evidence of end organ damage in patients with hypertension? *Laryngoscope.* **109,** 1111-1115.

Majewska, K., Czechowicz-Janicka, K., Przadka, L., Piotrowicz, M. and Chrabalowski, Z. (1976). Computer data processing in the examination of retinal vessels in essential hypertension and atherosclerosis. *Ophthalmologica.* **172**, 445-448.

Mancia, G., Grassi, G., Pomidossi, G., Gregorini, L., Bertinieri, G., Parati, G., Ferrari, A. and Zanchetti, A. (1983). Effects of blood pressure measurement by the doctor on patient's blood pressure and heart rate. *Lancet.* **8352**, 695-698.

Mancia, G., Sega, R., Mileesi, C., Cesana, G. and Zanchetti. (1997). Blood pressure control in the hypertensive patient. *Lancet* **349**, 454-457.

Marshall, E. C. and Malinovsky, V. E. (1998). Hypertension and the eye: applications of the sixth report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. *J. Am. Optom. Assoc.* **69**, 281-291.

Martin, E. A. (1994). Oxford Medical Dictionary. 4th Edition. *Oxford University Press.* 321.

McCutcheon, E. P. and Rushmer, R. F. (1967). Korotkoff sounds an experimental critique. *Circ. Res.* **20**, 149-161.

McGregor, E., Isles, C., Jay, J. L., Lever, A. F. and Murray, G. D. (1986). Retinal changes in malignant hypertension. *B. M. J.* **292**, 233-234.

McMahon, T. T. and Maino, J. H. (1982). Hypertensive choroidopathy. *J. Am. Optom. Assoc.* **53**, 713-717.

Mengden, T., Hernandez Medina, R. M., Beltran, B., Alvarez, E., Kraft, K. and Vetter, H. (1998). Reliability of reporting self-measured blood pressure values by hypertensive patients. *Am. J. Hypertens.* **11**, 1413-1417.

Messerli, F. H., Grossmar, E. and Michalewicz, C. (1997). Combination therapy and target organ protection in hypertension and diabetes mellitus. *Am. J. Hypertens.* **10**, 1985-2015.

Michaelson, I. C., Eliakim, M., Avshalom, A., Medalie, J. H., Ivry, M., and Neumann, E. (1967). An approach to the investigation of the vascular changes in the fundus of the eye in hypertension and arteriosclerosis. *Acta XX Conc. Ophthalm. Germania.* **1**, 207 - 219.

Michelson, E. L., Morganroth, J., Nichols, C. W. and Mac Vaugh, III. H. (1979). Retinal arteriolar changes as an indicator of coronary artery disease. *Arch. Intern. Med.* **139**, 1139-1141.

Michelson, G. and Schmauss, B. (1995). Two dimensional mapping of the perfusion of the retina and optic nerve head. *Br. J. Ophthalmol.* **79**, 1126-1132.

Moore, T. J., Vollmer, W. M., Appel, L. J., Sacks, F. M., Svetkey, L. P., Vogt, T. M., Conlin, P. R., Simons-Morton, D. G., Carter-Edwards, L. and Harsha, D. W. (1999). Effect of dietary patterns on ambulatory blood pressure: results from the dietary approaches to stop hypertension (DASH) trial. DASH collaborative research group. *Hypertension.* **34**, 472-477.

Morse, P. H. (1968). Elschnig's spots and hypertensive choroidopathy. *Am. J. Ophthalmol.* **66,** 844-852.

National High Blood Pressure Education Program. (1997). The sixth report of the J.N.C. on prevention, detection, evaluation, and treatment of high blood pressure. Bethesda (MD): US department of health and human services. Public health service, national institutes of health, national heart, lung, and blood institute, *NIH Publication* No. 98-4080.

National Statistics. (accessed April 2003). UK population: by ethnic group: Census update. www.statistics.gov.uk/StatBase/Expodata/Spreadsheets/D6588.xls.

Newsom, R. S., Sullivan, P. M., Rassam, S. M., Jagoe, R. and Kohner, E. M. (1992). Retinal vessel measurement: comparison between observer and computer driven methods. *Graefes Arch. Clin. Exp. Ophthalmol.* **230**, 221-225.

NHS Direct Online. (accessed January 2003). Alcoholism. www.nhsdirect.nhs.uk /en.asp?TopicID=14&AreaID=3439&LinkID=2514.

Nielson, P. E., Larsen, B., Holstein, P., and Poulsen, H. L. (1983). Accuracy of blood pressure measurements in hypertensive and obese subjects. *Hypertension.* **5**, 122-127.

North, R. V. (1999). Hypertension and its effect on the eye. *CE Optometry.* **2**, 60-65.

O'Brien, E., Mee, F., Atkins, N. and Thomas, M. (1996). Evaluation of three devices for self measurement of blood pressure according to the revised British Hypertension society protocol: the Omron HEM-705CP, Philips HP5332, and Nissei DS-175. *Blood Press. Monit.* **1**, 55-61.

Parr, J. C. and Spears, G. F. S. (1974). General calibre of the retinal arteries expressed as the equivalent width of the central retinal artery. *Am. J. Ophthalmol.* **77**, 472-477.

Phillips, R., Forrester, J. and Sharp, P. (1993). Automated detection and quantification of retinal exudates. *Graefes Arch. Clin. Exp. Ophthalmol.* **231**, 90-94.

Pickering, T. G. (1994). Blood pressure measurement and detection of hypertension. *Lancet* **344**, 31-35.

Palmberg, P., Smith, M., Waltman, S., Krupin, T., Singer, P., Burgess, D., Wendtlant, T., Achtenberg, J., Cryer, P., Santiago, J., White, N., Kilo, C. and Daughaday, W. (1981). The natural history of retinopathy in insulin-dependent juvenile-onset diabetes. *Ophthalmol.* **88**, 613-618.

Pickering, T. G., James, G. D., Boddie, C., Harshfield, G. A., Blank, S. and Laragh, J. H. (1988). How common is white coat hypertension? *J.A.M.A.* **259,** 225-228.

Port, M. J. A. and Pope, C. A. (1988). Referrals and notifications by British optometrists. *Ophthal. Physiol. Opt.* **8**, 323-326.

Quigley, H. A., Reacher, M., Katz, J., Strahlman, E., Gilbert, D. and Scott, R. (1993). Quantitative grading of nerve fiber layer photographs. *Ophthalmol.* **100**, 1800-1807.

Ramalho, P. S. and Dollery, C. T. (1968). Hypertensive retinopathy. *Circulation.* **33**, 580-588.

Rassam, S. M., Patel, V., Brinchmann-Hansen, O., Engvold, O. and Kohner, E. M. (1994). Accurate vessel width measurement from fundus photographs: a new concept. *Br. J. Ophthalmol.* **78**, 24-29.

Rassam, S. M., Patel, V. and Kohner, E. M. (1993). The effect of acetazolamide on the retinal circulation. *Eye.* **7**, 697-702.

Reeves, B. C., Hill, A. R. and Aspinall, P. A. (1987). The clinical significance of change. *Ophthal. Physiol. Opt.* **7**, 441-446.

Rumsey, K. E. (1988). Common systemic diseases in geriatric patients. *Am. J. Optom. Physiol. Optics.* **65**, 308-315.

Salus, R. (1958). Diagnosis of arteriosclerosis and hypertension. *Am. J. Ophthalmol.* **45**, 81-92.

Scarpelli, P. T., Brancato, R., Merncini, U., Santoro, P. and Lamanna, S. (1977). The close interrelationship between increased vascular retinal permeability and blood pressure level. Evidence from retinal fluoroangiography. *Ophthalmologica.* **175**, 309-320.

Scheie, H. G. (1953). Evaluation of ophthalmoscopic changes of hypertension and arteriolar sclerosis. *A. M. A. Arch. Ophthalmol.* **49**, 117-138.

Schmidt, D. and Löffler, K. U. (1993). Elschnig's spots as a sign of severe hypertension. *Ophthalmologica.* **206**, 24-28.

Schubert, H. D. (1998). Ocular manifestations of systemic hypertension. *Curr. Opin. Ophthalmol.* **9**, 69-72.

Sharp, P. S., Chaturvedi, N., Wormold, R., McKeigue, P. M., Marmot, M. G. and McHardy Young, S. (1995). Hypertensive retinopathy in Afro-Caribbeans and Europeans: prevalence and risk factor relationships. *Hypertension.* **25**, 1322-1325.

Silagy, C. A. and McNeil, J. J. (1992). Epidemiologic aspects of isolated systolic hypertension and implications for future research. *Am. J. Cardiol.* **69**, 213-218.

Silverman, W. A. (1977). The lesson of retrolental fibroplasia. *Sci. Am.* **236**, 100-107.

Singh, S. D. and Williams, A. J. (1999). The prevalence and incidence of medical conditions in healthy pharmaceutical company employees who volunteer to participate in medical research. *Br. J. Clin. Pharmacol.* **48**, 25-31.

Sixth report of the J.N.C. on detection, evaluation, and treatment of high blood pressure, (1997). *Arch. Intern. Med.* **157**, 2413–2446.

Southgate, D. C. (1989). Optometric referrals, diabetic patients and pre-scribing patterns. *Clin. Exper. Optom.* **72**, 194-199.

Stanton, A. V., Mullaney, P., Mee, F., O'Brien, E. T. and O'Malley, K. (1995). A method of quantifying retinal microvascular alterations associated with blood pressure and age. *J. Hypertens.* **13**, 41-48.

Stanton, A. V., Wasan, B., Cerutti, A., Ford, S., Marsh, R., Sever, P. P., Thom, S. A. and Hughes, A. D. (1995). Vascular network changes in the retina with age and hypertension. *J. Hypertens.* **13**, 1724-1728.

Stein, M. R. and Parker, C. W. (1971). Reactions following intravenous fluorescein. *Am. J. Ophthalmol.* **72**, 861.

Streiner, D. L. and Norman, G. R. (1996). Health measurement scales: a practical guide to their development and use. Oxford Medical publications, UK.

Stokoe, N. L. (1975). Clinical assessment of the hypertensive fundus. *Trans. Ophthalmol. Soc. UK.*. **95**, 463-471.

Stokoe, N. L. and Turner, R. W. D. (1966). Normal retinal vascular patterns. *Br. J. Ophthalmol.* **50**, 21-40.

Sugiyama, T., Schwartz, B., Takamoto, T. and Azuma, I. (1999). Evaluation of the circulation in the retina, peripapillary choroid and optic disk in normal-tension glaucoma. *Ophthalmic. Res.* **32**, 79-86.

Sugiyama, T., Schwartz, B., Takamoto, T. and Azuma, I. (2000). Evaluation of the circulation in the retina, peripapillary choroid and optic disk in normal-tension glaucoma. *Ophthalmic. Res.* **32**, 79-86.

Svardsudd, K., Wedel, H., Aurell, E. and Tibblin, G. (1978). Hypertensive eye ground changes: prevalence, relation to blood pressure, and prognostic importance. *Acta Med. Scand.* **204**, 159-167.

Talks, S. J., Good, P., Clough, C. G., Beevers, D. G. and Dodson, P. M. (1996). The acute and long-term ocular effects of accelerated hypertension: a clinical and electrophysiological study. *Eye.* **120**, 321-327.

Terry, J. E. (1976). The interpretation of systemic arterial blood pressure. Part III: hypertensive retinopathy. *J. Am. Optom. Assoc.* **47**, 1521-1531.

Terry, J. E. (1976). The measurement of systemic arterial blood pressure. *J. Am. Optom. Assoc.* **47**, 571-577.

Terry, J. E. and Schoessler, O. D. (1976). Systemic arterial blood pressure and its relevance to optometric practice. *J. Am. Optom. Assoc.* **47**, 48-52.

Thomson, W. A. R. (1974). Black's medical dictionary. A and C. Black Ltd. London. 31st Edition. 26-30.

Tielsch, J. M., Katz, J., Sommer, A., Quigley, H. A. and Javitt, J. C. (1995). Hypertension, perfusion pressure, and primary open angle glaucoma. *Arch. Ophthalmol.* **113**, 216-221.

Tortora, G. J. and Anagnostakos, N. P. (1987). Principles of anatomy and physiology. Harper International edition. 5th Edition. 487-498.

Tso, M. O. M. and Jampol, L. M. (1982). Pathophysiology of hypertensive retinopathy. *Ophthalmol.* **89**, 1132-1145.

University of Wisconsin – Madison (accessed 2002). Fundus photograph reading center department of ophthalmology and visual sciences. www.eyephoto.ophth.wisc.edu/researchareas/diabetes/diabetes.html.

UK Prospective Diabetes Study Group. (1998). Tight blood pressure control and risk of macrovascular and microvascular complications in type 2 diabetes: U. K. P. D. S. 38. *B. M. J.* **317**, 703-713.

Van Buchem, F. S. P., Hemel-Aghina, J. W. M. and Henvel, J. E. A. (1964). Hypertension and changes in fundus oculi. *Acta Med. Scand.* **176**, 539.

de Venecia, G. and Jampol, L. M. (1984). The eye in accelerated hypertension. II. localized serous detachments of the retina in patients. *Arch. Ophthalmol.* **102**, 68-73.

Veterans Administration Cooperative Study Group on Antihypertensive Agents (1970). Effects of treatment on morbidity and mortality. I. Results in patients with diastolic blood pressure averaging 115 through 129 mmHg. *J.A.M.A.* **202,** 1028.

Veterans Administration Cooperative Study Group on Antihypertensive Agents (1970). Effects on treatment on morbidity in hypertension. II. Results in patients with diastolic blood pressure averaging 90 through 114 mmHg. *J.A.M.A.* **213,** 1143-1152.

Vinicor, F. (December 2002). The diabetes epidemic: Where is it going? *American Academy of Optometry, Annual Meeting, San Diego.*

Wagener, H. P., Clay, G. E. and Gipner, J. F. (1947). Classification of retinal lesions in the presence of vascular hypertension. *Trans. Am. Ophthamol. Soc.* **45**, 57-73.

Wallow, I. H., Bindley, C. D., Reboussin, D. M., Gange, S. J. and Fisher, M. R. (1993). Systemic hypertension produces pericyte changes in retinal capillaries. *Invest. Ophthalmol. Vis. Sci.* **34**, 420-430.

Walsh, J. B. (1982). Hypertensive retinopathy. description, classification, and prognosis. *Ophthalmol.* **89**, 1127-1131.

Wasloski, E. J. (1999). How to take the doubt out of blood pressure screening. *Rev. Optom.* **136**, 58-60.

Weinberger, D., Stiebel-Kalish, H., Priel, E., Barash, D., Axer-Siegel, R. and Yassur, Y. (1999). Digital red free photography for the evaluation of retinal blood vessel displacement in epiretinal membranes. *Ophthalmol.* **106**, 1380-1383.

Weinberger, M. H. (1974). Hypertension - Mechanisms, Diagnosis and Management H. P. Publishing Co. inc Eds. Davis, J. O., Laragh, J. H. and Selwyn, A.

Whittaker, K. W., Ikram, K., Anderson, D .F., Kiel, A. W. and Luff, A. J. (1999). Non – communication between ophthmologists and optometrists. *J. R. Soc. Med.* **92**, 247-248.

W.H.O. (1978). Arterial hypertension. *W. H. O. Tech. Rep. Ser.* **628**, 57.

W.H.O. (1997). Highlights on health in the United Kingdom. http://www.who.dk/ document/e62043.pdf. Accessed April 2003.

Williams, T. D. (1982). Quantification of arteriolar tortuosity in two normotensives age groups. *Am. J. Optom. Physiol. Optics.* **59**, 675-679.

Willis, C. E., Rankin, S. J. and Jackson, A. J. (2000). Glaucoma in optometric practice: a survey of optometrists. *Ophthal. Physiol. Opt.* **20**, 70-75.

Wilson, R. J. (1986). Subconjunctival hemorrhage: overview and management. *J. Am. Optom. Assoc.* **57**, 376-380.

Wise, G. N., Dollery, C. T. and Henkind, P. (1971) The retinal circulation. Harper and Row Publishers Inc., New York. First edition. 20, 34-38.

Wolf, E. (1953). Diseases of the eye. 4th Edition. Cassel, London. 78.

Wolf, S., Werner, E., Schulte, K. and Reim, M. (1998). Acute effect of metipranolol on the retinal circulation. *Br. J. Ophthalmol.* **82**, 892-896.

Wolffsohn, J. S., Napper, G. A., Ho, S-M., Jaworski, A. and Pollard, T. L. (2001) Improving the description of the retinal vasculature and patient history taking for monitoring systemic hypertension. *Ophthal. Physiol. Opt.* **21**, 441-449.

Wong, T. Y., Klein, R., Sharrett, A. R., Bruce, B. D., Couper, D. J., Tielsch, J. M., Klein, B. E. K. and Hubbard, L. D. (2002). Retinal arteriolar narrowing and risk of coronary heart disease in men and women, *J.A.M.A.* **287**, 1153-1159.

Wong, T. Y., Klein, R., Klein, B. E. K., Tielsch, J. M., Hubbard, L. and Nieto, F. J. (2001). Retinal microvascular abnormalities and their relationship with hypertension, cardiovascular disease and mortality. *Surv. Ophthalmol.* 46, 59-80.

Wood, P. (1956). Disease of the heart and circulation. 2nd Edition. Eyre and Spottiswoode, London.

World Health Organization, Guidelines Subcommittee. (1999). International society of hypertension guidelines for the management of hypertension. *J. Hypertens.* **17**, 151-183.

Wu, D. C., Schwartz, B., Schwoerer, J. and Banwatt, R. (1995). Retinal blood vessel width measured on color fundus photographs by image analysis. *Acta. Ophthalmol. Scand. Suppl.* **215**, 33-40.

Xu, H, Manivannan, A., Goatman, K. A., Liversidge, J., Sharp, P. F., Forrester, J. V. and Crane, I. J. (2002). Improved leukocyte tracking in mouse retinal and choroidal circulation. *Exp. Eye Res.* **74**, 403-410.

Yu, T., Mitchell, P., Berry, G., Weining, L. and Wang, J. J. (1998). Retinopathy in older persons without diabetes and its relationship to hypertension. *Arch. Ophthalmol.* **116**, 83-89.

APPENDIX - 1

Further Investigative Techniques Questionnaire

Personal Details

University from which you graduated:

[1] Aston [2] Bradford [3] Cardiff [4] City [5] Glasgow
[6] Ulster [7] UMIST [8] Other ___________ (zero for no reply)

Gender: male (1) / female (2) ***Years qualified:*** ____ yrs

Your main form of employment:

(i) Location: [1] Single practice
Practice with 2 <10 branches, 3 for 11-20; 4 > 20 branches
[5] Hospital
[6] University
[7] Other [8] = Unknown [9] = 2 Places [10] = several Independent

(ii) Nature: [1] Self-employed locum [2] Employee [3] Partner of practice / group
[4] Owner of practice [5] Other [6] Combination (0 for no reply)

(iii) Mode: [1] Full-time [2] Part-time

Blood Pressure Measurement

The measurement of blood pressure is a good example of an additional procedure not currently part of a standard eye examination. This section allows you to express your opinions on its value in optometric practice.

1. For the following statements, please ring the number that best represents your opinion.

Blood pressure measurement in optometric practice	Agree	Neutral	Disagree
is appreciated by patients	+3	0	-3
is unnecessary	-3	0	+3
advances the profession	+3	0	-3
is not financially viable	-3	0	+3
should be measured on-indication	+3	0	-3
is treading on GP's toes	-3	0	+3
could be performed by an optometric assistant	+3	0	-3
is unpopular because of the extra chair time	-3	0	+3
should be measured routinely	+3	0	-3
would produce results I wouldn't know how to interpret	-3	0	+3

2. When recording details on a patient's general health and medication, do you usually ask any specific questions regarding their vascular health along the lines of:

	Never		Sometimes				Always	If >40yrs	
"Have you been diagnosed with high BP?"	1	2	3	4	5	6	7	yes	no
"Do you take medication for high BP?"	1	2	3	4	5	6	7	1	0
"When did your GP last check your BP?"	1	2	3	4	5	6	7	1	0
"Do you know what the last BP reading was?"	1	2	3	4	5	6	7	1	0
"Do you have any cardiovascular disease?"	1	2	3	4	5	6	7	1	0
"Do you have raised cholesterol?"	1	2	3	4	5	6	7	1	0
Other ______________________	1	2	3	4	5	6	7	1	0

3. *Would you adapt your routine when examining a hypertensive patient?*

[0] No [1] Yes ⇒
[1/0] Direct ophthalmoscopy with a red-free filter
[1/0] Dilation
[1/0] Head mounted BIO
If yes, which <u>additional</u> procedures do you perform
[1/0] Visual field test
[1/0] Fundus lens (e.g. Volk)
[1/0] Fundus photography
[1/0] Other ________________ ____

4. *Do you have access to a blood pressure monitor in your main place of practice?*

[0] No [1] Yes ⇒
[1] Mercury column
[2] Aneroid
[3] Automated
If yes, what type of instrument is it [4] Other_ [5] Combination [6] Not Sure

How often do you use it on the following patient groups:

	Never			Sometimes			Always
all patients	1	2	3	4	5	6	7
hypertensives	1	2	3	4	5	6	7
suspect hypertensives	1	2	3	4	5	6	7
patients with headaches	1	2	3	4	5	6	7
other ________________	1	2	3	4	5	6	7

5. *How important are the following criteria in influencing your referral of a patient to their GP for suspected high blood pressure?*

	Not at all		Relatively Important			Very Important	
symptoms	1	2	3	4	5	6	7
haemorrhages	1	2	3	4	5	6	7
elevated BP	1	2	3	4	5	6	7
tortuosity	1	2	3	4	5	6	7
arterio-venous crossing changes	1	2	3	4	5	6	7
focal arteriolar constriction	1	2	3	4	5	6	7
arterio-venous ratio	1	2	3	4	5	6	7
arteriolar reflex	1	2	3	4	5	6	7

Routine pupil dilation

This section is designed to find out your opinion on the value of routine pupil dilation: note that for the purposes of this questionnaire, 'routine pupil dilation' can be defined as the use of mydriatic drops in the majority of adult patients' eye examinations.

6. *For the following statements, please ring the number that best represents your opinion.* Routine pupil dilation...

	Agree	Neutral	Disagree
is appreciated by patients	+3	0	-3
is unnecessary	-3	0	+3
advances the profession	+3	0	-3
is not financially viable	-3	0	+3
is unpopular due to light glare and drops stinging	-3	0	+3
is unpopular because of the extra chair time	-3	0	+3
protects against legal negligence claims	+3	0	-3
is unpopular because of the need to drive	-3	0	+3
improves the detection of retinal pathology	+3	0	-3
is dangerous due to inducing acute glaucoma	-3	0	+3

7. *In your estimate, what percentage of adult patients (including special groups such as those with diabetes) do you dilate?* _______% (x for no reply)

Procedures that require topical anaesthesia

Many additional ophthalmic procedures require the use of anaesthetic eye drops and direct contact with the eye: for example, Perkins' tonometry or gonioscopy. This section is designed to find out your opinions on such procedures.

8. *For the following statements, please ring the number that best represents your opinion.*

Procedures that require topical anaesthesia

	Agree	Neutral	Disagree
are appreciated by patients	+3	0	-3
are unnecessary	-3	0	+3
advance the profession	+3	0	-3
are risky due to potential epithelial abrasions or melting	-3	0	+3
are not financially viable	-3	0	+3
should be performed on-indication	+3	0	-3
are unpopular due to the drops stinging	-3	0	+3
are unpopular because of the extra chair time	-3	0	+3
should be performed routinely	+3	0	-3
are risky due to potential cross-infection	-3	0	+3

9. *Do you use any of the following direct contact instruments in practice?*

	Yes	No
applanation tonometer (e.g. Goldmann / Perkins)	[1]	[0]
ocular blood flow tonometer	[1]	[0]
gonioscope	[1]	[0]
other:______________________________	[1]	[0]

Does or would the possibility of cross infection prevent you from using contact instruments that do not have disposable tips: for example, gonioscope lenses?

Yes [1]   No [0] Not Sure [2]

Thank you for your time and co-operation

If you have any further comments on the questionnaire or the issues it examines, please make them below:

APPENDIX - 2

ASTON UNIVERSITY

NEUROSCIENCES RESEARCH INSTITUTE

INFORMATION SHEET FOR VOLUNTEER SUBJECTS

PROJECT TITLE: The Ocular Manifestations of Systemic Hypertension

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RESEARCH WORKERS:	P G Hurcomb	BSc (hons) MCOptom
	J S W Wolffsohn	BSc (hons) PhD, PGDipAdvClinOptom, FAAO, MCOptom

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The purpose of this study is to investigate the appearance and possible variations over time of blood vessels both at the back of the eye (retina) and on the white of the eye (sclera) in relation to an individual's blood pressure. Some information from your routine clinical optometric examination will be recorded and accompany a completed questionnaire on the topic of blood pressure and lifestyle. Supplementary tests of blood pressure and retinal/scleral photographs will then be taken.

This study is also looking at ways to increase the co-operation between Optometrists and General Practitioners (GP) in the management of patients with systemic hypertension (high blood pressure). For this part of the research, with your consent, we would supply your GP with the blood pressure readings taken in the clinic and a brief report on the health of your eyes from the sight test. The GP in return would be asked to answer questions regarding your blood pressure and any other information he feels is appropriate to the study.

Techniques

Patient Questionnaire – Information about the patient's general health, medication, blood pressure and lifestyle (eg diet, exercise) will be recorded.

Blood Pressure – The patient's blood pressure will be recorded twice with an automated blood pressure monitor.

Retinal / Scleral Photographs – Photographs will be taken of the back (retina) and the front (sclera) of the patient's eyes. No eye drops will be administered for this supplementary test. No adverse effects will be experienced except for a possible short-lived after image from the camera flash.

These tests should take approximately twenty minutes.
Your participation will greatly assist in the recording and monitoring of blood vessel changes due to variations in blood pressure and time. These results will assist us in making improvements in the way both Optometrists and GPs manage their patients with un/diagnosed systemic hypertension.

Important

Taking part in this study is optional and you are free to withdraw at any time. Doing so will not affect your eye-care in any way. You are encouraged to ask any questions before, during or after the study. All of the information that you provide is treated confidentially. The information is available to you, your GP and your eye care specialist. The research and ethics committees based at Aston University have approved this study.

If you have any concern about the study, please contact Dr James Wolffsohn at Aston University on 0121 359 3611 (extension 5160).

ASTON UNIVERSITY
NEUROSCIENCES RESEARCH INSTITUTE

CONSENT FORM FOR VOLUNTEER SUBJECTS

PROJECT TITLE: The Ocular Manifestations of Systemic Hypertension

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RESEARCH WORKERS: P G Hurcomb BSc (hons) MCOptom
J S W Wolffsohn BSc (hons) PhD, PGDipAdvClinOptom, FAAO, MCOptom

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VOLUNTEERS STATEMENT

I have read and understand the attached information sheet for participating subjects. I have had the opportunity to discuss the project with the investigators and to ask any questions.
I, ______________________________________ agree to take part in the above project and I under- stand that I am free to withdraw at any time and that doing so will not affect my medical care.

Signed: ______________________________________

Witness: ______________________________________

Dated: ______________________________________

I acknowledge that:

(a) The procedures for recording blood pressure and photographing the back of my eye have been explained to me.

(b) Findings from this study on my blood pressure and the health of my eyes can be passed onto my GP. I am happy for my GP to inform the above research workers of any relevant medical history from their records.
Volunteers who delete this point may still participate in the study.

(c) I have been informed that I am free to withdraw from the project at any time and for any reason and that this will not affect my future treatment or care.

(d) I have been informed that the confidentiality of the information I provide will be safeguarded.

(e) I am free to ask any questions at any time before, during and after the study.

(f) I have been provided with the information sheet for participating subjects.

Blood Pressure Questionnaire (Yr 1) Date: . . / . . / . .

1) Do you have any problems with your general health? No [ ] →Q2 Yes [ ] Please list:

. . . .

. . . .

2a) Do you have any of the following:		Duration	Medication
Diabetes	No / Yes →	. . . .	. . . .
Heart Disease	No / Yes →	. . . .	. . . .
Angina	No / Yes →	. . . .	. . . .
High / Low Blood Pressure	No / Yes →	. . . .	. . . .
Kidney Problems	No / Yes →	. . . .	. . . .
High Cholesterol	No / Yes →	. . . .	. . . .
Oral Contraceptives	No / Yes →	. . . .	. . . .
2b) Have you had either of the following?		(m/y)	
Heart Attack	No / Yes →	. . . /	. . . .
Stroke	No / Yes →	. . . /	. . . .

2c) Do you suffer from either of the following:			Frequency
Subconjunctival Haemorrhage	No / Yes →	Last occurrence . . . / . . .	. . . . /yr
Nose Bleeds	No / Yes →	Last occurrence . . . / . . .	. . . . /yr
		Medical assistance reqd? No / Yes	

2d) Were you a premature baby? Yes [ ] No[ ] Not Sure [ ]

3a) Have you had your blood pressure checked before? Yes [ ] → Q3b No [ ] → Q4

3b) Who has taken the reading(s)?
GP / Doctor / Nurse / Optician / Yourself / Other: . . . .

3c) When was the last reading taken?. . . . months / years ago [ ] Not Sure

3d) Were you informed of your blood pressure reading? Yes [ ] → Q3e No [ ] → Q3f

3e) Do you remember what the blood pressure reading was on that occasion?
Yes [ ] → . . . . . / . . . . .mmHg No [ ] BP Okay [ ]

3f) Do you know when the next scheduled review of your blood pressure is?
Yes [ ] → . . /52 . . /12 No (not sure) [ ] No review planned [ ]

3g) When was the last time you visited your:
Optometrist . . . .
GP . . . .

4) Certain foods / activities have an influence on your blood pressure. Please list your weekly consumption of the following:

4a) Smoking .... cigarettes/week Non Smoker [ ]

4b) Alcohol .... units/week Non Drinker [ ]

4c) Physical Activity .... hours/week None [ ]

4d) Stress - Minimal ... Extreme

Work	1	2	3	4	5	6	7	.... hrs/ wk
Home	1	2	3	4	5	6	7	

4e) Diet -

Very Poor	1	2	3	4	5	6	7	Excellent/Healthy

4f) Height: ...... ft/ins / cm

4g) Weight: ...... st / kg

Patient Details

Name:...............................

Address:...

....

Gender: M/F RC:.... Date of birth: (m/y):.... / ....

GP Name / Practice: Dr. ....

....

Routine Sight Examination Date: ... / ... / ...

Refraction R. .... VA .... IOP R. ... mmHg
L. .... L. ... mmHg

Comments:...

Supplementary Tests Date: ... / ... / ...

Blood Pressure 1: ... / ... mmHg Time: .. : .. am/pm Av: .... / ... mmHg
2: ... / ... mmHg .. : .. am/pm
3: ... / ... mmHg .. : .. am/pm

Fundus Photographs – File Number: ... / ... tif

Blood Pressure Questionnaire (Yr 2) Date: . . / . . / . .

1) Do you have any problems with your general health? No [ ] →Q2 Yes [ ] Please list:

. . . .

. . . .

2a) Do you have any of the following:		Duration	Medication
Diabetes	No / Yes →	. . . .	. . . .
Heart Disease	No / Yes →	. . . .	. . . .
Angina	No / Yes →	. . . .	. . . .
High / Low Blood Pressure	No / Yes →	. . . .	. . . .
Kidney Problems	No / Yes →	. . . .	. . . .
High Cholesterol	No / Yes →	. . . .	. . . .
Oral Contraceptives	No / Yes →	. . . .	. . . .
2b) Have you had either of the following?		(m/y)	
Heart Attack	No / Yes →	. . . /	. . . .
Stroke	No / Yes →	. . . /	. . . .

2c) Do you suffer from either of the following: Frequency

Subconjunctival Haemorrhage No / Yes → Last occurrence . . . / . . . . /yr

Nose Bleeds No / Yes → Last occurrence . . . / . . . . /yr

Medical assistance reqd? No / Yes

3a) When was the last BP reading taken? . . . . months / years ago [ ] Not Sure

3b) Were you informed of your blood pressure reading? Yes [ ] → Q3e No [ ] → Q3f

3c) Do you remember what the blood pressure reading was on that occasion?
Yes [ ] → . . . . . / . . . . .mmHg No [ ] BP Okay [ ]

3d) Do you know when the next scheduled review of your blood pressure is?
Yes [ ] → . . /52 . . /12 No (not sure) [ ] No review planned [ ]

3e) When was the last time you visited your: Optometrist . . . . . GP . . . .

I am happy to have my blood pressure checked by my GP [ ] Yes [ ] No

If my optometrist felt it was necessary, I would be happy to have my blood pressure checked at the optician's [ ] Yes [ ] No

I am happy to have my blood pressure checked, by my optometrist, as a routine part of every eye test [ ] Yes [ ] No

I am happy to have my blood pressure checked, by the optometrist's assistant, each time I have an eye test [ ] Yes [ ] No

4) Certain foods / activities have an influence on your blood pressure. Please list your weekly consumption of the following:

4a) Smoking . . . . . . .cigarettes/week Non Smoker [ ]

4b) Alcohol . . . . . . .units/week Non drinker [ ]

4c) Physical Activity . . . . . . .hours/week None [ ]

4d) Stress - Minimal							Extreme	
Work	1	2	3	4	5	6	7	. . . . hrs/ wk
Home	1	2	3	4	5	6	7	

4e) Diet -

Very Poor	1	2	3	4	5	6	7	Excellent/Healthy

4f) Height: . . . . . . ft/ins / cm

4g) Weight: . . . . . . st / kg

Patient Details

Name:. . . . .

Address:. . . . .

. . . .

Gender: M/F RC:. . . . Date of birth: . . . / . . . /19 . . .

GP Name / Practice: Dr. . . . .
. . . .

Spectacle Prescription

Date . . . . . . (yr)

Focimeter R . . . .
L . . . .

Supplementary Tests

Date: . . . / . . . / . . .

Blood Pressure 1: . . . / . . . mmHg Time: . . : . . am/pm Av: . . . ./ . . . mmHg
2: . . . / . . . mmHg . . : . . am/pm
3: . . . / . . . mmHg . . : . . am/pm

Fundus Photographs – File Number: . . . / . . . tif

Blood Pressure Questionnaire (Yr3)

Date: . . / . . / . .

Name: «FirstName» «LastName»

Address: «Address1», «Address2», «PostalCode».

Date of birth: :«DateBirth»

<Circle address correctly identified>

GP Name / Practice: Dr. «GPName»,
«GPPractice», «GPAddress1», «GPAddress2», «GPPostcode».

1a) General health/medication.

Last visit: . . . . Present: . . . .

. . . .

. . . .

. . . .

. . . .

1b) Oral Contraceptives

Last visit: . . . . Present: . . . .

2a) Have you had any of the following since our last meeting? (m/y)

Heart Attack No / Yes → . . . / . . . .

Stroke No / Yes → . . . / . . .

3a) Date of last meeting with: BP measured

GP	. . . . /	. . .months ago	Yes/No
General Practice Nurse	. . . . /	. . .months ago	Yes/No
Optician	. . . . /	. . .months ago	Yes/No

3b) Last blood pressure reading date? . . . . / . . . . . . .months ago

3c) Blood pressure reading on that occasion? . . . . / . . . .mmHg

High [ ] Okay [ ] Low [ ] Not Sure [ ] Not told [ ]

4) Lifestyle factors:

Smoking		Alcohol		Physical Activity	
. . . .c/wk [NS]	. . . .c/wk [NS]	. . . .u/wk [ND]	. . . .u/wk [ND]	. . . .hrs/wk	. . . .hrs/wk

	Stress		Diet
	Work	Home	
Last Visit	. . . . hrs/wk	. . . .	. . . .
Present	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

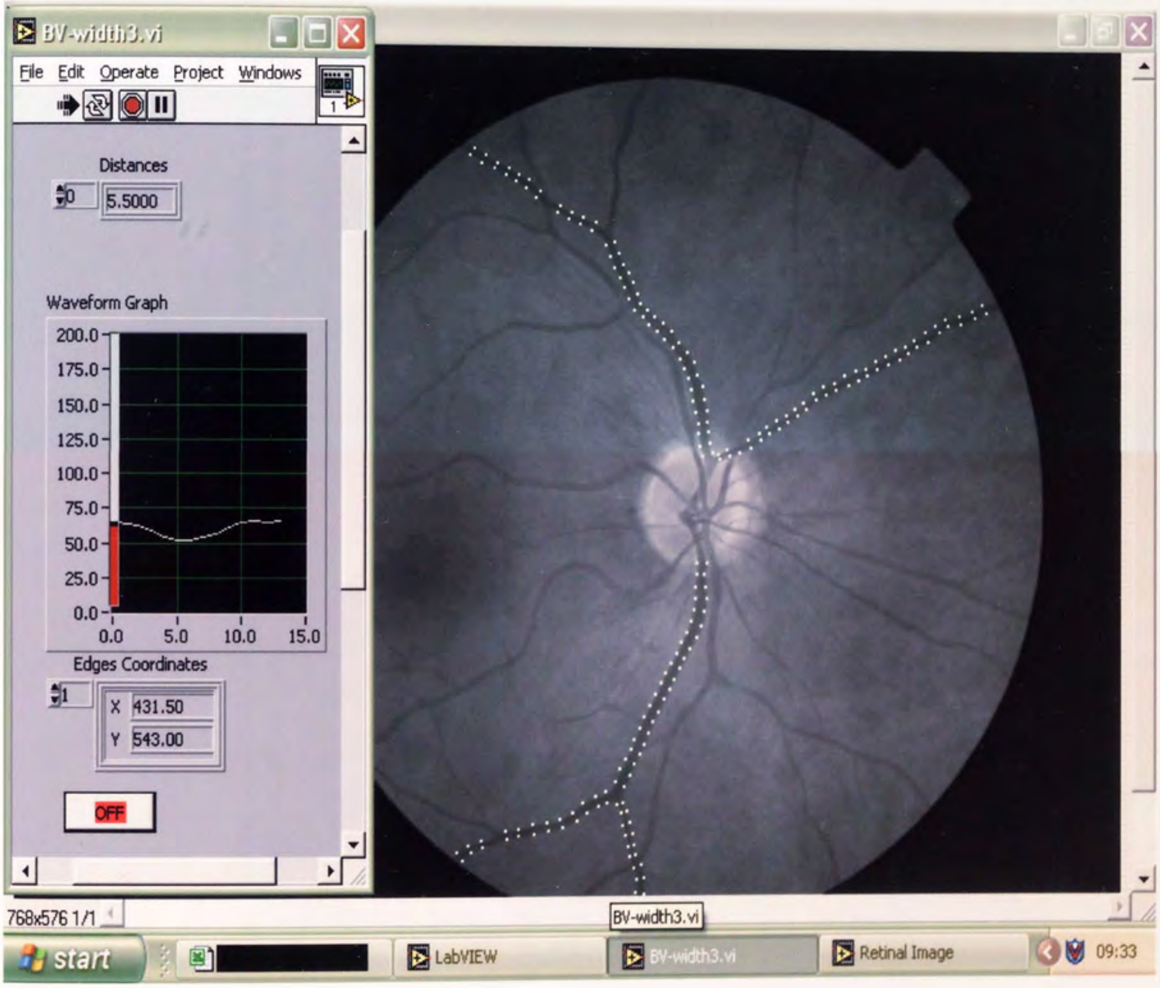
Height	. . . . . . ft/ins / cm	Weight:	. . . . . . st / kg
	. . . . . . ft/ins / cm		. . . . . . st / kg

Blood Pressure

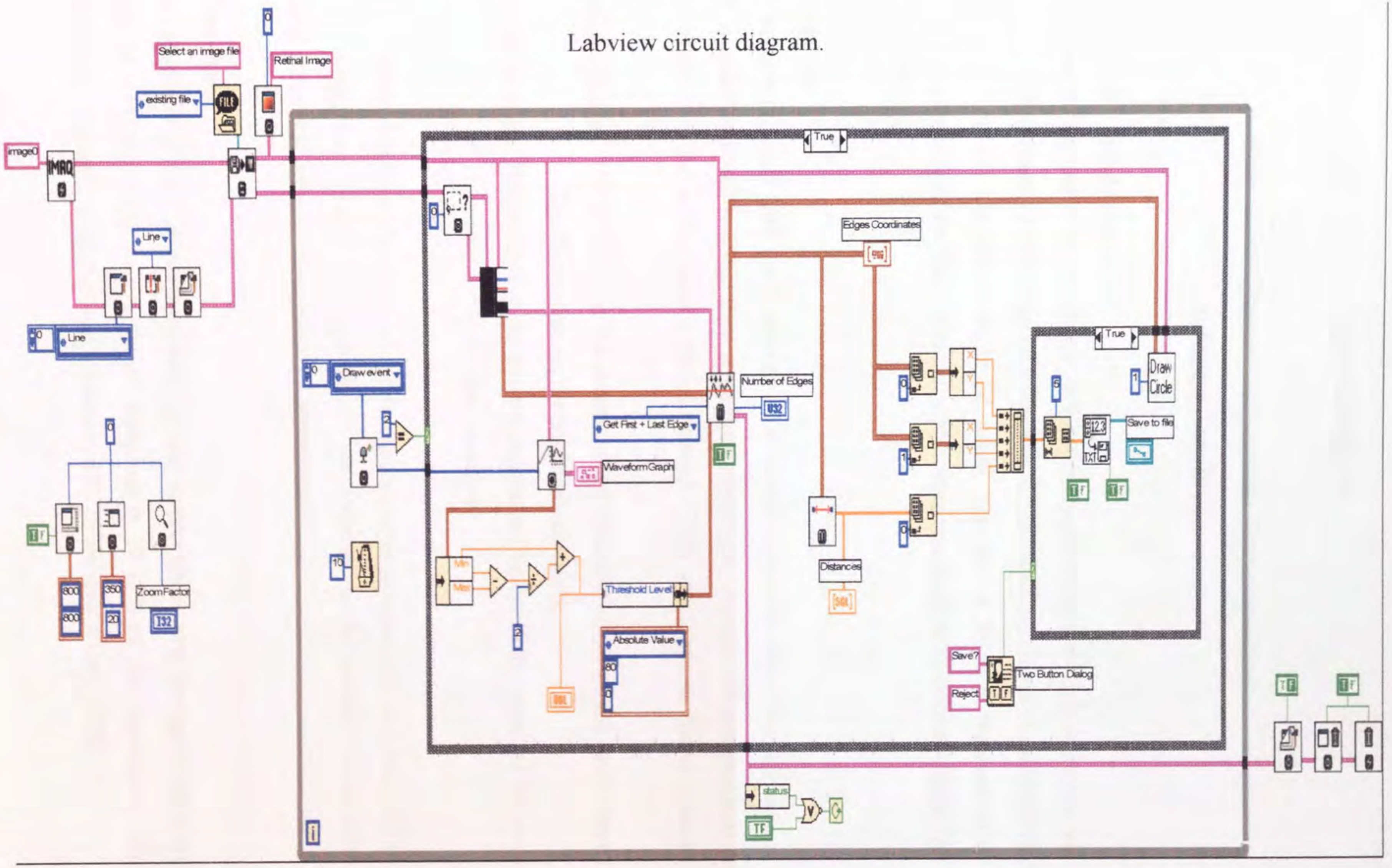
1: . . . / . . . mmHg	Time: . . : . . am/pm	Av: . . . / . . . mmHg
2: . . . / . . . mmHg	. . : . . am/pm	
3: . . . / . . . mmHg	. . : . . am/pm	

APPENDIX - 3

Screen shot of image analysis



Labview circuit diagram.



APPENDIX - 4

High Blood Pressure (Systemic Hypertension)
Information Sheet

1. What is high blood pressure?

Blood pressure maintains the circulation of blood throughout the body and is vital to life whilst high blood pressure (HBP) can be a threat to it. HBP is the persistent elevation of the arterial blood against the wall of the blood vessel. This rise in BP is in response to an increase in resistance of the blood vessels, which have narrowed or thickened obstructing the flow of blood.

2. Diagnosis

HBP is asymptomatic until the symptoms of its complications develop. The diagnosis of HBP is based upon the readings from a sphygmomanometer. Arterial BP measurement is traditionally recorded as the Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP):

Systolic Pressure: The pressure in the arteries when the contraction of the heart forces blood into them (at the height of pulsation).

Diastolic Pressure: The pressure in the arteries, maintained by the elastic recoil of the large arteries during cardiac relaxation.

Blood Pressure has been classified into groups according to measures of SBP and DBP to aid its management (Table 1). These figures are variable, as the patient's co-existing medical status will influence the clinician's management.

3. Prevalence

The occurrence of high BP increases with age and its prevalence over the age of 40 years (taken as >160/90mmHg) in the United Kingdom is 10-15% of the population. The prevalence is greater (~21%) in Afro-Caribbeans. HBP in children is rare, 1-2%.

Table 1: Blood pressure classification and management for adults (≥18 years).

Category	SBP	(mmHg)	DBP	Recommended Follow up
Optimal	<120	and	<80	
Normal	<130	and	<85	Recheck in two years
High normal	130 –139	and	85 – 89	Recheck in 1 year/provide lifestyle advice
HBP - Stage 1	140 – 159	or	90 – 99	Confirm within 2 months/ lifestyle advice
HBP - Stage 2	160 – 179	or	100 – 109	Evaluate/refer to care within 1 month
HBP - Stage 3	≥ 180	or	≥ 110	Evaluate/refer depending on clinical situation

4. Risk Factors

The major risk factors for developing HBP are: hereditary factors, organic diseases, medicines and lifestyle (weight, diet, smoking, stress, emotional strain, alcohol consumption, and exercise). HBP leads to an increased tendency to blood vessel damage, and blood clot formation that may result in heart attacks disease, stroke, or kidney damage. Morbidity can be reduced by early diagnosis and management of the hypertensive patient for the remainder of their lives. Hypotension (low BP) can also be damaging to the body, e.g. cardiovascular complications.

5. Treatment

The treatment of HBP is started after a review of the patient's BP and medical history. Treatment (non-pharmacological or pharmacological) is a life long co-operation between the patient and doctor. Non-pharmacological management of the mild hypertensive patient includes: career change (reducing stress levels / emotional tension), relaxation, weight reduction, reduction in alcohol consumption, regular mild exercise, change in diet (reduction in salt and saturated fat) and cessation of smoking. The long-term treatment of patients (<65 years old) with systemic hypertension has shown a 40% drop in strokes and 14% drop in coronary heart disease rate.

APPENDIX - 5

SUPPORTING PUBLICATIONS

Publications

Hurcomb, P.G., Wolffsohn, J.S. and Napper, G.A. (2001). Ocular signs of systemic hypertension: a review. *Ophth. Physiol. Opt.* **21**, 430-440.

Wolffsohn, J.S. and **Hurcomb, P.G.** (2002). Hypertension and the Eye. *Current Hypertension Reports.* **4**, 471-476.

Abstracts

Hurcomb, P. and Wolffsohn, J. (2002). Quantification of the normal retinal vasculature and the influence of age. *Optom. Vis. Sci.* **79**, 12s. 20.

Hurcomb, P. and Wolffsohn, J. (2003). Verification of a pictorial grading scale for pre-malignant systemic hypertensive retinopathy. *Optom. Vis. Sci.* **80**, 12s. 9.