EVALUATING AND OPTIMISING GLAUCOMA REFERRAL REFINEMENT PATHWAYS WITH SPECIFIC REFERENCE TO THE CHANGES SCHEME

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Signed Declaration

I, Gokularaj Ratnarajan, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

1 SECTION I: Overview

1.1 Abstract

Background: The Hospital Eye Service (HES) was receiving an unsustainable level of new referrals for suspected glaucoma, which was resulting in delays in clinic appointments. In an attempt to reduce the burden on the HES the concept of refining a referral from the high street optometrist was introduced. Glaucoma Referral Refinement schemes (GRRS) have proliferated across the country over the past decade, often demonstrating marked variation in pathway design, referral criteria as well as the level of specialist optometrist competency and training. Standardisation of GRRS through national policy is required.

Plan of Research: The investigations are focused around 6 parts. The first three parts address referral criteria of GRRS and the agreement between eye health professionals through a multi-site review of schemes in England. The next two parts look at the experience of care and the access to eye health in a GRRS. The last section builds upon the findings from the first three parts and focuses on safety and in particular the role of virtual review in these schemes.

Results: Specialist optometrists working within GRRS can reduce the proportion of patients discharged at the first visit in the HES. However overemphasis on intra-ocular pressure as a criterion for referral is having an adverse effect on detection of glaucomatous optic nerve features. Low-risk referrals are suitable for specialist optometrist review, with virtual review an effective extra safety measure. High-risk referrals should be reviewed directly in the HES.

Clinical Significance: GRRS is a safe and cost effective method of reviewing low-risk glaucoma referrals. This research can contribute evidence to help establish a national policy for both the referral criteria and the organisational set-up of GRRS in the UK.

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1.5 Acknowledgements

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2 SECTION II: Introduction

2.1 Glaucoma

2.1.1 Definition

Glaucoma is the name given to a group of disorders that are characterised by both optic nerve head damage and visual field loss (Hitchings, 1996). The characteristic enlargement of the optic nerve cup and visual field loss are a result of retinal ganglion cell death. The traditional triad of raised intra-ocular pressure (IOP), enlargement of the optic nerve cup and visual field loss are perceived to be the hallmark features of glaucoma.

Although raised IOP does not form part of the definition for glaucoma, a raised IOP is recognised as one of the strongest risk factors for glaucoma (Wilson and Martone, 1996). Large, population-based epidemiological studies have demonstrated the mean IOP to be 15.5mmHg with a standard deviation of 2.6mmHg (Leydhecker, 1976). Subsequently a “normal” IOP range was defined as 2 standard deviations above and below the mean, approximately 10-21mmHg. The Baltimore Eye Survey showed increased risk of glaucomatous optic nerve damage with increased IOP, particularly above 22mmHg (Sommer et al., 1991b). Despite this trend there is no IOP that can effectively be labelled as “safe” with damage occurring in some individuals with IOP as low as 12mmHg (Infeld and O'Shea, 1998).

2.1.2 Classification

Glaucoma is classified as open angle or closed angle as well as primary or secondary. Open angle glaucoma is classified as primary when no anatomically identifiable underlying cause to outflow obstruction and IOP elevation can be found. Glaucoma can be classified as secondary when there is a known abnormality and pathogenesis. It is argued that all glaucomas are in fact secondary to some abnormality, whether currently identified or not (Cioffi et al., 2010).

2.1.2.1 Primary Open Angle Glaucoma (POAG)

POAG can be further sub-divided on the basis of the untreated IOP into High Tension Glaucoma (HTG) and Normal Tension Glaucoma (NTG), with HTG being the commonest cause of glaucoma worldwide.

Prevalence varies depending on age and ethnicity. It is estimated the worldwide prevalence for POAG in those aged over 40 is 2.1% (2.1% among white Europeans, 4.2% among black Africans and 1.4% among Asians) (Rudnicka et al., 2006). The UK prevalence of POAG in those aged over 40 has been estimated at 1.2% (Tuck and Crick, 1998).

POAG is usually insidious in onset, slowly progressive and demonstrates some bilaterality. The disease is often asymptomatic until significant visual field loss has occurred as central vision is relatively unaffected until late in the disease. For a diagnosis of HTG to be given the anterior chamber angle must be open on gonioscopic examination, the IOP have exceeded 21mmHg at some point in the disease and the optic nerve have evidence of glaucomatous damage. Visual field loss does not necessarily have to be present to reach the diagnosis as evidence has demonstrated anatomical changes can occur before detectable functional changes; so called pre-perimetric glaucoma (Quigley et al., 1982, Quigley et al., 1992, Sommer et al., 1991a, Sommer et al., 1979a).

NTG is diagnosed when the untreated IOP is always below 22mmHg in the presence of an open anterior chamber angle on gonioscopic examination and evidence of glaucomatous damage to the optic nerve. Whether NTG represents a distinct disease entity from HTG is the source of considerable debate as IOP is a continuous variable with no clear division of normality from abnormality (Caprioli and Spaeth, 1984, Chumbley and Brubaker, 1976, Drance et al., 1973a, Drance et al., 1973b, Lewis et al., 1983). Most of the evidence suggests that IOP is an important risk factor for NTG (Araie et al.,

1994, Jonas et al., 1998), though evidence for the opposite argument is also present (Noureddin et al., 1991). The prevalence of NTG for those aged over 40 years is 0.2% - 0.6% (Klein et al., 1992, Bonomi et al., 1998).

2.1.2.2 Ocular Hypertension

Primary ocular hypertension (OHT) is diagnosed in the presence of an elevated IOP (normally greater than 21mmHg) but in the absence of structural and functional damage and an open angle on gonioscopy. If there is an attributable cause, either ocular or systemic, for the elevated IOP this is termed secondary OHT. The prevalence of OHT varies widely depending on ethnicity and age. Prevalence amongst Japanese over the age of 40 years is 0.9% (Iwase et al., 2004), for a predominately white Australian population over the age of 49 years it is 3.7% (Mitchell et al., 1996), whilst in an African Caribbean population over 40 years the prevalence is 12.6% (Nemesure et al., 2003). The Framingham Eye Study showed 6.2% of Caucasians under 65 years of age had an IOP greater than 21mmHg, while this increased to 8.7% for those over 75 (Leibowitz et al., 1980). OHT is a risk factor for the development of POAG, with a 10% conversion risk over ten years if untreated (Kass et al., 2002).

2.1.2.3 Angle Closure Glaucoma

Angle closure is defined by the apposition of the peripheral iris to the trabecular meshwork and the resulting reduced drainage of aqueous humour. A person with 180 degrees or more of iridotrabecular contact in primary gaze on gonioscopy is at risk of angle closure glaucoma or an acute attack of angle closure. A person with this amount of iridotrabecular contact, no peripheral anterior synechaie, and a normal IOP is considered a primary angle closure suspect (Weinreb and Friedman, 2006). It accounts for half the total prevalence of glaucoma worldwide. Primary angle closure glaucoma (PACG), which can be acute or chronic, is the commonest cause of bilateral blindness (Cioffi et al., 2010). Incidence figures are more appropriate than prevalence

for acute PACG as it often manifests with acute and transient symptoms. Prevalence is more appropriate for chronic PACG. The prevalence of PACG varies widely depending on ethnicity with an age and gender standardised values of 4.7/100 000 in Finland (Teikari et al., 1987) to 15.5/100 000 among Chinese Singaporeans (Seah et al., 1997, Wong et al., 2000).

Some of the content from 2.1.3, 2.1.4 and 2.1.5 has been adapted from Shield's Textbook of Glaucoma and its references.

2.1.3 Epidemiology of POAG

Glaucoma affects more than 67 million people worldwide, of whom 10% are estimated to be blind (Quigley, 1996). Glaucoma is the leading cause of irreversible blindness worldwide, and only cataracts are a more common cause of blindness. In excess of £300 million was spent on glaucoma in the UK in 2002 (Rouland et al., 2005). Not only are more patients being started on topical treatment at an earlier stage, but also the cost of treatment is rising. Furthermore, only 45% of the costs associated with glaucoma are direct medical costs, with 20% direct nonmedical costs and 35% indirect costs (Rouland et al., 2005).

The two most important measures of all epidemiological studies are incidence and prevalence. Incidence is the number of new cases in a given population over a specified period of time, and is derived from cohort studies, trials and disease registers. Prevalence is the number of all cases in a given population at one point in time, and this can be determined from cross-sectional studies and disease registers.

The prevalence of open-angle glaucoma varies greatly among ethnic groups (table 2-1). Prevalence amongst black populations is generally higher than whites or Hispanics (4.7% vs 1.3% and 2.0%) (Tielsch et al., 1991, Quigley et al., 2001). The reported prevalence of POAG in Asian populations varies

considerably with several studies reporting incidences comparable to white populations (1.7% in India to 2.6% in Japan) (Ramakrishnan et al., 2003, Shiose et al., 1991), whilst others have reported lower incidences (Mongolian 0.5% and Alaskan Inuit 0.1%) (Arkell et al., 1987, Foster et al., 1996).

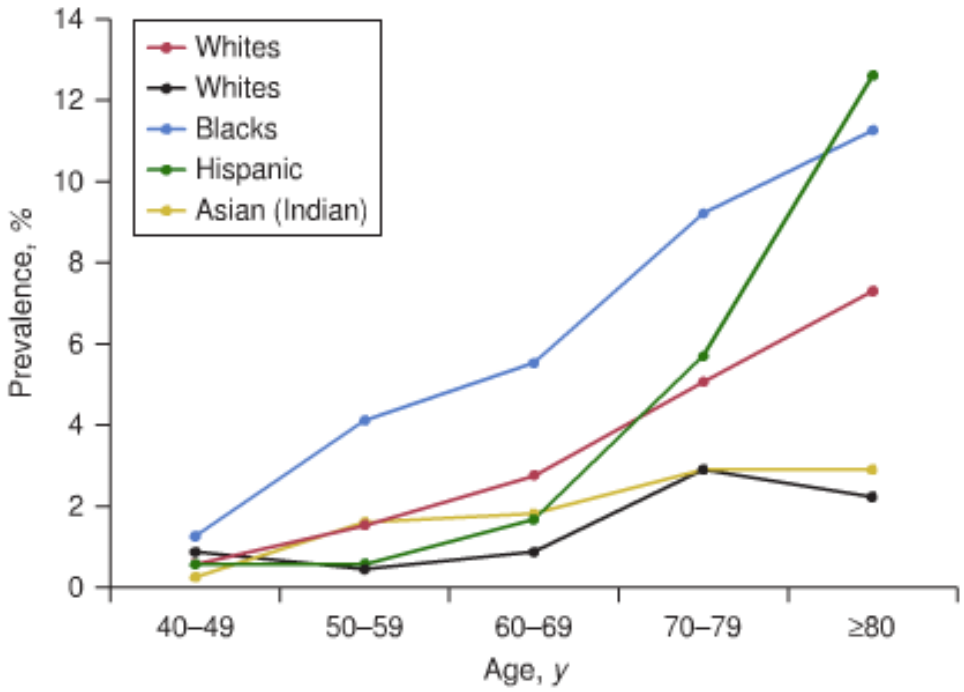
Age has an even more powerful influence (figure 2-1) and can be a useful clinical adjunct when assessing an individual's probability of POAG, especially when combined with their ethnic group; though some caution does need to be applied as the definition of glaucoma in these studies has varied considerably (Foster et al., 2002).

Table 2-1. Prevalence of open angle glaucoma in selected population-based studies
(Adapted from Shield's Textbook of Glaucoma)

Ethnic Group, Location and Year	Age Group (years)	Number of Participants	Prevalence of POAG
WHITE			
Baltimore, USA, 1991	>40	2913	1.3%
Beaver Dam, USA, 1992	43-84	4926	2.1%
Bedford, UK, 1968	>30	5941	0.7%
Blue Mountains, Australia, 1996	>49	3654	3.0%
Egna-Neumarkt, Italy, 1998	>40	5816	1.4%
Framingham, USA, 1977	52-85	2477	1.2%
Melbourne, Australia, 1998	40-98	3271	1.7%
Rhonda Valley, UK, 1966	40-74	4231	0.3%
Roscommon, Ireland, 1993	>50	2186	1.9
Rotterdam, Netherlands, 1994	>55	3062	3.1%
Reykjavik, Iceland, 2003	>50	1045	4.0%

BLACK			
Baltimore, USA, 1991	>40	2396	4.7%
Barbados, 1994	40-84	4709	6.6%
Kongwa, Tanzania, 2000	>40	3268	3.1%
St. Lucia, 1989	30-86	1679	8.8%
Temba, South Africa, 2003	>40	839	2.9%
HISPANIC			
Arizona, USA, 2001	>40	4774	2.0%
ASIAN			
Andhra Pradesh, India, 2000	>40	1399	2.6%
Japan, 1991	>40	8126	2.6%
Hovsgol, Mongolia, 1996	>40	1000	2.2%
Singapore, 2000	40-79	1717	2.4%
Tamil Nadu, India, 2003	>40	5150	1.7%

Figure 2-1. Age-specific prevalence of open angle glaucoma from selected surveys
(Adapted from Shield's Textbook of Glaucoma)



2.1.4 Risks factors for POAG and NTG

Understanding the risk factors for glaucoma is important when clinically assessing a patient and formulating risk assessment. Risk factors help identify patients at greatest risk of progressing to symptomatic glaucoma. Many of the risk factors for HTG also apply to NTG though there are certain risk factors that are more specific to NTG and therefore these will be described separately.

2.1.4.1 Risk factors for HTG

Optic Nerve Head

It can be argued that the appearance of the optic nerve head is both one of the strongest risk factors for POAG as well as a diagnostic sign. Evidence suggests a large cup:disc ratio in itself is a risk factor (Epstein et al., 1989, Schulzer et al., 1991), though some argue this merely represents undetected existing glaucomatous damage.

IOP

IOP is one of the strongest risk factors for glaucoma progression and much emphasis is placed on this measurement in the clinical assessment of patients (Gordon et al., 2002, Kass et al., 2002, Kass et al., 1989, Quigley et al., 1994). It is known that as the IOP increases the risk of POAG diagnosis also increases (Gordon et al., 2002). The Ocular Hypertension Treatment Study (OHTS) demonstrated that a reduction in IOP resulted in reduced incidence of glaucoma (Kass et al., 2002). The Early Manifest Glaucoma Trial (EMGT), the Collaborative Normal Tension Glaucoma Study Group (CNTGS) and the United Kingdom Glaucoma Treatment Study (UKGTS) highlighted that a reduction in IOP also resulted in reduced progression of glaucoma compared to no treatment (CNTGS, 1998, Heijl et al., 2002, Garway-Heath et al., 2015).

The diurnal variation, as well as the range over several days is also a risk factor (Asrani et al., 2000, Bengtsson et al., 2007, Wilensky et al., 1993).

Age

Age is known to be one of the most important risk factors for the presence and progression of POAG. The Baltimore Eye Survey found the prevalence of glaucoma increased dramatically with age, and this was more pronounced in black populations where prevalence in those aged over 80 was 11% (Tielsch et al., 1991). The Collaborative Initial Glaucoma Treatment Study (CIGTS) showed that visual field defects were 7 times more likely to develop in those aged over 60 compared to younger than 40 (Gillespie et al., 2003). The

EMGT identified the relative risk of progression of early glaucoma was 1.5 for those 68 years or older compared to those younger than 68 (Leske et al., 2003).

Race

POAG is four to six times more prevalent and develops at an earlier age in African Americans compared to Caucasians (Tielsch et al., 1991, Friedman et al., 2006, Lichter et al., 2001, Sommer et al., 1991c). A meta-analysis has confirmed the above findings, whilst also reporting Caucasians showed the steepest increase in POAG prevalence with age (Rudnicka et al., 2006). Chinese individuals have a reduced risk of progression compared to Caucasians as demonstrated in the CNTGS (Drance et al., 2001).

Family History

A family history is a known risk factor for POAG, although the exact inheritance pattern is unknown. The Glaucoma Inheritance Study in Tasmania found patients with genealogically confirmed familial POAG were significantly younger at diagnosis and had more severe disease than those with sporadic POAG (Wu et al., 2006). The Rotterdam Study found a 10-fold increase in the lifetime absolute risk of POAG at the age of 80 years in those with a positive family history of glaucoma (Wolfs et al., 1998). Likewise, the Barbados Family Study of Open-Angle Glaucoma found family history to be a major risk for POAG among black individuals (Leske et al., 2001).

Genetics

The genetics of glaucoma is complex with environmental interactions believed to play a crucial role in both its development and age of onset. However Mendelian inheritance is also observed in patients with MYOC mutations (Resch and Fautsch, 2009, Sheffield et al., 1993).

In order to develop a better understanding of the pathogenesis of all the glaucoma phenotypes a major emphasis has been placed in identifying the causative genes of inherited glaucoma. So far 15 glaucoma loci have been discovered, and can be grouped into three categories: GLC1, GLC2, and GLC3, referring to POAG, PACG, and congenital glaucoma (CG), respectively.

The causative gene at the GLC3A locus is CYP1B1, encoding a cytochrome P450 enzyme, involved in the metabolism of steroids, retinol/retinal, arachidonate, and melatonin (Stoilov et al., 1997, Vasiliou and Gonzalez, 2008). Mutations in the lysyl oxidase-like 1 (LOXL1) gene at chromosome15q22 cause exfoliative glaucoma (Thorleifsson et al., 2007). The gene underlying GLC1A is the trabecular meshwork-inducible glucocorticoid response factor (TIGR), also known as myocilin (MYOC) (Kubota et al., 1998, Stone et al., 1997). The gene underlying NTG on chromosome 10 is optineurin (OPTN) (Rezaie et al., 2002). GLC1 glaucoma results from WDR36 mutations (Monemi et al., 2005). Mutations of NTF4 (Pasutto et al., 2009) and LTBP2 (Ali et al., 2009, Moren et al., 1994, Narooie-Nejad et al., 2009) cause POAG and CG, respectively. Mutations of the PITX2 (Alward et al., 1998, Kulak et al., 1998, Semina et al., 1996) and FOXC1 (Mears et al., 1998) genes cause Axenfeld-Rieger syndrome.

Diabetes

The effect of diabetes on the development of POAG is controversial with several studies demonstrating a relationship between diabetes and POAG diagnosis and progression (Klein et al., 1994, Mitchell et al., 1997, Leske et al., 2003, 2002), although the Baltimore Eye Survey found this association weak (age-race adjusted odds ratio 1.03; 95% CI, 0.85-1.25). The OHTS suggested diabetes might actually be protective against progression from OHT to POAG (hazard ratio of 0.37 in the multivariate analysis with $p < 0.05$) (Kass et al., 1989).

Hypertension

Like diabetes the literature is divided with respect to the effect of hypertension on the development of POAG. The Blue Mountains Eye Study showed participants with POAG were more likely to have systemic hypertension compared to those without POAG (65.7%; 95% CI, 56.6-74.8 vs 45.4%; 95% CI, 43.8-47.1) (Lee et al., 2006). This association however was not observed in larger population based studies such as the Framingham Eye Study (Kahn et al., 1977). There is also epidemiological and trial evidence that the treatment for hypertension may be an important risk factor (Coleman and Miglior, 2008, De Moraes et al., 2012).

Lower perfusion pressure (blood pressure – IOP) was strongly associated with an increased prevalence of POAG, with a six fold increase for those in the lowest perfusion pressure category (Tielsch et al., 1995).

Myopia

Myopia is associated with an increased frequency of POAG and OHT, as well as an increased progression of OHT to POAG (Perkins and Phelps, 1982). POAG is found more commonly in those with a myopic refraction exceeding -6 dioptres compared to low myopia of -3 dioptres or less (Xu et al., 2007).

Pseudoexfoliation and migraine have also been reported as risk factors for glaucoma progression (Leske et al., 2003, Drance et al., 2001).

2.1.4.2 Risk factors for NTG

The clinical appearance of patients with HTG and NTG can be indistinguishable, however there is evidence to suggest that optic disc phenotypes and visual field characteristics differ (Ahrlich et al., 2010,

Broadway et al., 1999). Despite its name, a reduction of IOP reduces the risk of progression of NTG by two-thirds and implies IOP is involved in the pathogenesis. NTG and HTG are both multifactorial diseases where both IOP and non-IOP factors play a role. For NTG it seems the non-IOP factors play a relatively larger role, including some specific associations (Sommer and Tielsch, 1997).

Sleep Apnoea Syndrome

Repetitive closure of the upper airway in sleep apnoea results in hypoxia, hypercapnia and fragmented sleep. It has been postulated that this may lead to abnormal autoregulation of blood flow to the optic nerve as a result of blood gas abnormalities (Mojon et al., 1999). It has been reported the prevalence of NTG in patients with sleep apnoea is higher than controls (Mojon et al., 1999, Sergi et al., 2007), although others have found no association (Geyer et al., 2003, Girkin et al., 2006).

Blood Pressure

In the Low-pressure Glaucoma Treatment Study (LoGTS), 44.2% of the subjects were on hypertensive treatment (Krupin et al., 2005), a similar figure that was reported in other studies (Goldberg et al., 1981, Levene, 1980, Leske et al., 2007). NTG patients are reported to have lower systolic blood pressure than POAG patients (Drance et al., 1973b). In LoGTS, 17% of patients not on hypertensive treatment had a systolic pressure lower than 110mmHg and 21.7% had a diastolic pressure lower than 70mmHg (Krupin et al., 2005, De Moraes et al., 2012). This is likely to be linked to other studies associating postural and nocturnal hypotension with NTG (Hayreh et al., 1994, Meyer et al., 1996).

Migraine and Vasospasm

The reported occurrence of migraine in patients with NTG varies considerably from 37% to 4.4% (Klein et al., 1993, Krupin et al., 2005, Lewis et al., 1989, Phelps and Corbett, 1985). The association between migraine and Raynaud's disease to NTG is linked to abnormalities in blood flow caused by vasospasm or abnormal autoregulation. Endothelin-1 (ET-1) is a vascular endothelium

derived vasoconstricting peptide, which after exposure to the cold, has been reported to be raised in patients with glaucoma compared to healthy controls (Goldberg et al., 1981).

Autoimmunity

Autoantibodies to various antigens are present in higher concentrations in the sera of glaucoma patients compared to healthy controls. Antibodies to α-fodrin, heat shock proteins, phosphatidylserine and other antigens have been found in NTG (Grus et al., 2006, Kremmer et al., 2001, Wax et al., 1998). It is not known whether these autoantibodies represent a marker of injury to the optic nerve in glaucoma rather than being causative. If α-fodrin were a marker of optic nerve injury then it would be expected to be equally raised in all types of glaucoma; however it has been shown to be significantly more raised in NTG than POAG (Grus et al., 2006, Kremmer et al., 2001, Wax et al., 1998).

Optic Disc Haemorrhage

Optic disc haemorrhages are more common in NTG than other types of glaucoma, and optic disc haemorrhage is established as a risk factor (Drance et al., 2001).

2.1.5 Pathophysiology and anatomy relevant to POAG

2.1.5.1 Pathophysiology relevant to POAG

The pathogenesis of POAG is related to a disturbance of the structural or functional integrity of the eye leading to elevated IOP accompanied by progressive damage to the optic nerve and visual field loss. The main cause of elevated IOP in POAG is due to increased resistance to outflow through the trabecular meshwork (Becker, 1961, Larsson et al., 1995). Much less is known about uveoscleral outflow, though it has been demonstrated that eyes with severe glaucoma had an 80% increase of uveoscleral outflow compared to an 37% increase in contralateral eyes with less severe glaucoma. This suggests as POAG progresses there is a shift from trabecular meshwork

outflow to uveoscleral when the resistance for the former reaches a critical value (Toris et al., 2002, Yablonski et al., 1985).

Within the trabecular meshwork of glaucomatous specimens, endothelial numbers are decreased though the basement membrane is thickened, suggesting increased cellular activity (Alvarado et al., 1984). Plaques consisting of clusters of material appear in the corneoscleral beams and juxtacanalicular meshwork leading to reduced inter-trabecular spaces and narrowing of the flow pathways to the inner wall endothelium. This is age related, though also increased in eyes with POAG (Lutjen-Drecoll et al., 1986).

Alterations of the extracellular matrix components such as collagen fragmentation, altered orientation and abnormal spacing are present in specimens with POAG. Fibronectin is deposited in the sub-endothelial region of Schlemm's canal (Babizhayev and Brodskaya, 1989). In addition there is an increased expression of myocilin and αB-crystalline in the trabecular meshwork in some POAG specimens (Lutjen-Drecoll et al., 1998). In addition to the complex alterations to the trabecular meshwork described above, non-aqueous humour related factors such as diurnal variation in IOP (Liu et al., 1998, Liu et al., 1999a, Liu et al., 1999b, Liu et al., 2003) and blood pressure (Hayreh et al., 1994) are also known to be involved in the development of POAG.

2.1.5.2 Anatomy relevant to POAG

1.2 million axons of retinal ganglion cells converge at the optic disc to form the optic nerve. The distribution of these axons is important when interpreting glaucomatous visual field loss. Within the retina, fibres arising from the fovea follow a straight course to the optic nerve head, called the papillomacular bundle. Nasal retinal fibres also follow a relatively straight course to the nasal optic nerve, whereas temporal fibres follow an arcuate path around the papillomacular bundle and are the most vulnerable to glaucomatous damage.

Within the optic nerve head, fibres from the peripheral fundus lie deep within the retinal nerve fibre layer but occupy the peripheral portion of the optic nerve. In contrast fibres originating from near the optic nerve lie within the superficial portion of the nerve fibre layer but then occupy the central portion of the optic nerve (Kanski, 2003). However, Garway-Heath *et al*, demonstrated when the visual field is mapped to the optic disc in normal tension glaucoma this anatomical relationship is rather more complex (Garway-Heath et al., 2000).

As the retinal ganglion fibres bend sharply posteriorly at the optic disc they are unmyelinated and supported by astrocytes. At the periphery of the disc these fibres are covered by the internal limiting membrane of the retina but the retinal pigment epithelial cells and the choroid are absent. These fibres pass though the orifices of the lamina cribrosa and become myelinated and synapse at the lateral geniculate ganglion (Snell and Lemp, 1998).

2.1.5.3 Optic Disc Evaluation

Optic disc evaluation in glaucoma is complex. Certain characteristics are often found in glaucomatous optic disc such as progressive narrowing of the neuroretinal rim which may be a diffuse narrowing, localised notching, or both in combination (Jonas et al., 1988, Sommer et al., 1979b, Tuulonen and Airaksinen, 1991).

The cup to disc ratio alone is of limited value in glaucoma diagnosis without knowledge of the size of the disc. A cut-off CDR of 0.6 to identify discs as glaucomatous has been reported to have a sensitivity of 92% and specificity of 65% (Sommer et al., 1979b) and sensitivity of 85% and specificity of 91% (Garway-Heath et al., 1997).

As the cup enlarges in glaucoma, nasal displacement of the main disc vessels may occur. However, nasal exit is a feature of physiologically cupped discs (Armaly, 1969, Tomlinson and Phillips, 1971) and should not be regarded as acquired unless change is observed. A more specific, and early, sign of acquired cup enlargement is the bared circumlinear vessel (Herschler and Osher, 1980). Bayonetting refers to the

course of disc vessels up a steep cup slope, or undermined rim. The frequency of peripapillary atrophy increases in glaucoma compared to normal eyes (Jonas et al., 1989).

Hoyt (Hoyt et al., 1973, Hoyt and Newman, 1972) reported slit-like defects, wedge-shaped defects, and diffuse loss of the nerve fibre layer in glaucoma. Sommer (Sommer et al., 1991a) described nerve fibre layer defects up to 6 years before the onset of visual field loss in ocular hypertensive patients. The prevalence of nerve fibre layer defects in the normal population is very low, at less than 3% (Jonas and Schiro, 1994, Quigley et al., 1980). As with rim loss, the initial abnormality in glaucoma may be either diffuse thinning or localised defects (Quigley et al., 1980, Tuulonen and Airaksinen, 1991). Glaucoma suspects are more likely to have localised defects (Airaksinen et al., 1984, Quigley et al., 1980) and patients with field defects are more likely to have diffuse loss, with or without localised loss (Airaksinen et al., 1984, Tuulonen and Airaksinen, 1991).

The above features may or may not be present in a glaucomatous optic disc, and therefore the variation in the literature for inter-professional agreement between ophthalmologists, as well as between ophthalmologists and optometrists, is not surprising (Andersson et al., 2011, Kong et al., 2011, van der Schoot et al., 2013, Hadwin et al., 2013). It is also reported that quantitative imaging devices out perform clinicians at optic disc assessment (Reus et al., 2010). Agreement in optic disc assessment will be explored further in chapter 3.4.

2.2 Glaucoma Referral Pathway

2.2.1 The introduction of the NHS

During World War II the Conservative party produced the first White Paper in which it was proposed that health services would be run by local authorities (Health and Department of Health, 1944). However, after Labour's election victory in 1945, Bevan presented a radically different proposal to the Cabinet; a nationalised health service where free health care would be provided to all. After some concessions the plan was passed. The health service was almost entirely funded through central taxation with the wealthier contributing more. All persons, including temporary residents and visitors to the country were entitled to this free service. This organisation of healthcare had not been seen outside the Soviet block, with most 'western' countries favouring insurance based schemes.

Following the passing of the National Health Service Act of 1946, the National Health Service (NHS) was born on 5th July 1948. Society at this time was weary and accustomed to austerity following the efforts of World War II. Therefore the concept of free health care, including spectacles and dental treatment, was seen as a luxury and there was a concerted effort by the rich and poor alike to co-operate to help make the NHS a success.

2.2.1.1 The National Health Service Act, 1946

The National Health Service Act, 1946, is divided into 6 parts:

Part I:	Central Administration.
Part II:	Hospital and Specialist Services.
Part III:	Health Services Provided by Local Health Authorities.
Part IV:	General Medical and Dental Services, Pharmaceutical

Services and Supplementary Ophthalmic Services.

Part V: Special Provisions as to Mental Health Services.

Part VI: General

Parts I, II and IV are of most interest to the ophthalmic profession, although they are only specifically mentioned in Part IV (Scott, 1947). Further detailed guidance was given in a White Paper that was published simultaneously with the Bill (Health and Department of Health, 1946). The following extract from the White Paper describes the intention of the Minister with regard to Ophthalmic Services:

> "Eye Services
>
> 65. The Object is to secure that the care of the eyes, with sight-testing and the supply of spectacles is carried out – as rapidly as resources allow – in special ophthalmic departments and clinics forming part of the Hospital and Specialist Services. These clinics will be in the charge of the specialist medical ophthalmologists, and in them the qualified sight-testing opticians will also play their proper professional part. Spectacles will be obtainable at the clinics themselves or at the premises of dispensing opticians taking part in the service.
>
> 66. While the full eye clinic system is developing, however, a supplementary eye service is to be arranged by the Executive Councils in each area. Their arrangements are to be made with suitably qualified general medical practitioners, sight-testing opticians and dispensing opticians….
>
> 68. People will be entitled both to sight-testing and to the supply of spectacles, free of charge, either at the specialist ophthalmic clinics or through the supplementary scheme just described. The Bill provides, however, that as soon as the Minister is satisfied that adequate ophthalmic services are being provided in any area through the specialist service he may wind up the supplementary service in that area."

It is evident from the extract above it was the Minister's intention to provide all ophthalmic services under the NHS and this was to be carried out only in hospitals with eye departments and clinics. The supplementary ophthalmic services were seen only as a temporary measure during this transition.

Hospital clinics were to be run by specialist medical ophthalmologists, with ophthalmic opticians playing their “proper professional part” (Giles, 1953).

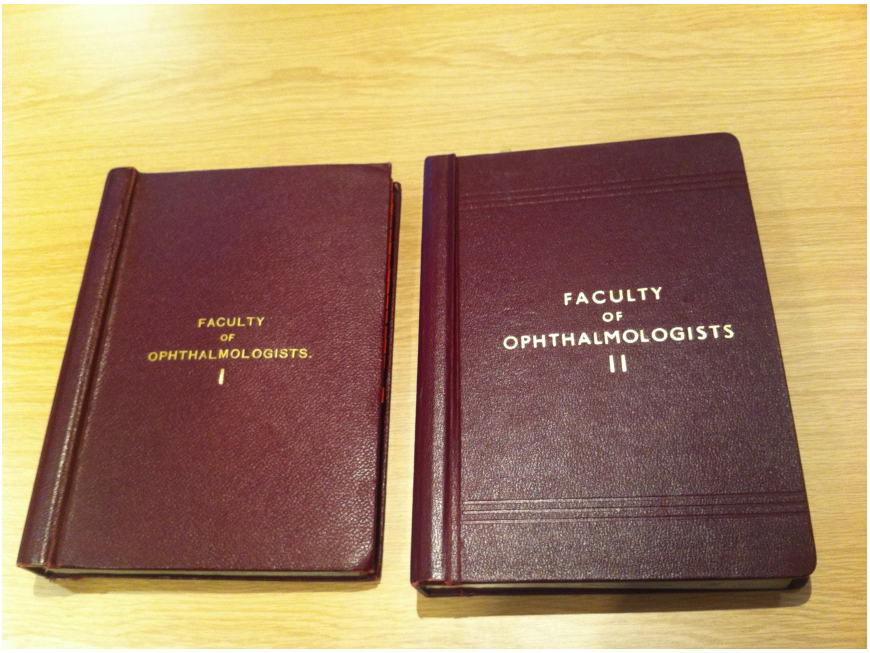
Minutes from the first Annual General Meeting of the Faculty of Ophthalmologists on the 1st June 1946 (figure 2-2) revealed a mixed reaction to the NHS Bill of 30th April 1946 (Council of Ophthalmologists, 1946). The Faculty in general welcomed the idea of opticians working under the supervision of ophthalmologists in the hospital setting and laid down three principles for which the National Eye Service should be based,

“ (a) the ultimate responsibility of the care of the eyes must rest with an ophthalmologist of full specialist status.

(b) that the Government accept the principle that qualified sight-testing opticians have a proper and full professional part to play, in association with ophthalmologists, in the work of these clinics.

(c) that no one can receive ophthalmic attention from the specialist service unless he comes in through the recommendation of the general practitioner.”

Figure 2-2. Photograph of Faculty of Ophthalmology Books kept at the Royal College of Ophthalmologists.



2.2.2 The National Health Service Act, 1951

The availability of free sight tests and spectacles for the first time resulted in extremely high usage of this service, particularly among older persons who often required two pairs of glasses. This is reflected in Ministry of Health Annual Reports (figure 2.3), where 7,000,000 lenses were supplied in England and Wales in 1949 after a total of approximately 5,500,000 sight tests. In 1950 over 8,000,000 lenses were supplied after approximately 4,500,000 sight tests. This together with the relatively expensive fees for sight testing was reflected in the high expenditure in the first 2 years of the NHS, £25.9 million in 1949 and £24.7 million in 1950 (figure 2.4). Other areas of NHS expenditure were also rising rapidly such as dentistry. Part of the rationale behind the National Health Services Act of 1951 was to try and keep total expenditure on health below £400 million. This brought significant changes to the organisation of ophthalmic services as detailed below:

> "New Arrangements for the Supply of Glasses
> 2. CHARGES – As from 21st May 1951 a person of 16 years of age and over, and a child in certain circumstances, using the supplementary ophthalmic services will be required to pay towards the cost of glasses –
>
> (i) a sum of £1 per pair (or 10s. if one lens only is supplied) and
> (ii) the whole cost of the National Health Service frames he selects for his glasses.
>
> 3. PAYMENTS BY EXECUTIVE COUNCIL AND BY PERSONS SUPPLIED.
> - For the supply of glasses following a sight test on or after 21st May –
>
> (i) The Executive Council's payment to the optician will cover only the dispensing fee and the cost of lenses less £1 per pair, or 10s. where only one lens is supplied.
> (ii) The person supplied will pay the optician the corresponding £1 per pair, on 10s. as the case may be, and the cost of the National Health Service frames he chooses for his glasses."

The effect of this Act was immediate and pronounced with the cost of the General Ophthalmic Services (GOS) in the United Kingdom reducing from

£24.7 million in 1950 to £11.1 million in 1952, of which only approximately £6 million was from public funding with the remaining £5 million from patient payments (figure 2.4). This represented a decrease in percentage of NHS funds devoted to the ophthalmic service from 5% to less than 1.5% (figure 2-5). This was largely due to the change in prescription patterns by opticians following the 1951 Act, with a dramatic reduction in the number of lenses supplied despite a relatively stable number of sight tests being carried out. In 1950 over 8,000,000 lenses were supplied after approximately 4,500,000 sight tests, whereas in 1952 approximately 3,300,000 lenses were supplied after approximately 3,700,000 sight tests (The Ophthalmic Service, 1970).

It would therefore seem that it was the cost of fully integrating the supplementary eye services into the NHS that led to its dissolution in the 1951 Act, a similar fate to that of dental services. Dentists are competent to provide virtually all medical services connected with teeth and therefore in theory are equally able to treat patients in a hospital or community based setting provided adequate instrumentation is available. However, ophthalmic opticians are primarily concerned with correcting refractive errors in vision and the provision of appliances to correct these errors. The diagnosis and treatment of eye disease is the role of medically qualified practitioners, either in general practice or in the hospital.

The NHS Act of 1951 contradicted two of the three principles stipulated by the Faculty of Ophthalmologists after the National Health Service Bill, and raised significant concern among ophthalmologists.

Minutes from the Faculty of Ophthalmologists meeting of the 29th February 1952 highlighted the divided opinion even within the Council (Council of Ophthalmologists, 1952). Three options were considered,

" (a) To approve the continuation of the Supplementary Ophthalmic Service;

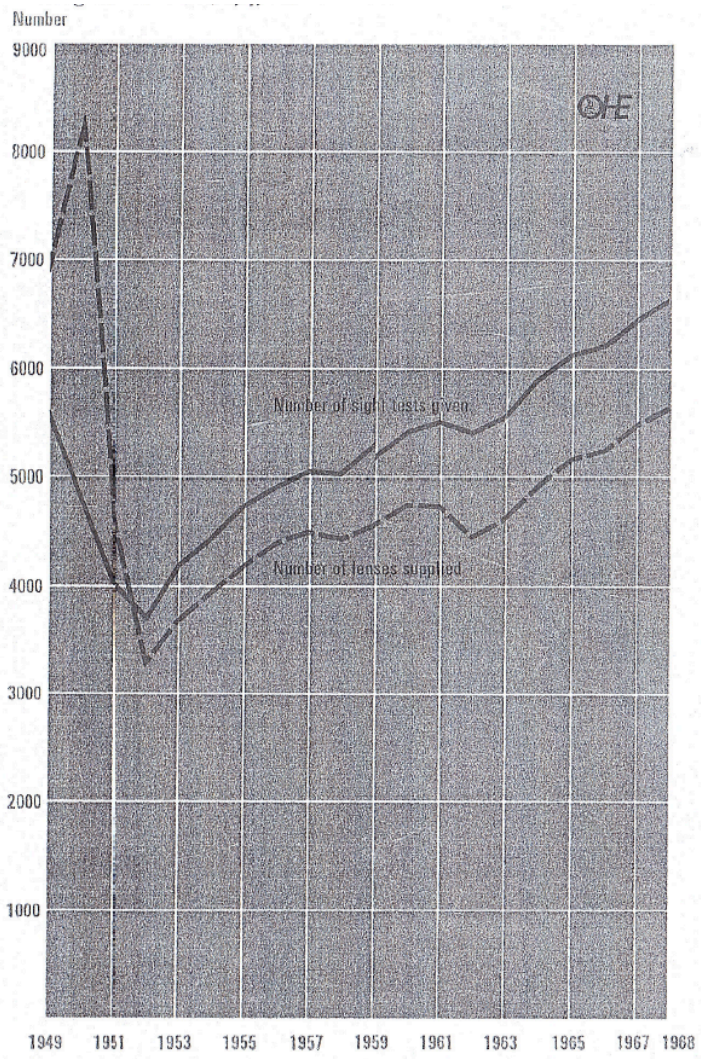
(b) To implement the Final Hospital Eye Service;

(c) To concentrate on the improvement of ophthalmological standards in this country, leaving the screening of the public to a higher grade of ophthalmic optician."

After a great deal of discussion, Sir Stewart Duke-Elder proposed and Dr Scott seconded the third option. Despite their approval, the Faculty expressed concerns whether ophthalmic opticians were fully competent to practice independent of medical control and therefore suggested this practice be reserved for low-risk individuals aged between school leaving age and the arbitrary age of 50. Every child was to have an exclusively ophthalmological service, and from age 50 onwards, all fundi, optic discs and lenses should be seen by ophthalmologists with ophthalmic opticians not to prescribe glasses for these persons.

In the majority of other medical specialities, technical and medical aspects of diagnosis and treatment are overseen by senior medical personnel, who takes ultimate responsibility for the care of the patient. Though ophthalmic opticians were not sufficiently qualified to diagnose and treat ocular disease, they played a crucial role in the opportunistic case finding of eye disease, which would have otherwise not been alerted to the attention of a medical practitioner.

Figure 2-3. Number of sight tests and number of lenses (in 1000's) supplied in England and Wales. (Adapted from The Ophthalmic Service).



Source Ministry of Health Annual Reports, various years.
Note In 1959 change in definition of number of sight tests.

Figure 2-4. Cost of the General Ophthalmic Service in the United Kingdom. (Adapted from The Ophthalmic Service).

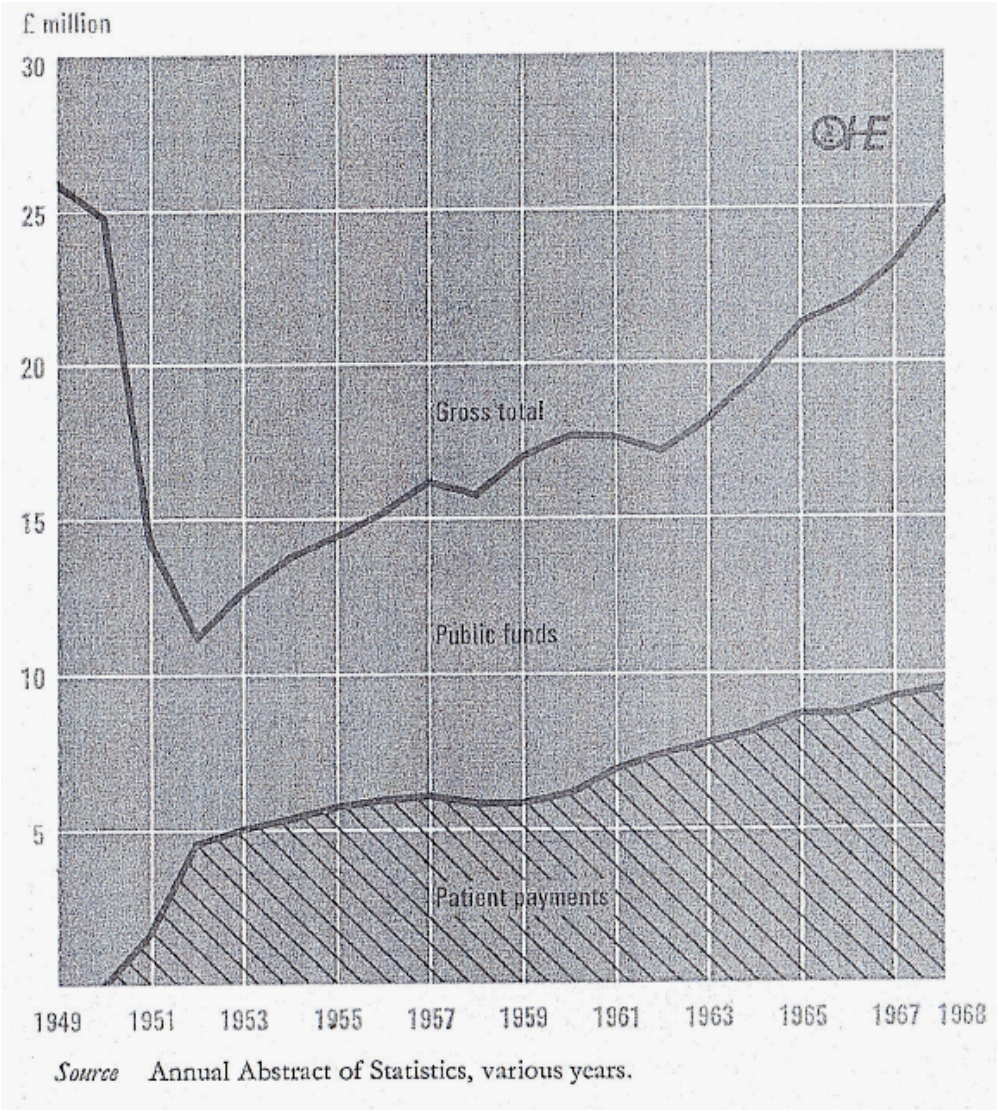
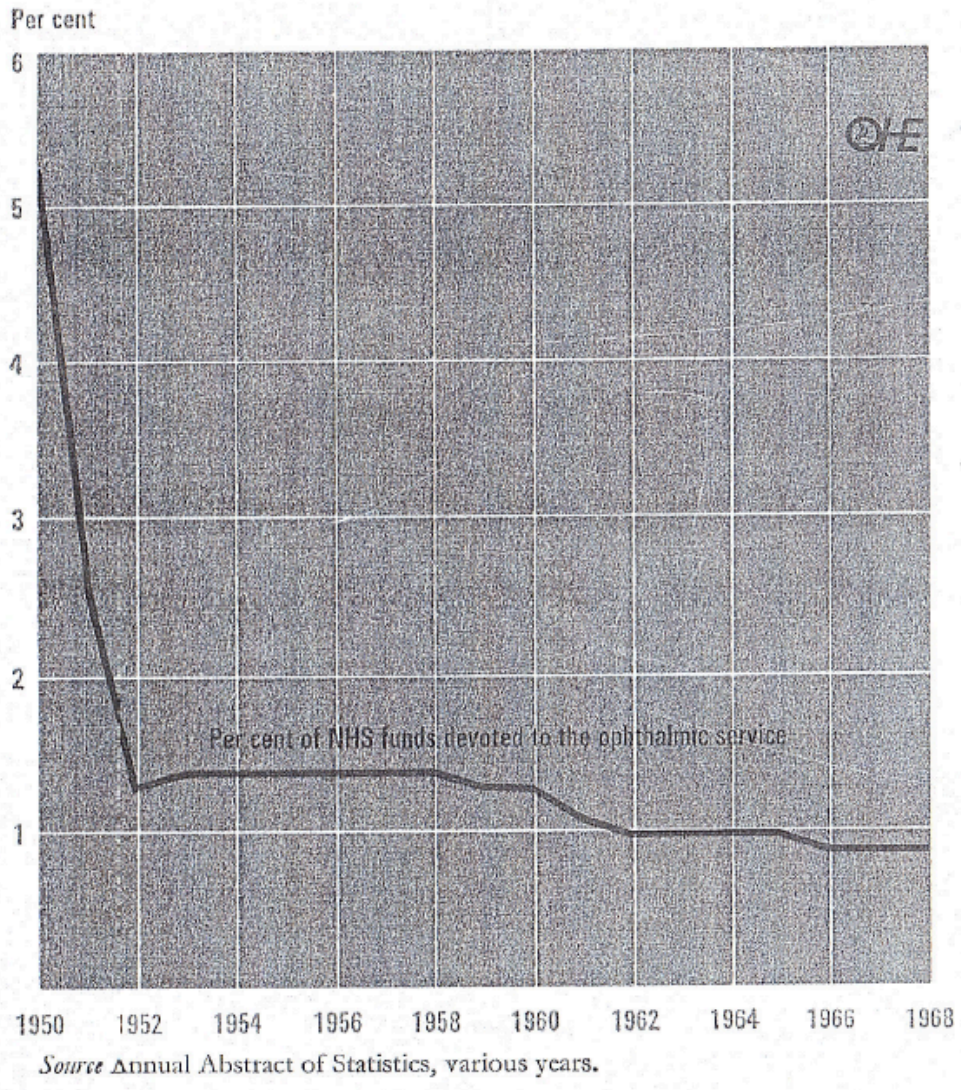


Figure 2-5. Percentage of NHS funds devoted to the ophthalmic service. (Adapted from The Ophthalmic Service).



2.2.3 Traditional Referral Pathways

After the National Health Service Act of 1951 ophthalmic opticians, or optometrists as they are now termed, would work in community practices rather than in the hospital as initially envisaged in the National Health Service Act of 1946. Optometrists perform an internal examination of the eye during all routine sight tests. If an abnormality is suspected this would be documented on a general optical services 18 form and relayed to the patients' General Practitioner (GP). The GP would then either examine the patient and offer appropriate treatment or alternatively refer the patient to an Ophthalmologist. GP's often examine for, and instigate treatment of, external eye and ocular surface pathology, however for intra-ocular pathology most GP's would refer to ophthalmologists due to the lack of appropriate instrumentation such as a slit lamp. The three largest causes for Ophthalmology referral; suspected glaucoma (20%), cataract and posterior capsule opacification (27%) and diabetic retinopathy (10%), can only be accurately diagnosed after an intra-ocular examination (Davey et al., 2011). This along with the increased sensitivity of investigations available at optometry practices such as visual field tests and optical coherence tomography have resulted in a larger proportion of referrals to the hospital eye services (HES) being instigated by optometrists (Davey et al., 2011). In 1999, direct referral by the optometrist to the HES was introduced (National Eye Care Services Steering Group, 1999), although the GP would be informed and be required to provide a medical summary for the patient. With the GP no longer necessarily acting as the "gate-keeper" for ophthalmology referrals closer communication between community optometrists and hospital-based Ophthalmologists should have been possible, a vision shared in the original National Health Service Act of 1946 and re-emphasised in the Joint Declaration by the Faculty of Ophthalmologists and the General Optical Council which was passed shortly after the Opticians Act of 1958.

2.2.4 The National Institute for Health and Clinical Excellence (NICE) guidelines and the Association of Optometrists (AOP)

The NICE guidelines for the diagnosis and management of chronic open glaucoma (COAG) and OHT were published in April 2009 (NICE, 2009a). Here it was recommended that people with COAG, suspected to have COAG or who have OHT should be offered tests and measurements including IOP, central corneal thickness (CCT), gonioscopy, visual field testing and assessment and imaging of the appearance of the optic nerve. It went on to say people at risk of developing glaucoma (irrespective of whether they are on treatment or not), should be monitored regularly using tests similar to those used to diagnose glaucoma. The frequency of these tests is determined by the risk of developing glaucoma and NICE recommends earlier consideration of alternative treatments for worsening glaucoma, such as surgery or laser treatment to avoid further disease progression.

These guidelines however did not include in their remit guidance on the detection and referral of suspected glaucoma by community optometrists. The professional representative organisation for optometry practice, the AOP, response to these guidelines was as follows:

> "English and Welsh PCTs and Health Boards may not have the resources to cope with the numbers of referrals – many of which, because they will have had their pressures taken using NCT, will be false positives. Nevertheless, in the absence of funding to repeat pressures using Goldmann, the AOP believes strongly that optometrists have no choice other than to refer a patient who has a sign of ocular hypertension – e.g. pressures measured at over 21 mmHg, using whatever tonometer they choose. To identify a sign of OHT and then not to act on it could be considered to be unprofessional, especially when the correct course of action has been well researched, by a panel of experts in the field, using evidence-based methods, and has been officially published by NICE" (Association of Optometrists, 2010).

Prior to this, an optometrist would use their clinical judgement as to whether a patient with normal ocular examination and a borderline IOP warranted referral based on other risk factors such as age and family history. However after the AOP's recommendation, all of these patients were now being referred with a resultant surge in numbers of referrals for suspected glaucoma in conjunction with an increase in patients discharged after the first visit. (Ratnarajan et al., 2012, Ratnarajan et al., 2013a, Ratnarajan et al., 2013b, Shah and Murdoch, 2011, Edgar et al., 2010).

Optometrists would argue these referrals are not "unnecessary" as their professional bodies recommend referral to the HES, and failure to comply with guidelines could result in professional misconduct charges. The literature to date often denotes these referrals as false positive, however the term "first-visit discharge proportion" is preferred in this work as it describes the outcomes of the referral in an absolute term, free from judgement.

2.2.4.1 Joint College Guidance

In December 2009, an attempt by the Royal College of Ophthalmologists and College of Optometrists to reduce the total number of referrals discharged at the first visit was made by issuing Joint College Group guidance (JCG) in relation to ocular hypertensive patients with low-risk of significant visual field loss in their lifetime. It was recommended that optometrists consider not referring patients aged over 80 years with an IOP of less than 26mmHg with an otherwise normal ocular examination. For patients aged between 65 and 80 this IOP recommendation was 25mmHg, as this subset of patients does not qualify for treatment under the current NICE guidance. For the latter group, it was recommended that these individuals be reviewed annually by a community optometrist (Royal College of Ophthalmologists and College of Optometrists, 2009).

The dissemination of referral guidelines to optometrists without specialist interest in glaucoma failed to translate into an improvement in the diagnostic yield or referral quality in a report of performance in the period before publication of the NICE guidelines (Vernon and Ghosh, 2001). This, in conjunction with large increases in the number of referrals to ophthalmology clinics after the AOP's recommendation, led to the concept of refining the quality and accuracy of the initial referral by involving an intermediary optometrist with specialist interest in glaucoma (OSI). This has the potential to improve the detection of sight-threatening glaucoma as well as lower the number of first visit discharges, with the associated reduction in costs and patient anxiety.

The most recent version of the JCG was published in March 2013 (Royal College of Ophthalmologists and College of Optometrists, 2013a) where it was recommended that repeat measurement schemes involving community optometrists should be established as a priority as it was shown they can significantly reduce false-positive referrals into the hospital eye service and are relatively easy to introduce. The JCG does however acknowledge that a referral refinement scheme can further reduce the false-positive proportion compared to a repeat measurement scheme alone. To improve the quality of referral refinement services, the College of Optometrists recommends that optometrists involved undertake a Professional Higher Certificate in Glaucoma from one of its accredited providers.

The 2013 JCG also suggests sharing the care of patients at relatively low-risk of progression between the hospital eye service and suitably trained community providers has the potential to reduce costs but acknowledges the need for shared clinical information and the appropriate information technology infrastructure.

2.2.5 Glaucoma referral refinement pathways

From April 2009, the HES were receiving unsustainable levels of new referrals for suspected glaucoma as a result of the AOP's response to the NICE glaucoma guidelines. This resulted in delays in clinic appointments for both new referrals as well as follow-up for those with established glaucoma. National Patient Safety Agency figures from June 2009 revealed that 44 patients lost part of their sight as a result of delayed follow-up appointments and a further 13 were rendered blind (National Patient Safety Agency, 2009). These cases of avoidable sight-loss, for which undoubtedly there are numerous more unreported examples, are a result both of the huge increase in referrals for suspected glaucoma as well as the inability of the hospital appointment allocation system to triage effectively the patients waiting for follow-up appointments. This situation has also lead to the Royal National Institute of Blind People (RNIB) to release a Policy Position Statement asking that NHS England, NICE, clinical commissioning groups and hospital managers to increase their respective efforts to prevent further avoidable sight-loss through delays in reviewing glaucoma patients (Royal National Institute of Blind People, 2014).

Concurrently the "Transforming Services for Acute Care Closer to Home" initiative was being implemented nationally to address the following issues (Department of Health, 2010):

- great variation in service quality and health outcomes
- activity and achievement going unmeasured
- lack of usable data, tariffs and currencies
- disparity in quality, productivity and costs
- outdated infrastructure
- access can be uncertain and confusing.

Ophthalmology, and glaucoma in particular, was highlighted as a service that has scope for more community-based assessments due to the demographics

of those mostly affected as well as the longevity of follow-up and care.

In an attempt to both reduce the burden on the HES as well as comply with "Transforming Services for Acute Care Closer to Home" initiative, the concept of refining a referral from the high street optometrist was introduced. These Glaucoma Referral Refinement schemes (GRRS) have proliferated across the country over the past decade, often demonstrating marked variation in pathway design, referral criteria as well as the level of OSI competency and training (table 2-2) (Ang et al., 2009, Bourne et al., 2010, Devarajan et al., 2011, Henson et al., 2003, Parkins and Edgar, 2011, Syam et al., 2010, Local Optical Committee Support Unit, 2012, Ratnarajan et al., 2012, Ratnarajan et al., 2013a, Ratnarajan et al., 2013b). The variation in national practice as well as the lack of national guidance results in differing levels of care provided which may impact on patient safety. This is partly addressed in the latest version of JCG (see above). However, there is a lack of good quality evidence to develop a safe and efficient model of glaucoma referral refinement that can be adopted on a national level. The work from this thesis is hoped to help inform professional bodies as well as commissioners of eye care how to optimise GRRS nationally.

Below is a summary of the leading GRRS currently in operation in the UK:

Huntingdon

The Community and Hospital Allied Network Glaucoma Evaluation Scheme (CHANGES) was established in 2006 and involves an initial triage of the community optometrist's referral letter by a hospital based optometrist into either low or high-risk according to a protocol. A referral is deemed low-risk if only one/none of the following risk factors was noted for either eye: abnormal optic disc, abnormal visual field, abnormal IOP (22-28mmHg or IOP asymmetry). All other referrals are deemed high-risk (including any reference to a shallow anterior chamber). Low-risk patients are seen by one of 8 community based OSIs and high-risk patients are seen directly in the hospital's specialist glaucoma clinic. Only those low-risk patients with a

normal ocular examination (IOP less than 22mmHg, normal optic disc and visual fields) are discharged by the OSI (Bourne et al., 2010).

Manchester

The Manchester glaucoma referral refinement scheme was established in 2000. All referrals to Manchester Royal Eye Hospital (MREH) for patients who are registered with a GP in central Manchester Primary Care Trust are reviewed by one of 12 OSIs. The current IOP criterion necessitating referral to MREH is a modification of the original criterion to reflect the JCG. Other single referral criteria include unequivocal pathological cupping of the optic disc noted after pupil dilation or visual field loss consistent with a diagnosis of glaucoma confirmed at a second visit. Combined referral criteria include IOP ≥22 mmHg plus a suspicious optic disc appearance or optic disc asymmetry. An abnormal optic disc and corresponding visual field defect irrespective of the IOP necessitates a referral. Additional referral criteria include anterior segment signs of secondary glaucoma with IOP >22 mmHg on two occasions, or suspected angle closure (symptoms of sub-acute attacks or occludable angle and IOP >22 mmHg) (Henson et al., 2003).

Gloucestershire

The Gloucestershire glaucoma referral refinement scheme was established in 2008. All community optometrists are offered the opportunity to participate and become accredited to the scheme. Patients who are registered with a Gloucestershire GP practice are seen by one of 103 (85% of the total number of optometrists in this area) accredited community optometrists and have their referral refined by the same accredited optometrist. The optometrist is only reimbursed for referral of those patients who meet the following NICE compliant referral criteria: patients younger than 65 years with IOP in either eye of ≥ 22mmHg, patients aged 65 years or older with an IOP ≥ 25mmHg, measured twice on each of 2 separate patient visits. If initial measurement is ≥ 30mm Hg and/or angle closure is suspected, repeated IOP measurements on one occasion are sufficient for referral. Regardless of IOP, patients are referred if the optic disc appearance is glaucomatous and/or a reproducible visual field defect (evident on two separate occasions) is noted with

automated perimetry. When a patient attends a non-accredited optometrist, a referral is made in the usual way, without refinement, via the patient's GP to the hospital.

Nottingham

The glaucoma referral refinement scheme based at The Queens Medical Centre was established in 2009. All new referrals for suspected glaucoma are assessed by one of 3 hospital-based optometrists. Patients found to have a normal ocular examination by these optometrists are discharged. Those patients who are found to have unequivocal glaucoma and who require urgent treatment or who are identified as having occludable anterior chamber angles are discussed with a consultant on the same day with a treatment plan established and an appropriate prescription issued if necessary. Those with advanced glaucoma (Mean deviation of >12dB on visual field testing or a visual field defect within 10 degrees of fixation) are directed to a specialist glaucoma clinic. Patients diagnosed as ocular hypertensive, with less severe glaucoma or in whom glaucoma is suspected are given a review appointment in a general clinic, which may or may not be run by a glaucoma specialist.

Carmarthen

The Carmarthen glaucoma referral refinement scheme was established in 2003, and is run by 19 accredited OSIs. Single referral criteria are IOP ≥ 26mmHg on two occasions, visual-field defect on two occasions, or pathological disc cupping or asymmetry of > 0.2. Combined referral criteria are IOP > 22mmHg and visual-field defect, suspected optic disc defect and visual-field defect, IOP > 22 and suspect optic discs. Additional referral criteria are optic disc change or haemorrhage, signs of secondary glaucoma, pigment dispersion, pseudoexfoliation and uveitis, rubeosis and finally history suggesting angle closure (Devarajan et al., 2011).

The Carmarthen glaucoma referral refinement also includes a further OSI review at 12 months for those patients found to be normal at initial OSI review. This has been included to further increase the safety of the scheme (Devarajan et al., 2011).

Grampian

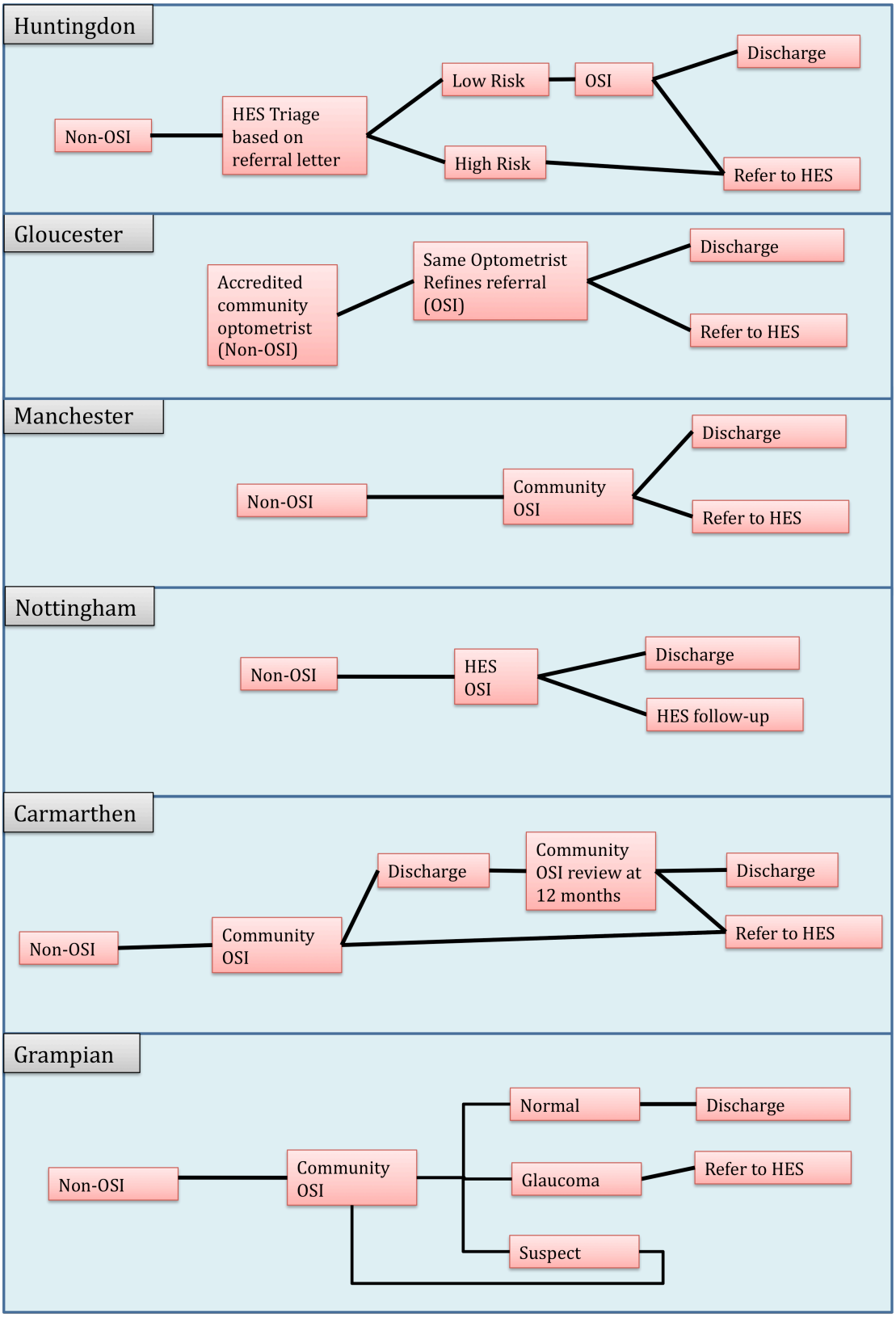
In 2004 a new optometric glaucoma service, including referral refinement, was established in Grampian. The schemes described above relate solely to refining a referral for suspected glaucoma, whereas the Grampian scheme also encompasses a follow-up service for suspects, in addition to permitting the three accredited glaucoma optometrists to initiate anti-glaucoma treatment by instructing the GP to provide a topical prostaglandin prescription.
Patients who are found by the accredited glaucoma optometrist to be normal are discharged. Low-risk glaucoma suspects or OHT patients are given a further review appointment by the same optometrist. High-risk glaucoma suspects or OHT patients as well as those with definite glaucoma are referred to an ophthalmologist (Azuara-Blanco et al., 2007).

Table 2-2. Summary of some glaucoma referral refinement schemes in the UK

	Huntingdon	**Manchester**	**Gloucestershire**	**Nottingham**	**Carmarthen**	**Grampian**
All glaucoma referrals seen in GRRS	No	Yes	No	Yes	Yes	Yes
Setting of GRRS	Community	Community	Community	Hospital	Community	Community
Contact (Goldmann/Perkins) tonometry required	Yes	Yes	Yes	Yes	Yes	Yes
Dilated disc assessment required	Yes	Yes	At discretion of refining optometrist	Yes	At discretion of refining optometrist	Yes
Visual Field machine requirement	Humphrey	Any Suprathreshold	Any Suprathreshold	Humphrey	Any Suprathreshold	Humphrey
Year of introduction	2006	2000	2008	2009	2003	2004
Number of GRR optometrists involved	8	12	103	3	19	3
Cost of GRR appointment (£)	50.00	46.50	50.00 (only if referred)	118.08	38.00	50.00 (based on session fee of £400 for 8 patients)
Hospital accreditation of optometrist	Yes	Yes	Yes	Yes	Yes	Yes
Specialist qualification in glaucoma	Preferred, not essential	Preferred, not essential	Preferred, not essential	Preferred, not essential	Preferred, not essential	Preferred, not essential

Figure 2-6. Schematic flow chart of the organizational structure of each of the 6 glaucoma referral refinement schemes

(HES = Hospital Eye Service)



Each of these schemes requires participating optometrists to gain local accreditation of core optometric competencies (such as Goldmann applanation tonometry, slit-lamp binocular indirect ophthalmoscopy and visual field interpretation) through a hospital approved training scheme.

The relatively few reports published on referral refinement schemes have demonstrated that they can serve as an effective method of reducing the first visit discharge proportion to the hospital, but opinion is divided on the optimal pathway design, triaging and referral criteria, to ensure efficiency but also patient safety. The results from this research will attempt to address this with the objective of helping to establish a national framework for glaucoma referral refinement.

NICE acknowledged the value that refining referrals for suspect glaucoma has had on reducing referrals to the HES in its guideline published in March 2011, entitled ‘’Glaucoma Quality Standard” (NICE, 2011). This guidance detailed the differences between referral refinement and repeat measurement schemes as follows:

“Definitions of referral refinement and repeat measures

Referral refinement

A two-tier assessment in which initial evidence of abnormality during case-finding assessment or screening is validated by a subsequent enhanced assessment which adds value beyond that achieved through a simple 'repeat measures' scheme. A referral refinement service involves the undertaking of tests sufficient for diagnosis of ocular hypertension and suspected chronic open angle glaucoma and the interpretation of these clinical findings, with specialist practitioners who are delivering this service independently, being qualified and experienced in accordance with NICE guidance.

Repeat measures

Primarily describes the repeated measurements of eye pressures, but may also include repeated measurements of visual fields and other relevant ocular parameters when clinically necessary.”

In March 2012, NICE published commissioning guidelines titled “Services for people at risk of developing glaucoma” (NICE, 2012b). In this guidance risk stratification was also addressed, with a recommendation that patients with an IOP of greater than 30mmHg be referred to secondary care without delay suggesting that these patients are not suitable for a community-based refinement of the referral.

2.2.6 The role of Central Corneal thickness (CCT) in GRSS

At the time of this work, none of the schemes described above in 2.2.5 were calibrating IOP measurements based on CCT using pachmetry, whereas in the first-visit to the HES this was routine practice. The use of pachymetry to further improve the quality of OSI referrals is still largely unexplored. Sandhu et el, demonstrated significant reductions in referrals of suspected ocular hypertensive patients through retrospective modelling (Sandhu et al., 2011). The use of pachmetry by OSIs does raise many questions. The remit of an OSI is to refine the quality of the referrals and to safely discharge normal patients. It can be argued that the use of pachymetry to discharge a patient that would otherwise have been referred to the HES actually substantiates to a diagnosis of low-risk ocular hypertension, and is out of the remit of GRR. The cost effectiveness of GRRS could be reduced if additional instrument costs are required, and OSI would not want to shoulder the cost of purchasing the pachymeter as their profit margins are minimal at present, and certainly less profitable than dispensing spectacles (Ratnarajan et al., 2013a, Parkins and Edgar, 2011). From my discussions with commissioners of eye care services and optometrists alike, the cost of purchasing the pachymeter is the main limitation to its current widespread use in GRRS. This will be discussed further in section 3.2.

2.2.7 Local Optical Committee Support Unit (LOCSU)

The Local Optical Committee Support Unit (LOCSU) describe themselves as, "a key link between national professional optical bodies such as the Association of British Dispensing Opticians, the Association of Optometrists or the Federation of Ophthalmic and Dispensing Opticians and the local optician or optometrist working to improve eye services in their region."

The LOCSU have developed enhanced service pathways for glaucoma and cataract. The glaucoma pathway was set up in May 2009, one month after the NICE glaucoma guidelines were published, and was revised in June 2012 (Local Optical Committee Support Unit, 2012). They are broadly divided into two levels, with level one further subdivided. Level 1(a) is an IOP repeat measuring scheme using Goldmann or Perkins tonometry and use onward referral criteria similar to those recommended by the JCG. Except for a suspicious IOP then the rest of the eye examination must be deemed normal. Level 1(b) is a visual field (VF) repeat scheme for patients where this was the only suspicious finding on initial examination. Level 1(c) was established to allow referral refinement for patients seen initially by a non-LOCSU accredited optometrist. This patient will be referred to a LOCSU optometrist, who will carry out a more comprehensive eye examination including anterior chamber and optic disc assessment. The more detailed examination is warranted as this optometrist is now assuming clinical responsibility for the patient, and must base the reason to refer or discharge based on clinical findings they have elicited and not on the findings of the original optometrist. The Level 2 scheme is an OHT or COAG monitoring scheme for patients with a confirmed diagnosis. The clinical examination involves Goldmann tonometry, suprathreshold perimetry, Van Herick's test, and dilated slit lamp biomicroscopic examination of the optic nerve head. After each review the patient is either followed-up or referred to the HES or equivalent (Local Optical Committee Support Unit, 2012). The LOCSU schemes run independently of secondary care providers. A report of audit data from LOCSU claims a 'deflection rate' of 72% for repeat IOP measurement schemes and 38.6% for repeat visual fields schemes. 'Deflection rate' was

used to describe a patient that was not then referred to the HES after review in the LOCSU scheme (Local Optical Committee Support Unit, 2014). These data are audit data from Webstar patient records and have not been validated against another health professional, such as the Ophthalmologist, to determine what proportion of these deflections are appropriate

2.2.8 The new General Ophthalmic Services contract in Scotland

In April 2006, a new GOS contract for NHS community optometrists was implemented in Scotland as part of the Smoking, Health and Social Care (Scotland) Act. All those attending routine sight tests were now to have a comprehensive eye examination by the community optometrist, which includes the use of supplementary examinations, such as contact applanation tonometry, dilated indirect fundoscopy, and threshold automated perimetry. The main aim was to reduce inappropriate referrals to the HES (Ang et al., 2009).

All community optometrists in Scotland wishing to be involved in the new GOS contract attended mandatory workshops. Here the basic competencies of applanation tonometry, slit lamp biomicroscopy, threshold VF, and indirect ophthalmoscopy were assessed before accreditation was gained.

The old GOS contract in Scotland, much like the current GOS contract in England, states a mandatory refraction is carried out on all patients attending a community optometrist. There was no provision for supplemental examinations unless paid for privately by the patient. The new GOS contract does not state refraction is mandatory and allows the optometrist to decide which tests need to be performed based on the patient's specific presenting complaint. It has been shown that this patient specific approach to examining patients in community optometry practices has resulted in both a reduction in the first visit discharge proportion (36.6% pre GOS contract to 21.7% post GOS contract) as well as an improvement in the quality of the referral to HES (Ang et al., 2009).

2.3 Preventable sight loss: a Public Health Indicator

The Public Health Outcomes Framework ‘ Healthy lives, healthy people: Improving outcomes and supporting transparency’ (Department of Health, 2012) sets out a strategy for public health, desired outcomes and the indicators that will help us understand how well public health is being improved and protected.

The framework concentrates on two high-level outcomes to be achieved across the public health system, and groups further indicators into four ‘domains’ that cover the full spectrum of public health. The outcomes reflect a focus not only on how long people live, but on how well they live at all stages of life.

In January 2012, preventable sight loss was included as a public health indicator, thereby establishing eye health as a public health priority by the government. Eye health was chosen as a public health indicator because half of sight loss is estimated to be avoidable. In 2011 alone 22,500 were certified as sight impaired (partially sighted) or severely sight impaired (blind).

The data used will be based on certificate of visual impairment (CVI) registrations and will be measured annually based on rate of sight loss through chronic glaucoma, age related macular degeneration and diabetic retinopathy per 100,000 of the population.

The indicator will enable the eye health and sight loss sector to work with the new NHS and Public Health England to improve eye health as well as address inequality across England. Furthermore a VISION 2020 UK Ophthalmic Public Health Group has been created to inform eye health professionals about public health issues. I am a member of this group, and the data from this work have been included in discussions during meetings.

2.4 Index of Multiple Deprivation

The Communities and Local Government Department have calculated local measures of deprivation in England the latest of which were constructed in 2010 and form the English Indices of Multiple Deprivation (IMD) 2010 (Communities and Local Government, 2011). The IMD is a measure of deprivation, not affluence, and within even the least deprived areas there will be some deprived individuals. Deprivation covers a broad range of issues and refers to unmet needs caused by a lack of resources of all kinds, not just financial. The IMD scores are a continuous measure of relative deprivation therefore there is no definitive point on the scale below which areas are considered to be deprived and above which they are not.

2.5 Equity Profile

Equity profiles are an established public health tool for embedding evidence on health inequalities into planning, commissioning, and service delivery. They quantify how fairly services or other resources are distributed in relation to the health needs of different groups and areas. It is an important tool when planning new models of care such as community based eye-health care, the majority of which are provided by optometrists, who operate outside the umbrella of the NHS. Whilst offering NHS services such as free sight-testing to those entitled, they are essentially private providers of eye care, either working independently or as part of a chain or franchise. The location of community optometrist practices has been shown to be poorly correlated with service demands with fewer optometrists in areas of higher social deprivation (Day et al., 2010). Individuals from these deprived areas were also shown to present with more advanced disease (Fraser et al., 2001, Day et al., 2010). These studies focused on deprived and urban populations, and may not be a reflection of the problem nationally.

2.6 The Health Innovation and Education Cluster (HIEC)

2.6.1 Organisational set-up

The HIEC is a national collaborative organisation of NHS bodies, universities, third sector and commercial organisations that together aim to improve the health of the immediate population. The HIEC for North East London, North Central London and Essex has 3 founding partners; Barts and The London School of Medicine and Dentistry Queen Mary University London, UCL Partners and the Post Graduate Medical Institute Anglia Ruskin University.

2.6.2 HIEC Glaucoma Pathways Project

The Glaucoma Pathways project was one work stream for the HIEC. This project involved both the acquisition of data from GRRS across England to create an evidence base for future national guidance, but also the direct engagement with commissioners of eye care services, Ophthalmologists, Optometrists and LOCs in areas of north London and Essex. This work entailed numerous meetings with all stakeholders to update and develop new GRRS within this area. The work described in this thesis was an invaluable evidence source to all stakeholders, and the HIEC's impartial position helped overcome organisational, sector and professional boundaries in order to drive change.

There was a relative paucity of GRRS in operation in north London and Essex when the HIEC Glaucoma Pathways project began in April 2011. Multiple meetings with relevant stakeholders has resulted in a general increase in the awareness GRRS, and how implementation of these schemes can successfully result in many more patients being reviewed in a community setting in keeping with the Care Closer to Home initiative, as well as reducing the considerable burden new glaucoma out-patients appointments are placing on Ophthalmology departments nationwide. It is

anticipated that these meetings will serve as a platform for continued communication between all stakeholders.

In the 12 months from April 2011 – April 2012 a new glaucoma referral refinement scheme has been agreed upon in Islington. The majority of glaucoma referrals to Moorfields Eye Hospital are generated by optometrists working within Islington and this scheme should successfully reduce the number of referrals for suspected glaucoma to Moorfields Eye Hospital by 25% in keeping with the recent NICE commissioning guidance on glaucoma.

Through close collaboration with the HIEC, the GRRS in Barnet has been successfully updated to reflect national and College guidance. Education and training has been provided to both participating specialist optometrists as well as non-participating optometrists in an endeavour to raise the awareness and skills of optometrists in this region.

3 SECTION III: Investigations

3.1 Aims of Research

1. **The impact of glaucoma referral refinement criteria on referral proportions and first-visit discharge proportions –** the aim of this study was to evaluate the low and high-risk criteria of the CHANGES scheme in order to maximise efficiency of this glaucoma referral refinement pathway (Ratnarajan et al., 2013a).
2. **Multi-site review of glaucoma referral refinement schemes -** the aim of this study was to conduct a multi-site review of established organisationally distinct GRRS across the UK, with the objective of helping to establish a national framework for glaucoma referral refinement (Ratnarajan et al., 2013b).
3. **Agreement between eye health professionals -** the aim of this study was to assess the effect on agreement in clinical findings between clinicians in the referral pathway since the publication of the NICE guidelines and AOP/ABDO/FODO response (Ratnarajan et al., 2012).
4. **The experience of care and awareness of sight testing entitlements in patients referred for suspected glaucoma -** the aim of this study was to explore the reported experience of care of new patients attending a glaucoma clinic appointment as well as their awareness of sight testing entitlements. Factors associated with experience of care in glaucoma have not previously been reported for new patients to a glaucoma clinic (Ratnarajan et al., 2014).
5. **The Equity profile of an Enhanced Optometry scheme -** the aim of this study was to perform an equity profile for an enhanced optometry scheme to establish if effective eye health care was being provided to its catchment population (Ratnarajan, 2015).
6. **The false negative proportion and the role for virtual review in a nationally evaluated glaucoma referral refinement scheme –** the primary aim of this study was to establish the numbers of patients who may be falsely discharged by community-based specialist optometrists

involved in this GRRS. The secondary aim of this work was to compare decision-making between a specialist optometrist and a consultant ophthalmologist when evaluating optic disc images for the presence of glaucomatous optic neuropathy (Ratnarajan et al., 2015).

3.2 The impact of glaucoma referral refinement criteria on referral proportions and first-visit discharge proportions.

3.2.1 Background

As stated in 2.2.4 the number of referrals for suspected glaucoma, particularly those discharged at the first visit to the HES, had increased after the publication of the NICE guidelines 'Glaucoma: Diagnosis and management of chronic open angle glaucoma and ocular hypertension' in April 2009 and the response of the Association of Optometrists (AOP), Association of British Dispensing Opticians (ABDO) and the Federation of Ophthalmic and Dispensing Opticians (FODO) (Association of Optometrists, 2010, Edgar et al., 2010 , Henson et al., 2003, Khan et al., 2012, NICE, 2009a, Shah and Murdoch, 2011, Vernon, 1998, Lawrenson, 2013). Therefore the concept of refining a referral for suspected glaucoma in the community, to reduce the referral rate to the HES, seemed appropriate as this is where most referrals are generated (Bowling et al., 1997, Burr et al., 2007, Davey et al., 2011).

As stated in 2.2.5 numerous glaucoma referral refinement schemes are currently in operation in the UK, with marked variation in pathway design and criteria for onward referral (Ang et al., 2009, Bourne et al., 2010, Devarajan et al., 2011, Henson et al., 2003, Local Optical Committee Support Unit, 2012, Parkins and Edgar, 2011, Ratnarajan et al., 2012, Ratnarajan et al., 2013a, Ratnarajan et al., 2013b, Syam et al., 2010, Warburton, 2010).

The Community and Hospital Allied Network Glaucoma Evaluation Scheme (CHANGES) involves risk stratification of patients based on the referral letter from the community optometrist. Bourne *et al* demonstrated a reduction in the number of referrals discharged at the first hospital visit between 2006-2007 (Bourne et al., 2010). Since this time a number of new guidelines have been published. The first of these was the NICE 'Guidelines For The Diagnosis And

Management Of Chronic Open Glaucoma' in April 2009 (NICE, 2009a). The response from the AOP, ABDO and FODO to recommend optometrists to refer all patients with an intraocular pressure (IOP) greater than 21mmHg, led to an increase in the number of referrals for suspected glaucoma (Association of Optometrists, 2010).

Subsequently in December 2009, the College of Optometrists and Royal College of Ophthalmologists released Joint College Group (JCG) referral guidance recommending additional criteria: that a practitioner may consider not referring a patient aged 80 years and over with an IOP of less than 26mmHg, or patients aged 65 years and older with IOP less than 25mmHg, if the remainder of the ocular examination is normal, as these patients are not recommended for treatment under the current NICE guidance (College of Optometrists, 2010).

A more recent guideline published by NICE in March 2012, entitled 'Services for people at risk of developing glaucoma', was aimed at the commissioning of glaucoma services. It recommends that patients with an IOP of greater than 30mmHg be referred to secondary care without delay suggesting that these patients are not suitable for a community-based refinement of the referral (Royal College of Ophthalmologists and College of Optometrists, 2013a).

In the light of this additional guidance on glaucoma referrals, there was a need to re-evaluate to maximise efficiency.

3.2.2 Purpose

The aim of this study was to evaluate the low and high-risk criteria of the CHANGES scheme in order to maximise efficiency of the glaucoma referral refinement pathway.

3.2.3 Methods

Outcomes of all patients referred under the CHANGES scheme from its introduction in August 2006 until June 2011 were analyzed. This constituted a local audit/service review and was approved by the Trust Caldicott Guardian and audit department. This work did not require research and ethics approval as no patient identifiable information was used.

CHANGES scheme

Eight optometrists with specialist interest in glaucoma (OSI) working in the CHANGES scheme review all low-risk referrals for the catchment area of Hinchingbrooke Hospital, Cambridgeshire. The equipment used by each OSI is standardised to that used in the hospital glaucoma service, namely a slitlamp, a Humphrey visual field analyser (www.meditec.zeiss.com), applanation tonometer (www.haag-streit-usa.com) and digital fundus camera for imaging of the optic disc (www.topconmedical.com). Each optometrist received training by the hospital glaucoma team in the form of four half-day sessions including practical sessions on examination of the optic disc and the correct use of the Goldmann tonometer. In addition, they had all achieved a nationally recognised postgraduate certificate in glaucoma shared care (City University London).

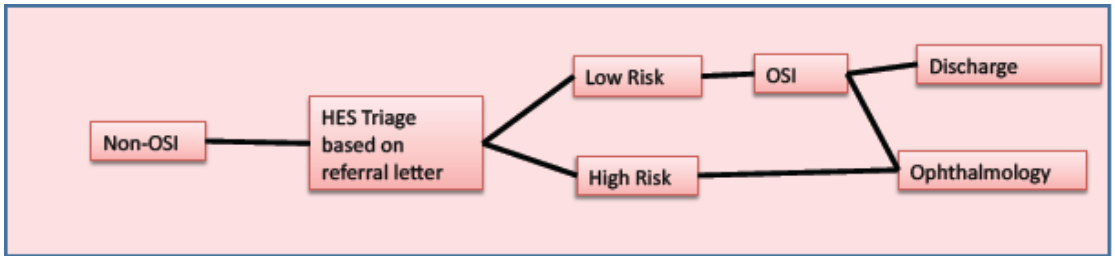
Present study organisation

All referral letters for suspected glaucoma are categorized by an experienced hospital-based optometrist as either low- or high-risk according to a protocol based on the examination findings listed in the letter (see figure 3-1.). A referral is deemed low-risk if only one of the following risk factors was noted: abnormal optic disc (cup to disc ratio of greater than or equal to 0.7, or cup to disc ratio asymmetry of greater than or equal to 0.2, or the presence of a notch in the disc rim), abnormal visual field, raised IOP (22-28mmHg) or IOP asymmetry (>5mmHg). A referral is categorised as high-risk if more than one low-risk factor was present, or alternatively if a shallow anterior chamber, IOP

>28mmHg, optic disc haemorrhage, pigment dispersion or pseudoexfoliation were detected.

Low-risk patients are reviewed by an OSI of their choice within their community practice and high-risk patients are seen directly in the hospital glaucoma clinic. IOP, optic disc and VF findings are recorded by all OSIs. A patient is discharged by the OSI if they are found to have all the following features in both eyes: a Goldmann IOP below 22mmHg, a normal optic disc after dilated optic disc examination, normal visual fields and van Herick's temporal limbal chamber depth deeper than 15% of corneal thickness.

Figure 3-1. Schematic diagram of the CHANGES scheme



The outcomes following assessment by the OSI for low-risk referrals and at the hospital appointment for high-risk referrals were reviewed to establish the first-visit discharge proportion (FVDP) based on reason for referral.

Data management and statistical analysis

Patient information from the referral forms of the community optometrist and the OSI, as well as the hospital patient records, was collated on a database in Microsoft Excel; statistical analysis was performed in R (version 2.15.1, R foundation for statistical computing). The application of referral criteria based on the guidance from the JCG and the NICE commissioners guide 'services for people at risk of developing glaucoma' on the composition of referrals was also modelled.

3.2.4 Results

The analysis included 2912 patients (average age 61.4 years; 45% male) of these 2154 (74%) were categorised as high-risk (average age 63.6 years; 44% male) and 758 (26%) were deemed low-risk (average age 59.5 years; 46% male).

Outcomes and temporal trends of low-risk referrals from community optometrists

Raised IOP or IOP asymmetry

429 referrals from community optometrists were due to moderately raised IOP (22-28mmHg), of which 34% were discharged by the OSI. Of those referred on by the OSI to the hospital, 45% were discharged by the consultant, giving a total discharge proportion of 64%.

38 referrals were for IOP asymmetry > 5mmHg of which 45% were discharged by the OSI. Of those referred on by the OSI, 53% were discharged by the consultant, giving a total discharge proportion of 74%.

The percentage of low-risk referrals made for a moderately raised IOP alone were 33%, 33%, 21%, 72%, 73% and 75% for each year from 2006 to 2011, respectively. For IOP asymmetry, the respective percentages were 19%, 7%, 13%, 3%, 1% and 0% (see figure 3-2).

Abnormal optic disc.

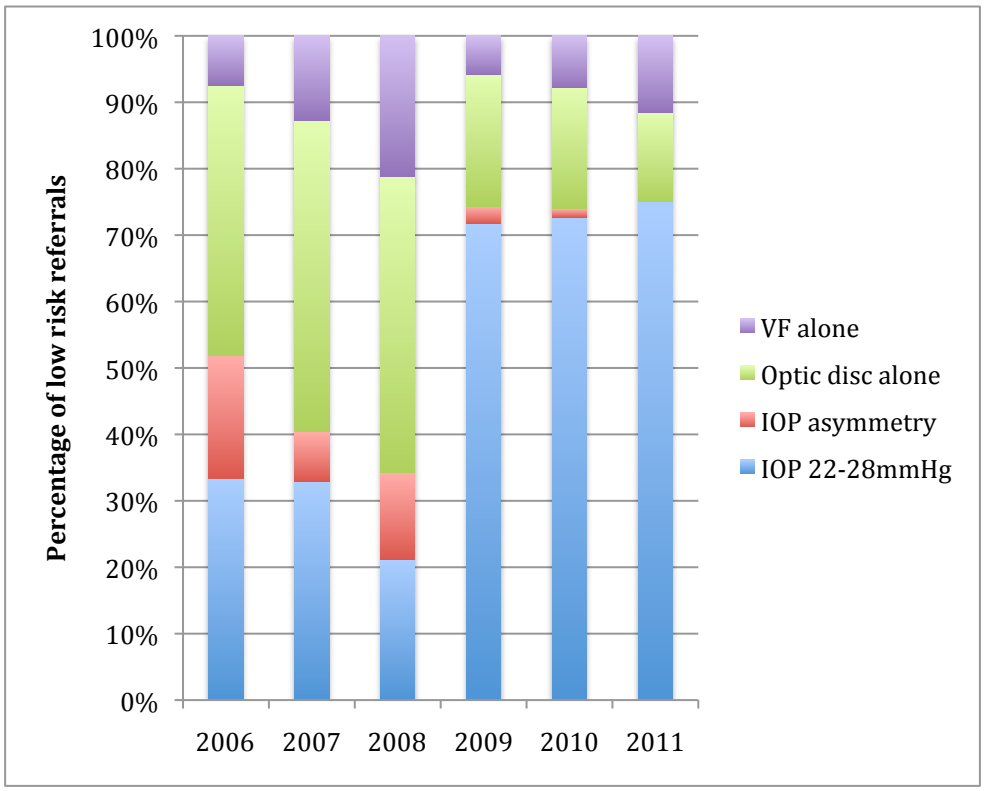
207 referrals from community optometrists were for an abnormal optic disc alone, of which 37.7% were discharged by the OSI. Of those referred on by the OSI, 19% were discharged by the consultant, giving a total discharge proportion of 50%.

The percentage of low-risk referrals made for an abnormal optic disc alone were 41%, 47%, 45%, 20%, 18% and 14% for each year from 2006 to 2011, respectively.

Abnormal visual field test.

84 referrals from community optometrists were for an abnormal VF alone, of which 51% were discharged by the OSI. Of those referred on by the OSI, 46% were discharged by the consultant, giving a total discharge proportion of 74%. The percentage of low-risk referrals made for only an abnormal VF were 8%, 13%, 21%, 6%, 8% and 12% each year from 2006 to 2011, respectively.

Figure 3-2. Temporal trend in reason for referrals as a percentage of total low-risk referrals



Outcomes and temporal trends of high-risk referrals from community optometrists reviewed directly by the hospital glaucoma service.

IOP > 28mmHg only

494 referrals (22.9% of all high-risk referrals) from community optometrists were for an IOP > 28mmHg, of which an average of 22% were discharged by the consultant over the years 2006 to 2011. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was 22%, 19%, 25%, 25%, 15% and 29%, respectively (see figure 3-3).

Raised IOP and abnormal optic disc and visual field

429 referrals (19.9% of all high-risk referrals) were for a raised IOP and abnormal optic disc and VF, of which 26% were discharged by the consultant. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was, 35%, 29%, 29%, 17%, 17% and 14%, respectively.

Raised IOP and abnormal visual field

187 referrals (9% of high-risk referrals) were for a raised IOP and abnormal VF, of which 54% were discharged by the consultant. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was 10%, 7%, 7%, 8%, 11% and 9%, respectively.

Raised IOP and abnormal optic disc

448 referrals (21% of high-risk referrals) were for a raised IOP and abnormal optic disc, of which 32% were discharged by the consultant. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was 20%, 20%, 17%, 22%, 25% and 20%, respectively.

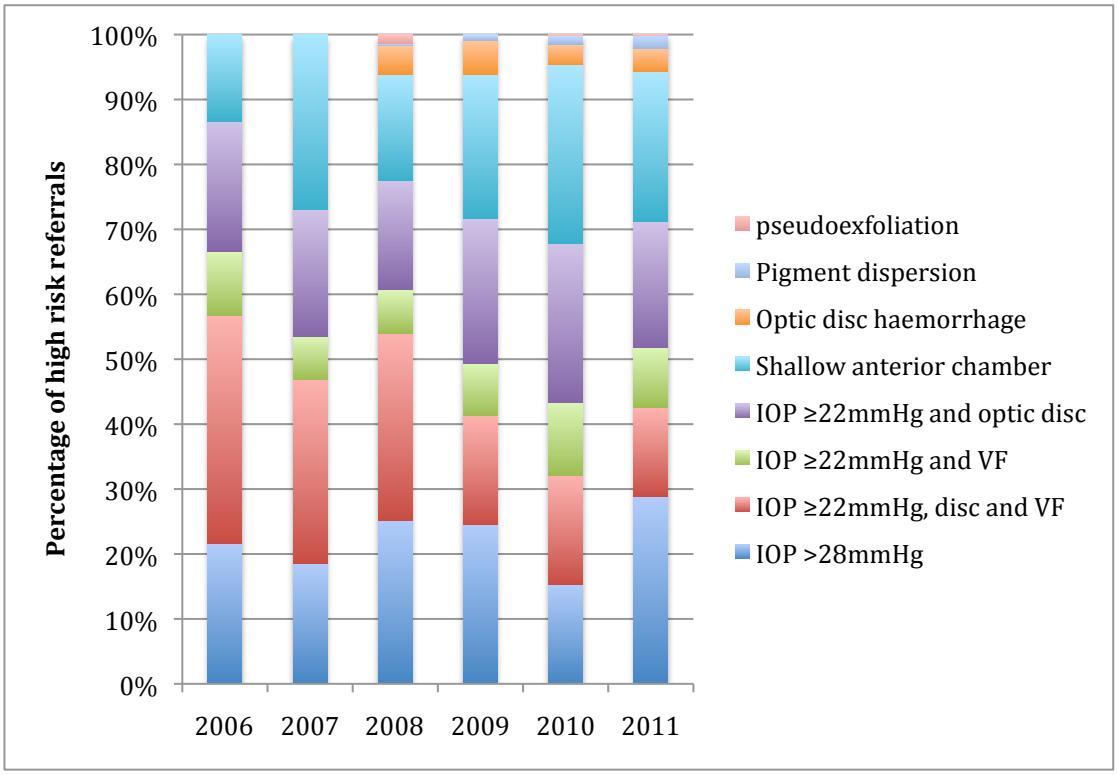
Shallow anterior chamber

493 referrals (23% of high-risk referrals) were for a shallow anterior chamber, of which 25.8% were discharged by the consultant. The percentage of high–

risk referrals each year from 2006 to 2011 for this criterion was 13%, 27%, 16%, 22%, 27% and 23%, respectively.

Few patients were referred on the basis of an optic disc haemorrhage, the presence of signs of pseudoexfoliation or pigment dispersion. 74 referrals (3% of high-risk referrals) were for an optic disc haemorrhage, of which 41% were discharged by the consultant. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was 0%, 0%, 4%, 5%, 3% and 3%, respectively. 22 referrals (1% of high-risk referrals) were for pigment dispersion, of which 64% were discharged by the consultant. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was 0%, 0%, 0%, 1%, 2% and 2%, respectively. 7 referrals (0% of high-risk referrals) were for pseudoexfoliation, of which 57% were discharged by the consultant. The percentage of high–risk referrals each year from 2006 to 2011 for this criterion was 0%, 0%, 1%, 0%, 0% and 0%, respectively.

Figure 3-3. Temporal trend in reason for referrals as a percentage of total high-risk referrals



Modelling of referrals based on Joint College Group Guidance

A total of 282 patients had been referred by OSIs to the HES due to an IOP between 22-28 mmHg. 70 (25%) of patients were 65 - 80 years old, and 10 (4%) were over 80. Modelling of the JCG guidance to this sample based on age and the IOP findings at the OSI review demonstrated that 51 of the 70 (73%) patients who were aged between 65-80 and had been referred on the basis of raised IOP only would have satisfied the JCG criteria for non-referral. For the over 80 age category 6 of the 10 (60%) would have satisfied the JCG criteria for non-referral. In addition, all 6 of these patients aged over 80 would also have not been referred under the 65-80 JCG group criteria had no upper age limit been set as the IOPs were all < 25mmHg.

Modelling referrals based on NICE commissioners guide 'services for people at risk of developing glaucoma'.

494 patients had been referred by community optometrists for an IOP > 28mmHg in the presence of a normal optic disc and visual field. 28 (6%) fewer patients would have been referred direct to the HES if the threshold were increased to > 30mmHg as recommended by the NICE commissioners guide.

Financial analysis of the CHANGES scheme.

In 2010, a total of 701 patients were seen as part of the CHANGES scheme. 470 (67%) were deemed to be high-risk referrals and were seen directly by the HES and 231 (33%) were low-risk and seen by the OSI of which 101 (44%) were subsequently discharged. Therefore this scheme reduced the numbers of patients attending the hospital by 15% (33% x 44%) in 2010. The cost saving of the CHANGES scheme was £16,258, which represents a 13% reduction compared to if all patients were seen directly by the HES. A breakdown of these costs is found in table 3-1. Ophthalmology outpatient tariff was based on the Department of Health's 2010-2011 national tariffs (Department of Health, 2009). The cost of an OSI appointment was £50.

Table 3-1. Cost analysis for the CHANGES scheme for 2010 compared with the costs if all patients were seen by the Hospital Eye Service (HES). Monitoring costs used Parkins and Edgar's estimation of 1.10 HES follow ups prior to HES discharge of 55% of glaucoma suspects (Parkins and Edgar, 2011).

CHANGES scheme in 2010 (701 patients)	
Low-risk (231 patients)	
OSI costs	£10,650
Onward referral costs (130 x £141)	£18,330
Monitoring costs prior to discharge[+] [1.10 x (55% x 130) x £67]	£5,270
High-risk (470 patients)	
New glaucoma out-patient and visual field clinic cost	£66,270
Monitoring costs prior to discharge[+] [1.10 x (55% x 470) x £67]	£10,478
TOTAL	£110,998
Equivalent HES costs (701 patients)	
New glaucoma out-patient clinic cost	£98,841
Monitoring costs prior to discharge[+] [1.10 x (55% x 701) x £67]	£28,415
TOTAL	£127,256
SAVING	£16,258 (13%)

3.2.5 Discussion

Referrals involving a raised IOP alone were the most common reason for referral, with a temporal increase in their proportion particularly for the low-risk group. Within the low-risk group, a considerable increase in referrals was demonstrated between 2008 and 2009 (31 to 112), and this is likely to be related to the introduction of the NICE guidelines and the AOP/ABDO/FODO response to these guidelines (Association of Optometrists, 2010).

The proportion of referrals for an IOP > 28mmHg, or referrals for IOP and a suspicious optic disc or visual field, generally increased steadily from 2006, with an overall FVDP of 22%, 32% and 54% respectively. The high FVDP for referrals for IOP and visual fields (54%), coupled with the fact that OSIs in this scheme use equipment that is consistent with that used in the hospital eye services (calibrated Goldmann tonometry and Humphrey visual field analysers), would suggest that re-categorisation of this group of referrals as low-risk rather than high-risk would improve the efficiency of the CHANGES scheme. The numbers of referrals involving abnormal IOP and optic disc and visual field demonstrated little variation with a FVDP of 26%, however their proportion of the total referrals reduced particularly from 2009 largely due to an increased proportion of referrals for IOP > 28mmHg and shallow anterior chamber.

34% of patients referred by community optometrists on the basis of an IOP 22-28mmHg alone were discharged directly by the OSI. If the OSI adopted JCG as onward referral criteria (rather than IOP > 21mmHg) this figure that would have increased to 48%.

Calibration of IOP based on CCT using pachmetry is routinely carried out in the HES, especially the first-visit. The use of pachymetry to further improve the quality of OSI referrals is still largely unexplored. Sandhu et el, demonstrated significant reductions in referrals of suspected ocular hypertensive patients through retrospective modelling (Sandhu et al., 2011). The use of pachmetry by OSIs does raise many questions. The remit of an

OSI is to refine the quality of the referrals and to safely discharge normal patients. It can be argued that the use of pachymetry to discharge a patient that would otherwise have been referred to the HES actually substantiates to a diagnosis of low-risk ocular hypertension, and is out of the remit of GRR.

A survey of current and anticipated use of standard and specialist equipment by UK optometrists showed optometrists are increasingly employing modern equipment and IT services to enhance patient care, although questions were raised as to whether this actually was cost effective (Dabasia et al., 2014). Certainly the cost effectiveness of GRRS will be reduced if additional instrument costs are required, and OSI would not want to shoulder the cost of purchasing the pachymeter as their profit margins are minimal at present, and certainly less profitable than dispensing spectacles (Ratnarajan et al., 2013a, Parkins and Edgar, 2011).

Whilst the HES acknowledges that GRRS are needed to improve the quality of referrals and prevent inappropriate referrals, from an economic standpoint new referrals to the HES are an important source of revenue and crucial to its sustainability.

The reverse argument is that the OSI will already be anaesthetising the cornea to carry out GAT, and therefore why not measure the CCT to further increase the accuracy of the IOP measurement.

Modelling based on NICE commissioners guidance would have prevented 28 (5.7%) referrals to HES. Despite its modest impact, its inclusion into the low-risk category will crucially, from a medico-legal aspect, enable the OSI to practise within the remit of a national guidance.

The low FVDP for shallow anterior chamber referrals suggests it is appropriate for this to remain a high-risk criterion. This is particularly as this subset of patients can have rapidly progressing pathology and represent a source of preventable visual field loss if treated in a timely manner. It would seem the use of the van Herick test by community optometrists is associated

with a relatively low false positive proportion when compared to the gonioscopic finding of the consultant (Foster et al., 2000, Dabasia et al., 2015a, Jindal et al., 2015).

The 3 least common groups of high-risk referral letters involved patients with suspected optic disc haemorrhage, pigment dispersion or pseudoexfoliation but in the absence of a raised IOP, abnormal visual field or suspicious optic disc. Referral refinement by the OSIs may successfully lower the number of inappropriate referrals for these patients that are currently classified as high-risk.

Bourne *et al* reported an 8% reduction in referrals to the hospital as a result of the CHANGES scheme in a pre-NICE glaucoma guideline time period (2006 and 2007) (Bourne et al., 2010). Using identical referral and triaging criteria, this report has shown a 15% reduction in referrals to the hospital in a post-NICE time period (2010) suggesting a greater benefit of this glaucoma referral refinement scheme in the context of current referral patterns for suspected glaucoma. This translated into an annual saving of £16,258 (13%).

Recommendations

The following recommendations from this study aim to reduce the demand on the hospital glaucoma service whilst simultaneously not reducing the quality of care received by patients in the CHANGES scheme.

It is recommended the general organisation of this referral refinement scheme remain unchanged, with risk stratification of the patient based on the referral form into low- and high-risk categories and with low-risk referrals being directed to an OSI and the high-risk referrals being directly assessed by the hospital glaucoma service. However, the criteria for categorisation into low- and high-risk could be adjusted. The category of referrals that is deemed low-risk (currently either a suspicious optic disc, abnormal VF, raised IOP (22-28mmHg) or IOP asymmetry (>5mmHg) could be widened to include patients with:

a. an IOP ≤ 30mmHg (currently ≤28mmHg) in conjunction with a normal optic disc and VF, thus complying with NICE commissioners guidance.
b. an IOP ≤ 30mmHg in conjunction with an abnormal VF.
c. an optic disc haemorrhage, evidence of pigment dispersion and pseudoexfoliation in conjunction with a normal IOP, normal VF and no evidence of glaucomatous optic disc cupping.

In addition, the OSI should partially adopt the JCG referral criteria, whereby an OSI need not refer a patient aged ≥ 65 years with an IOP < 25mmHg in both eyes with an otherwise normal ocular examination (currently IOP > 21mmHg). This report suggests increasing the IOP threshold to < 26 for the over 80's has little impact on further reducing referrals. The role of CCT measurements in GRRS also needs further exploration.

To ensure the revised criteria of this scheme is both safe and effective, all low-risk patients that are discharged by the OSI will have an additional review by the Consultant in the hospital eye service for the initial two months to confirm the appropriateness of discharge and hence the false negative proportion.

3.3. Multi-site review of glaucoma referral refinement schemes

3.3.1. Background

Glaucoma is the world's leading cause of irreversible blindness (Quigley, 1996). This progressive optic neuropathy is characterised by damage to the optic nerve head and nerve fibre layer, with visual field loss which is usually asymptomatic until the disease becomes advanced. Twenty percent of referrals to ophthalmology clinics are for suspected glaucoma, with the annual cost for monitoring patients with this chronic condition estimated to be £22,469,000 (Davey et al., 2011, NICE, 2009b).

In the UK, most referrals for suspected glaucoma are generated through opportunistic surveillance during sight-tests by community-based optometrists (hereafter referred to as an Optometrist with no Specialist Interest in glaucoma, non-OSI) (Bowling et al., 2005, Burr et al., 2007, Davey et al., 2011).

As part of a sight-test, the non-OSI is required to perform an internal examination of the eye including the optic disc. If clinically indicated VF testing and IOP measurements are performed. IOP is typically measured using 'air puff' non-contact tonometry (NCT) which is prone to higher variability and over-estimating the IOP (in individuals with thick corneas) compared to Goldmann contact tonometry used in hospital ophthalmology departments (Vincent S J et al., 2012). Visual field testing is also carried out if clinically indicated and completes the established triad of examinations/tests to detect glaucoma.

The number of patients being referred to ophthalmology departments is rapidly increasing due to an ageing population, advances in diagnostic and screening tools such as visual field testing, and changes in national and professional guidance with regard to glaucoma care.

The NICE guidelines for the diagnosis and management of COAG and OHT were published in April 2009 (NICE, 2009a). These guidelines however did not include in their remit guidance on the detection and referral of suspected glaucoma by community optometrists as it was felt this would make the guidelines unmanageably large (Sparrow, 2012).

As mentioned in the introduction, the professional representative organisations for optometry practice (AOP, ABDO and FODO) response to these guidelines was as follows:

"English and Welsh PCTs and Health Boards may not have the resources to cope with the numbers of referrals – many of which, because they will have had their pressures taken using NCT, will be false positives. Nevertheless, in the absence of funding to repeat pressures using Goldmann, the AOP believes strongly that optometrists have no choice other than to refer a patient who has a sign of ocular hypertension – e.g. pressures measured at over 21 mmHg, using whatever tonometer they choose. To identify a sign of OHT and then not to act on it could be considered to be unprofessional, especially when the correct course of action has been well researched, by a panel of experts in the field, using evidence-based methods, and has been officially published by NICE." (Association of Optometrists, 2010).

This response by the AOP meant optometrists had no choice but to refer patients that previously may not have required a hospital review after other factors such as age and family history were taken into consideration. The result was a surge in the number of referrals for suspected glaucoma and, consequently, an increase in first-visit discharges (Edgar et al., 2010 , Ratnarajan et al., 2012, Ratnarajan et al., 2013a, Shah and Murdoch, 2011).

The aforementioned JCG of December 2009 was an attempt by the Royal College of Ophthalmologists and College of Optometrists to reduce the total number of first-visit discharges. It targeted ocular hypertensive patients with low-risk of significant visual field loss in their lifetime, recommending that

optometrists consider not referring patients aged over 80 years with an IOP of less than 26mmHg with an otherwise normal ocular examination. For patients aged between 65 and 80 this IOP criterion was less than 25mmHg, as NICE guidance does not recommend offering treatment to these subsets of patients. For the latter group, it was recommended that these individuals be reviewed annually by a community optometrist (College of Optometrists, 2010). The most recent JCG, published in March 2013, recommended introduction of repeat IOP measurement schemes to reduce false-positive referrals to the hospital eye service, and recommended where possible to facilitate the implementation of glaucoma referral refinement schemes (GRRS) to further reduce the false-positive referral proportion (Royal College of Ophthalmologists and College of Optometrists, 2013b).

In order to provide a local service for patients and to direct patients requiring review to the hospital eye service the concept of refining referrals for suspected glaucoma has been developed and GRRS have been shown to successfully reduce first-visit discharges for suspected glaucoma to secondary care (Bourne et al., 2010, Devarajan et al., 2011, Henson et al., 2003, Local Optical Committee Support Unit, 2012, Parkins and Edgar, 2011, Syam et al., 2010, Ratnarajan et al., 2013a). Opinion is however still divided on optimal pathway design, triaging and referral criteria, to ensure efficiency but also patient safety.

3.3.2. Purpose

The aim of this study was to conduct a multi-site review of established organisationally distinct GRRS in England, with the objective of helping to establish a national framework for glaucoma referral refinement.

3.3.3. Methods

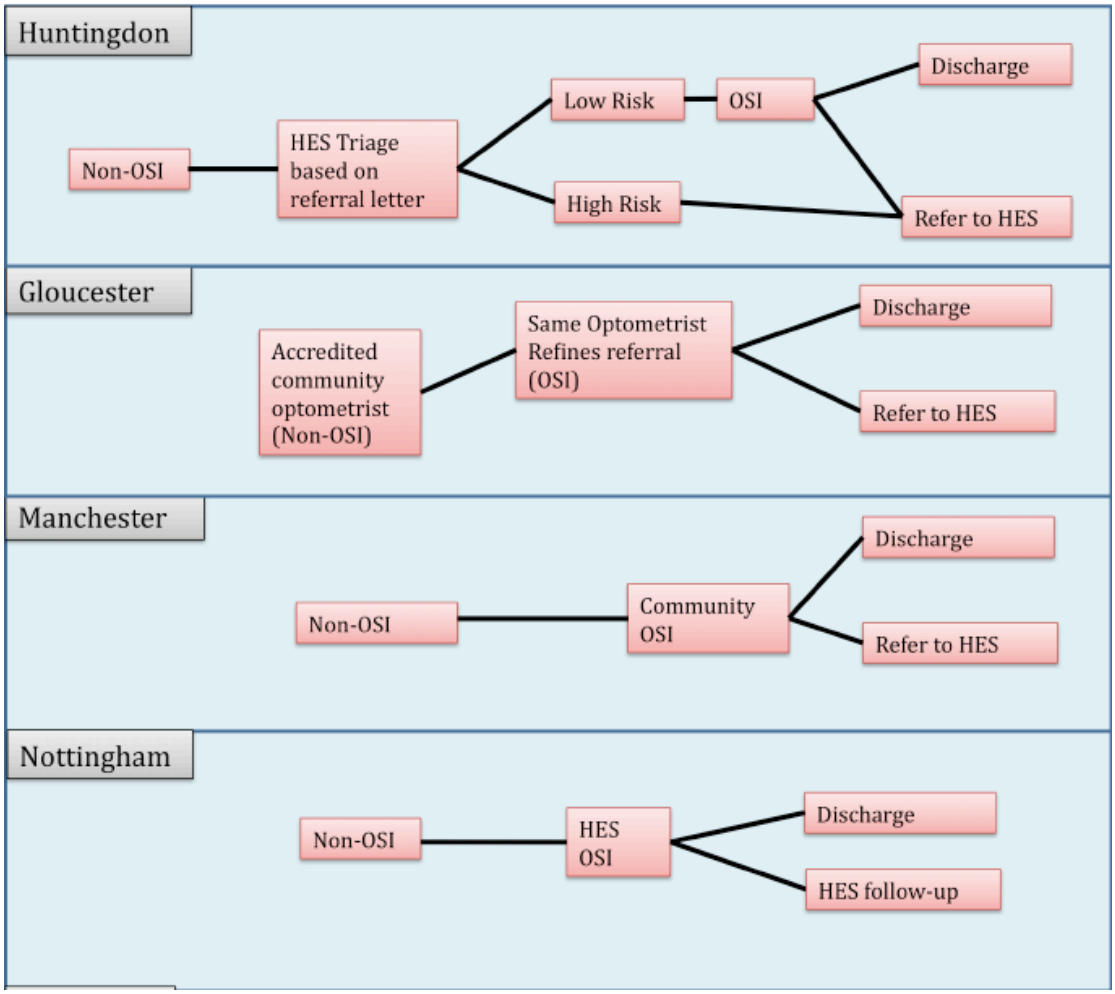
The outcomes of GRRS in Huntingdon, Manchester, Gloucestershire and Nottingham were retrospectively analysed during four 2 month time periods: pre NICE (March and April 2009), post NICE (November and December 2009), post JCG (August and September 2010) and current practice (March and April 2011). Seasonal variation was not taken into account and this study was looking specifically at open angle glaucoma.
This work was classified as an audit/service review. Each participating Trust gained approval by the Trust Caldicott Guardian and audit department. This work did not require research and ethics approval as no patient identifiable information was used.

Each scheme is organisationally distinct and reflects the range of variation between schemes in England. See section 2.2.5 and Figure 3-4 for more details.

Each scheme requires participating optometrists to gain local accreditation of core optometric competencies (such as Goldmann contact tonometry, slit-lamp binocular indirect ophthalmoscopy and visual field interpretation) through a hospital approved training scheme. A specialist qualification in glaucoma is not a prerequisite (City University, 2012, College of Optometrists, 2011a, WOPEC, 2012).

In Huntingdon and Nottingham the data from the non-OSI referral as well the subsequent findings from the next eye health professional were collected (for Nottingham and low-risk Huntingdon patients this was the OSI and for high-risk Huntingdon patients this was a glaucoma consultant). In Manchester and Gloucestershire the data from the OSI referral and the hospital visit were analysed.

Figure 3-4. Schematic flow chart of the organisational structure of each of the 4 glaucoma referral refinement schemes (HES = Hospital Eye Service)



Statistical Analysis

Data from electronic and paper patient records and paper referral letters were collated using Microsoft Excel; statistical analysis was performed in R (version 2.15.1, R foundation for statistical computing). Percentages of FVDP were compared using Fisher's exact test, and confidence limits for the differences between percentages were calculated using Newcombe's Hybrid Score Interval Method. Confidence limits and p values within a set of factor levels have been corrected for multiplicity using the Dunn-Sidak method.

The FVDP was defined as the percentage of referrals from an OSI or a non-OSI that was discharged at the first visit to the final provider. Agreement rate proportions on diagnostic accuracy and referral appropriateness always use the diagnosis given by the final clinician and assumes their finding to be the gold standard.

3.3.4. Results

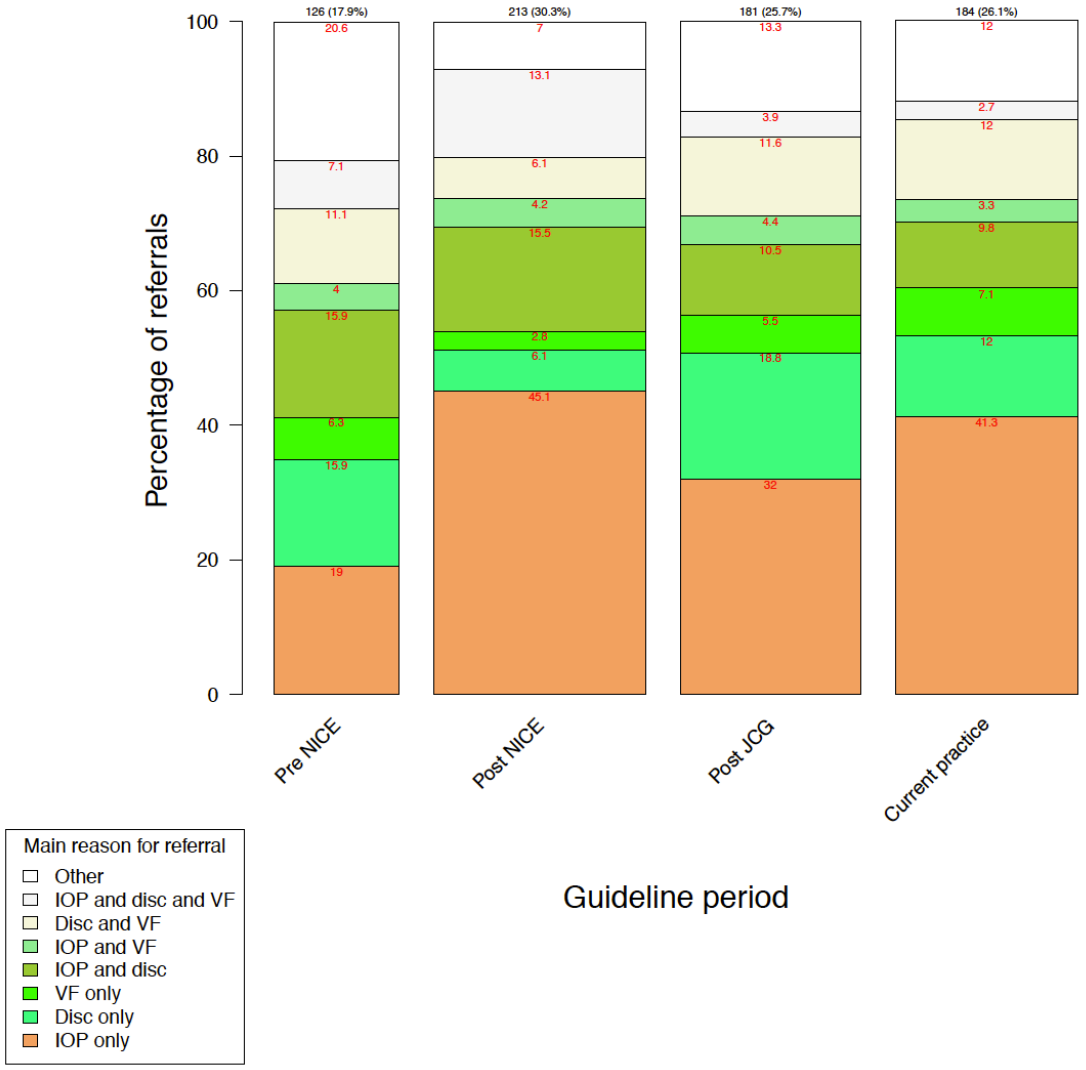
Data of 1086 patients were analyzed: 190 (17.5%) pre NICE, 338 (35.7%) post NICE, 287 (26.4%) post JCG and 271 (25.0%) from the current practice group. 434 (40.0%) patients were from Huntingdon (304 high and 130 low-risk), 179 (16.5%) from Manchester, 204 (18.8%) from Gloucestershire and 269 (24.8%) from Nottingham.

56.1% of patients referred from OSIs were male as compared to 43.7% from non-OSIs. Mean age of patients referred by the OSIs was 63.2 years compared to 62.0 years for non-OSIs.

Reason for Referral from non-OSI and OSI optometrists

The most common reason for non-OSI referral across all observation periods was for an elevated IOP-only (36.1%). In the pre NICE timeframe, there were 24 referrals for IOP-only, which accounted for 19.0% of referrals. This increased to 96 referrals in the post NICE period, which accounted for 45.1% of referrals. This was coupled with a decrease in many other stated reasons for referral by the non-OSI, particularly those not including IOP, exemplified by disc only referrals which reduced from 20 (15.9%) pre NICE to 13 (6.1%) post NICE (see table 3-2, table 3-4 and figure 3-5).

Figure 3-5. The percentage of non-OSI referrals by Guideline period.
Bar widths are proportional to the number of referrals



The most common reason for OSI referral across all observation periods was also for raised IOP only. In the pre NICE time period 7 referrals (10.9%) were for IOP only increasing to 35 referrals (28.0%) post NICE,(see table 3-2, table 3-3 and figure 3-6).

Table 3-2. Reason for non-OSI and OSI referral by time period.

Reason for referral	Guideline period								Total	
	Pre NICE		Post NICE		Post JCG		Current Practice			
	Non-OSI (%)	OSI (%)	Non-OSI (%)	OSI (%)	Non-OSI (%)	OSI (%)	Non-OSI (%)	OSI (%)	Non-OSI (%)	OSI (%)
IOP only	19.0	10.9	45.1	28.0	32.0	41.5	41.3	27.6	36.1	28.8
Disc only	15.9	18.8	6.1	20.0	18.8	15.1	12.0	18.4	12.6	18.1
VF only	6.3	4.7	2.8	2.4	5.5	5.7	7.1	5.7	5.2	4.5
IOP+Disc	15.9	20.3	15.5	21.6	10.5	16.0	9.8	20.7	12.8	19.6
IOP+VF	4.0	6.2	4.2	6.4	4.4	3.8	3.3	2.3	4.0	4.7
Disc+VF	11.1	12.5	6.1	15.2	11.6	11.3	12.0	16.1	9.9	13.9
IOP+Disc+VF	7.1	26.6	13.1	6.4	3.9	3.8	2.7	6.9	7.0	9.2
Other	20.6	0.0	7.0	0.0	13.3	2.8	12.0	2.3	12.4	1.3

Table 3-3. Reason for OSI referral with percentages and counts for each time period.

	Guideline period								Total	
	Pre NICE		Post NICE		Post JCG		Current Practice			
	Count	%	Count	%	Count	%	Count	%	Count	%
IOP only	7	10.9	35	28.0	44	41.5	24	27.6	110	28.8
Disc only	12	18.8	25	20.0	16	15.1	16	18.4	69	18.1
VF only	3	4.7	3	2.4	6	5.7	5	5.7	17	4.5
IOP+Disc	13	20.3	27	21.6	17	16.0	18	20.7	75	19.6
IOP+VF	4	6.2	8	6.4	4	3.8	2	2.3	18	4.7
Disc+VF	8	12.5	19	15.2	12	11.3	14	16.1	53	13.9
IOP+Disc+VF	17	26.6	8	6.4	4	3.8	6	6.9	35	9.2
Other	0	0.0	0	0.0	3	2.8	2	2.3	5	1.3
Other than IOP alone*	57	89.1	90	72.0	62	58.5	63	72.4	272	71.2
Total	64	100.0	125	100.0	106	100.0	87	100.0	382	100.0

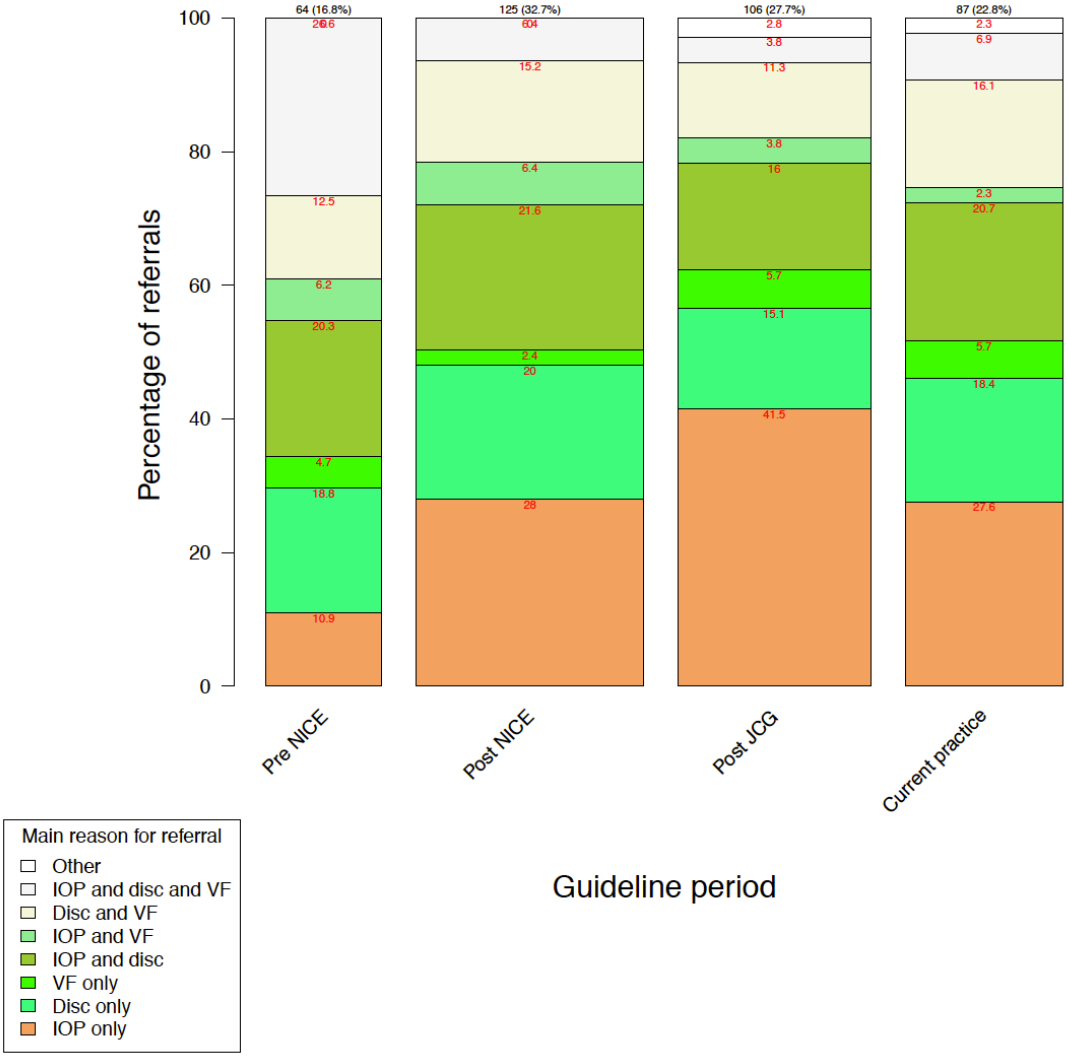
* This row does not contribute to the column totals

Table 3-4. Reason for Non-OSI referral with percentages and counts for each time period.

Reason for referral	Guideline period								Total	
	Pre NICE		Post NICE		Post JCG		Current Practice			
	Count	%	Count	%	Count	%	Count	%	Count	%
IOP only	24	19.0	96	45.1	58	32.0	76	41.3	254	36.1
Disc only	20	15.9	13	6.1	34	18.8	22	12.0	89	12.6
VF only	8	6.3	6	2.8	10	5.5	13	7.1	37	5.2
IOP+Disc	20	15.9	33	15.5	19	10.5	18	9.8	90	12.8
IOP+VF	5	4.0	9	4.2	8	4.4	6	3.3	28	4.0
Disc+VF	14	11.1	13	6.1	21	11.6	22	12.0	70	9.9
IOP+Disc+VF	9	7.1	28	13.1	7	3.9	5	2.7	49	7.0
Other	26	20.6	15	7.0	24	13.3	22	12.0	87	12.4
Other than IOP alone*	102	81.0	117	54.9	123	68.0	108	58.7	450	63.9
Total	126	100.0	213	100.0	181	100.0	184	100.0	704	100.0

* This row does not contribute to the column totals

Figure 3-6. The percentage of OSI referrals by Guideline period.
Bar widths are proportional to the number of referrals



First-visit discharge proportion associated with non-OSI and OSI optometrists

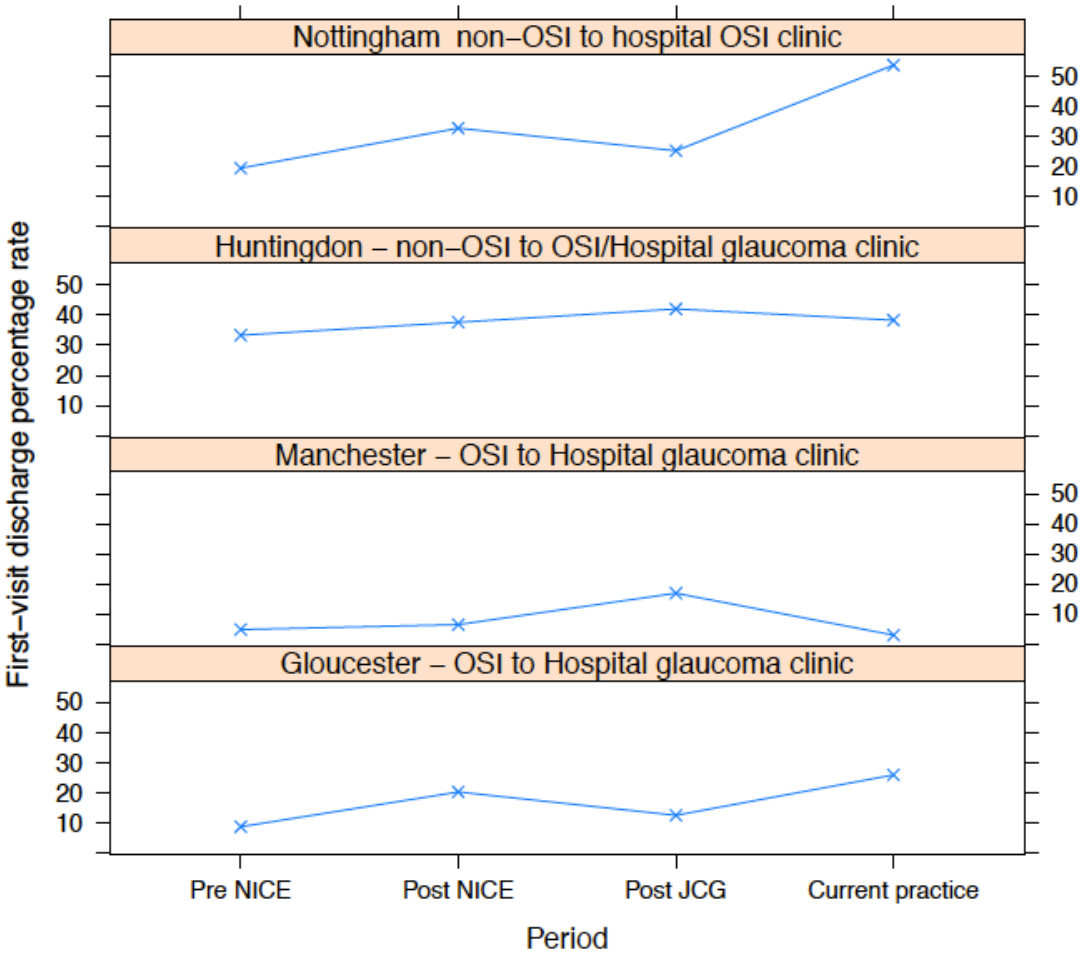
The overall FVDP for non-OSI referrals was 36.1% and for OSI referrals was 14.1% (difference 22%, CI 16.9% to 26.7%; p<0.001). FVDP pre-NICE was 21.9% compared with 35.4% in the current practice time period (difference 13.5%, CI −23.8% to −2.4%; p=0.006). For OSIs, FVDP was 6.3% pre-NICE and 17.2% current practice (difference 11.0%, CI −24.7% to 4.3%; p=0.18) and for non-OSIs FVDP was 29.2% pre-NICE and 43.9% current practice (difference 14.7%, CI −27.8% to −0.30%; p=0.03).

The FVDP for each site for each time period is given in Table 3-5. and figure 3-7. When interpreting these data it is important to note that for Nottingham and Huntingdon the FVDP is for referrals from a non-OSI, while for Manchester and Gloucestershire the FVDP is that of referrals from an OSI.

Table 3-5. First-visit discharge proportion (percentage of referrals) by site and by time period.

Site (professional initiating referral)	Period				All periods
	Pre NICE	Post NICE	Post JCG	Current practice	
Nottingham (non-OSI)	19.5	32.8	25.3	53.7	33.5
Huntingdon (non-OSI)	33.3	37.6	42.1	38.3	38.0
Mean non-OSI	**29.2**	**35.0**	**34.7**	**43.9**	**36.1**
Manchester (OSI)	4.9	6.5	16.9	3.0	8.9
Gloucestershire (OSI)	8.7	20.3	12.5	25.9	18.6
Mean OSI	**6.3**	**15.2**	**15.0**	**17.2**	**14.1**
Mean overall	**21.9**	**27.8**	**27.6**	**35.4**	**28.6**

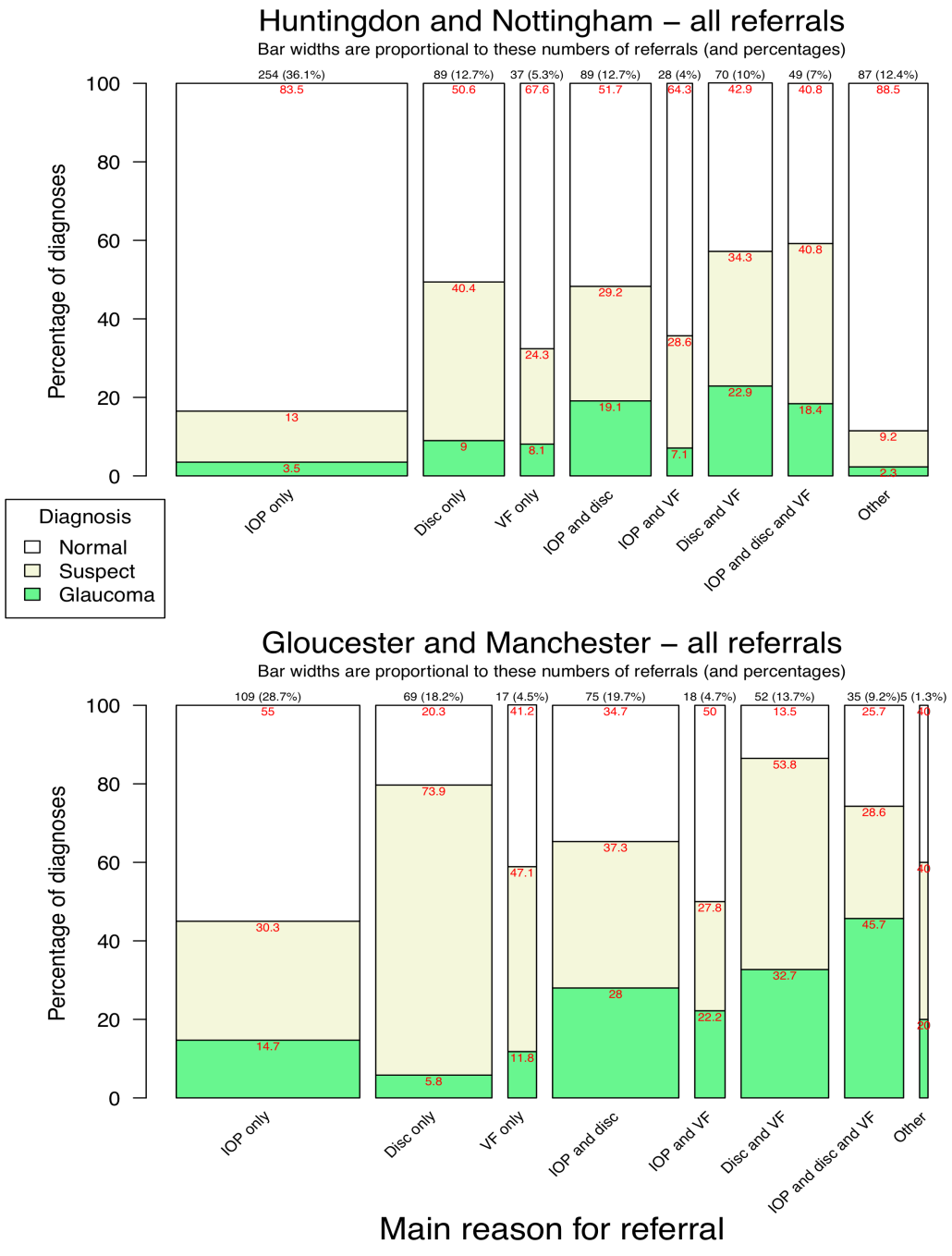
Figure 3-7. Graph showing first-visit discharge proportion by site and time period



Outcomes of referrals from non-OSI and OSI optometrists based on reason for referral

A referral for suspected glaucoma is characteristically based on the finding of an elevated IOP, an abnormal optic disc appearance, an abnormal visual field or a combination of these findings. These patients are then classified as either having glaucoma, a suspicion of glaucoma ('glaucoma suspect') or as being normal. The largest source of first-visit discharges for both non-OSIs and OSIs were for IOP-only related referrals, with 83.5% and 55.0% of these, respectively, being discharged. Referrals based on more than one criterion, such as those for abnormal IOP, optic disc and visual fields, resulted in fewer first-visit discharges (40.8% non-OSI and 25.7% OSI). More details are given in Figure 3-8.

Figure 3-8. The outcomes of patients referred by non-OSIs (top) and OSIs (bottom). The width of each bar is representative of the proportion of the total referral base.



3.3.5. Discussion

The main rationale for the refinement of referrals for suspected glaucoma has been to reduce the overall number of referrals to the HES whilst simultaneously increasing the quality and accuracy of the referral process.

Reason for Referral from non-OSI and OSI optometrists

Both non-OSIs and OSIs demonstrated a similar trend for the stated reasons for referral with IOP-only referrals being the largest category for referral, 36.1% and 28.8% respectively, followed by referrals for elevated IOP and abnormal optic disc, 12.8% and 19.6% respectively. Disc-only referrals and disc and VF referrals were the next largest categories in both groups, with the smallest category being for elevated IOP and a suspicious VF.

The temporal trend observed among the stated reasons for referral for the non-OSI and OSI displayed considerable variation. All referral categories by a non-OSI not involving IOP as a referral criterion demonstrated a decline post NICE compared to pre NICE, most notable disc only referrals which dropped from 20 referrals (15.9%) pre NICE to 13 (6.1%) post NICE. The reverse was seen for referrals involving IOP, particularly IOP-only referrals which increased from 24 referrals (19.0%) pre NICE to 96 referrals (45.1%) post NICE. The AOP's response to the NICE Guidelines seems to have had less effect on the temporal trend in referrals generated by OSIs. Exceptions being IOP-only referrals which increased from 7 (10.9%) pre NICE to 35 (28.0%) post NICE and referrals citing IOP, optic disc and visual fields which decreased from 17 referrals (26.6%) to 8 (6.4%). This would suggest that, post-NICE, optometrists initiating referrals concentrate more on IOP as a reason for referral with less emphasis being placed on concurrent assessment of the optic nerve and visual field.

It would seem that the introduction of JCG was successful in reducing the proportion of referrals by a non-OSI for only a raised IOP (96 referrals down to 58; or expressed as a percentage 45.1% to 32.0%) after the large increase post NICE. This trend was not observed in the OSI group where the number of referrals for raised IOP-only actually increased from 35 (28.0%) to 44 (41.5%).

First-visit discharge proportion associated with non-OSI and OSI optometrists

The overall FVDP for referrals by a non-OSI was statistically significantly higher than that for OSIs (particularly the Manchester GRRS), suggesting superior concordance of the OSI findings with the final provider.

The lack of legal indemnity for optometrists not complying with the AOP's recommendation interestingly has proved to be a really effective way of changing optometry practice, though unfortunately this directly resulted in more inappropriate referrals.

The introduction of JCG did not lower the FVDP in either group, as would have been expected, with FVDPs unchanged from the post NICE period, however there are inter-scheme differences for OSI performance in Manchester and Gloucestershire. This may be because the undue perception of the importance of IOP over other aspects of the ocular examination still remained. However, the current practice FVDP in the Manchester scheme did reduce to 3% from 16.9% in the post JCG time period, and may represent a delay in the full implementation of JCG criteria by its participating OSIs. It is worth noting that despite this drop in the FVDP in the current practice time period, the FVDP in Manchester was only 4.9% pre NICE and only 6.5% post NICE. Despite this for both OSIs and non-OSIs as a whole, the highest FVDPs were in the current practice time period, with the latter group reaching a statistical significant increase in FVDP compared to pre-NICE. This suggests the need for further multi-stakeholder guidance (such as the JCG) regarding detection and referral of suspected glaucoma to be used in

conjunction with the NICE guidance on the diagnosis and management of glaucoma and OHT. In addition, if the AOP's recommendation were withdrawn, this may have a significant impact on improving the quality of referrals and therefore lowering the FVDP.

The lower IOP threshold for referral to ophthalmology recommended in the NICE guidelines may explain the rise in the FVDP for the OSI post NICE, but also may reflect a culture by optometrists, OSI and non-OSI, to adopt a more risk averse approach to the clinical assessment of patients with suspected glaucoma with a lower threshold for referral in keeping with the AOP's recommendation. This is speculative, but the maintenance of the FVDP in the post JCG and current practice periods, with the exception of Manchester, imply that whatever factors caused the increase in first-visit discharges post NICE remained there for the duration of this analysis.

Features of the ocular examination performed at the referral refinement consultation that best predict a diagnosis of glaucoma

The width-adjusted bar graphs of outcome of referral based on reason for referral (Figure 3-8) demonstrate the large proportion of IOP-only referrals and its low diagnostic yield. In the non-OSI referrals, only 16.5% of these patients were given a follow-up appointment, with just 3.5% diagnosed with primary open angle glaucoma. These values were considerably higher for the OSI-initiated referrals (45% and 14.7%, respectively).

These findings highlight the majority of IOP-only referrals represent a waste of hospital out-patient resource. However, 14.7% of these IOP-only referrals were subsequently diagnosed with glaucoma implying the referring clinician had missed or not examined in sufficient detail to identify glaucomatous optic disc pathology, which by definition needs to be present to diagnose glaucoma.

Whether the addition of CCT measurements by the OSI would improve the accuracy of referrals, especially for IOP-only referrals, is debatable, and

certainly not carried out in the majority of GRRS. The issues surrounding CCT in GRRS are described further in 3.2.5 and the discussion.

79.7% of OSI referrals for solely a suspicious optic disc appearance were followed up by the hospital, but only 5.8% were diagnosed with glaucoma at the first review, the remainder being classified as glaucoma suspect. In contrast, only 49.4% of non-OSI disc-suspect referrals were followed-up by the hospital. This suggests the extra training received by OSIs resulted in more accurate referrals.

Multiple-criterion referrals by the OSI, such as an abnormal IOP, optic disc and visual field, resulted a higher percentage of patients being diagnosed with glaucoma, 45.7%. This leads me to question the effectiveness of the OSI in such referrals, as a substantial proportion will be subsequently referred to secondary care. The scheme in Huntingdon has adopted risk stratification through a paper triage of the non-OSI referrals carried out by the hospital, with only patients found to have one risk factor deemed low-risk and therefore suitable for glaucoma referral refinement. Our findings would suggest that the stratification of the referral letter according to risk, a strategy that could be incorporated across all medical specialities, could be an effective method to ensure patients with a high probability of having glaucoma are seen directly by secondary care without the need for the additional examination by an OSI. This is reflected by the glaucoma publication from NICE in March 2012: The NICE commissioners guide ‘services for people at risk of developing glaucoma’ which was produced to provide commissioners of eye services guidance as to how to safely and effectively manage patients at risk of glaucoma (NICE, 2012a). It recommends that patients with an IOP of greater than 30mmHg should be referred directly to secondary care.

Limitations

There are some limitations of this study that are important to consider. The false negative, or percentage of patients that were inappropriately discharged by the non-OSI and OSI, is not known.

The final provider in the schemes was not always a consultant ophthalmologist, and therefore a reference standard cannot be applied across all the schemes that were evaluated.

OSIs are not performing opportunistic screening and therefore their referrals are more likely to be appropriate compared to non-OSIs. However, the FVDP is the most appropriate metric to measure the 'added diagnostic value' an OSI introduces to the referral pathway in GRRS compared to the traditional referral pathway in which a non-OSI directly refers to the hospital eye service.

The time series for the study was carefully selected to encompass all the major changes in clinical guidelines and practice since 2009. However, by definition a retrospective observational time series study will not provide data on all time points.

An issue to note is that the prevalence of glaucoma does not affect sensitivity or specificity but it does affect the positive predictive value.

Recommendations

This research of activity from four established referral refinement schemes of differing design has demonstrated that OSIs can successfully refine the referrals from non-OSIs for suspected glaucoma leading to a reduction in the FVDP. Patients with a high chance of being diagnosed with glaucoma based on the examination findings of the non-OSI should be referred directly to secondary care and those at lower risk could effectively be reviewed by an OSI carrying out a comprehensive eye examination. The results of this analysis lead to the recommendation that 'low-risk' should be defined as referrals based on IOP only, optic disc only, VF only and IOP and VF, with all other referrals including any reference to a shallow anterior chamber angle better suited to a direct referral to secondary care.

The inclusion of VF and disc examination is clearly associated with a lower FVDP and, therefore a detailed disc and VF examination should form part of the referral refinement in conjunction with Goldmann/Perkins tonometry for measuring the IOP. Using the referral criteria of the JCG will crucially allows the optometrist to operate within a professional and legal framework.

3.4. Agreement between eye health professionals

3.4.1. Background

The vast majority of referrals to Ophthalmology departments in the United Kingdom for suspected glaucoma are initiated by community-based optometrists (Bowling et al., 2005). Detection of glaucoma, a progressive optic neuropathy, relies on accurate measurements of the optic disc and also the functional consequences of the disease, measured by visual field testing. Raised IOP is an important risk factor for glaucoma hence the importance of also performing this measurement in primary care. Measuring the IOP with Goldmann or Perkins tonometry and slit-lamp binocular indirect ophthalmoscopy of the optic disc are core competencies of an optometrist's training, although in day-to-day clinical practice these examination techniques are often not used by community optometrists as part of a routine eye examination (College of Optometrists, 2011b, Myint et al., 2011). The published literature also reports a wide variation in the agreement of examination and management between optometrists and ophthalmologists (Abrams et al., 1994, Spry et al., 1999, Harper et al., 2000, Marks et al., 2012, Azuara-Blanco et al., 2007).

As previously mentioned, there are numerous GRRS operating successfully in the UK, though, being locally commissioned, they have marked differences in organisation set-up and referral criteria (Ang et al., 2009, Azuara-Blanco et al., 2007, Bourne et al., 2010, Devarajan et al., 2011, Henson et al., 2003, Local Optical Committee Support Unit, 2012, Parkins and Edgar, 2011, Syam et al., 2010). A Diploma in glaucoma or accreditation by a local hospital Ophthalmology department is often a pre-requisite before an optometrist can undertake glaucoma referral refinement (City University, 2012, College of Optometrists, 2011a, WOPEC, 2012) .

The Community and Hospital Allied Network Glaucoma Evaluation Scheme (CHANGES) involves both a triage of the referral letter from the original

primary care optometrist into a high or low-risk category and subsequent clinical refinement of referrals for suspected POAG. It has demonstrated that community based OSIs can effectively reduce the number of unnecessary referrals attending the hospital glaucoma service in low-risk patients (Bourne et al., 2010). Good agreement between the examination findings of a specialist optometrist in glaucoma and the hospital were reported with this and other schemes before the National Institute for Health and Clinical Excellence (NICE) glaucoma guidelines were published in April 2009 (Bourne et al., 2010, Devarajan et al., 2011, Harper et al., 2000, Marks et al., 2012, Syam et al., 2010). The publication of the NICE guidelines prompted a recommendation from the AOP, Association of British Dispensing Opticians (ABDO) and the Federation of Ophthalmic and Dispensing Opticians (FODO) to refer all patients with an IOP of greater than 21mmHg regardless of the method of measurement (NICE, 2009a, Association of Optometrists, 2010).

Subsequently in December 2009, the Royal College of Ophthalmologists and College of Optometrists released JCG guidance, which was updated in December 2010. It was recommended that a practitioner may consider not referring a patient aged 80 years and over with an IOP of less than 26mmHg, or for patients aged 65 years and older with IOP less than 25mmHg, if the remainder of the ocular examination is normal (Royal College of Ophthalmologists and College of Optometrists, 2009).

The impact of both of these guidelines on GRRS, including agreement in examination findings, has not been reported.

3.4.2. Purpose

The aim of this study was to assess the effect on agreement in clinical findings between clinicians in the referral pathway since the publication of the NICE guidelines and AOP/ABDO/FODO response.

3.4.3. Methods

Outcomes of all patients referred under the CHANGES scheme from its introduction in August 2006 until June 2011 were analyzed. This constituted a local audit/service review and was approved by the Trust Caldicott Guardian and audit department. This work did not require research and ethics approval as no patient identifiable information was used.

CHANGES scheme

See 3.2.3

Present study organisation

See 3.2.3

Outcomes measured

An IOP measurement of greater than 21mmHg in either eye was considered 'abnormal' IOP and an optic disc that had an appearance that was considered suspicious for glaucoma, was considered an 'abnormal' optic disc.

Inter-professional agreement for components of the examination was assessed for OSI and consultant (Part 1) and non-OSI and a specialist clinician, be it OSI or consultant (Part 2).

Part 1: Agreement between the Optometrist with Specialist Interest and the Consultant Ophthalmologist specialising in glaucoma.

Data from all new patients seen by the OSI since the scheme started in August 2006 until June 2011 were analysed. The pre NICE and post NICE agreement between the OSI and one of 2 consultant ophthalmologists specialising in glaucoma (RB and LC) for the identification of an abnormal IOP and optic disc was undertaken. The analysis consisted of all referred patients by the OSI as well as a sample of discharged patients in order to calculate the appropriate-referral proportion as well as an estimate of the inappropriate-referral proportion.

An appropriate referral is defined as one where the consultant agreed with the decision to refer to the hospital, on account of one or more abnormal glaucoma examination findings.

Part 2: Agreement between the original primary care optometrist (non-OSI) with a clinician with specialist glaucoma training (either the OSI or the consultant ophthalmologist).

The examination data from the referral forms of non-OSIs were collected for all new patients in four 2 month time periods: pre NICE (March and April 2009), post NICE (November and December 2009), post JCG (August and September 2010 and current practice (March and April 2011).

The agreement between the gold standard professional (consultant ophthalmologist for Part 1 and either the OSI or the consultant ophthalmologist for Part 2), was expressed as a percent positive predictive value (PPPV) of the referring clinicians findings (IOP and disc assessment), and represents the proportion of referrals that were true positives based on the same clinical parameters.

Data management and Statistical Analysis

Data from electronic patient records and paper copies of referral letters were collated on Microsoft Excel; statistical analysis was performed in R (version 2.15.1, R foundation for statistical computing).

Fischers exact test was used to test for statistical significance, as the samples were non-matched.

3.4.4. Results

Part 1: Agreement between the Optometrist with Specialist Interest and the consultant ophthalmologist specialising in glaucoma.

A total of 850 patients with low-risk referral letters were sent an appointment to see the OSI, of which 760 attended (277 pre and 483 post NICE). The average age of attendees was 59.5 years and 46% were male.

In the 32 months from the scheme's introduction to the publication of the NICE guidelines a total of 277 patients were seen by an OSI (8.7 per month), of which 184 (66%) were referred to the hospital and 93 (34%) discharged. In the 19 months post NICE 483 patients were seen (25.4 per month), of which 289 (60%) were referred to the hospital and 194 (40%) discharged. This increase in the discharge percentage from 34% pre NICE to 40% post NICE is not statistically significant using Fisher's Exact test (P = 0.07).

Agreement for abnormal IOP assessment

The PPPV for correct identification of an abnormal (>21mmHg) IOP in either eye was 61% pre NICE compared to 61% post NICE (p=0.51, Fisher's exact test).

Agreement for abnormal optic disc assessment

The PPPV for the correct identification of an abnormal optic disc was 61% pre NICE compared to 43% post NICE (p=0.02, Fisher's exact test).

Agreement for outcome of OSI appointment

The appropriate referral proportion for all patients referred by an OSI to the hospital was 70% pre NICE and 61% post NICE (p=0.07, Fisher's exact test).

92% (11/12) of patients that were sampled and clinically reviewed by the consultant after a normal OSI assessment were confirmed as being normal

and discharged after this hospital visit, with 1 patient being retained for further follow-up and given a diagnosis of glaucoma suspect. There were no cases where the consultant diagnosed glaucoma through this sampling process.

Part 2: Agreement between the original primary care optometrist (non-OSI) with a clinician with specialist glaucoma training (either the OSI or the consultant ophthalmologist).

A total of 434 patients were referred by the non-OSI during the 4 two-month periods of data collection, with an average age of 62.1 years and 42% were male. 304 of these patients (39% male) were deemed to be high-risk, with an average age of 64.0 years. The remaining 130 patients were classified as low-risk (44% male), with an average age of 57.4 years. Patients with high-risk referrals were significantly older than low-risk (p=0.01, independent t test), while there was no significant gender difference.

Agreement for IOP assessment

The non-OSI had documented the IOP in 88% (380/434) of referral letters for suspected glaucoma (90% in the low-risk group and to 87% in the high-risk group), with the use of Goldmann applanation tonometry documented in 46 (12%) of referrals and ‘air puff’ non contact tonometry or no documentation of method of tonometry in the remainder.

The PPPV for correct identification of an abnormal IOP in either eye was 63% pre NICE compared to 51% post NICE (p=0.12, Fisher’s exact test).

Where the non-OSI noted an IOP between 22 and 28mmHg the OSI agreed that the IOP was abnormal in 49% (40/81). Where the non-OSI noted an IOP greater than 21mmHg (in conjunction with another examination finding suspicious of glaucoma or where the only abnormal finding was an IOP greater than 28mmHg) the consultant noted an IOP greater than 21mmHg in

56.0% (28/50). This increased to 75% when the non-OSI found the IOP to be greater than 28mmHg.

A temporal trend was observed where low-risk and to a lesser extent high-risk groups demonstrated a decline in the PPPV more recently, though an increase in the PPPV was noted in current practice time period (these are detailed in Table 3-6 and Figure 3-9).

Agreement for optic disc assessment

The non-OSI had documented the optic disc appearance in 79% (342/434) of all referral letters. Among the letters triaged as 'low-risk', 83% had optic disc appearance documented, while this was noted in 77% of high-risk letters.

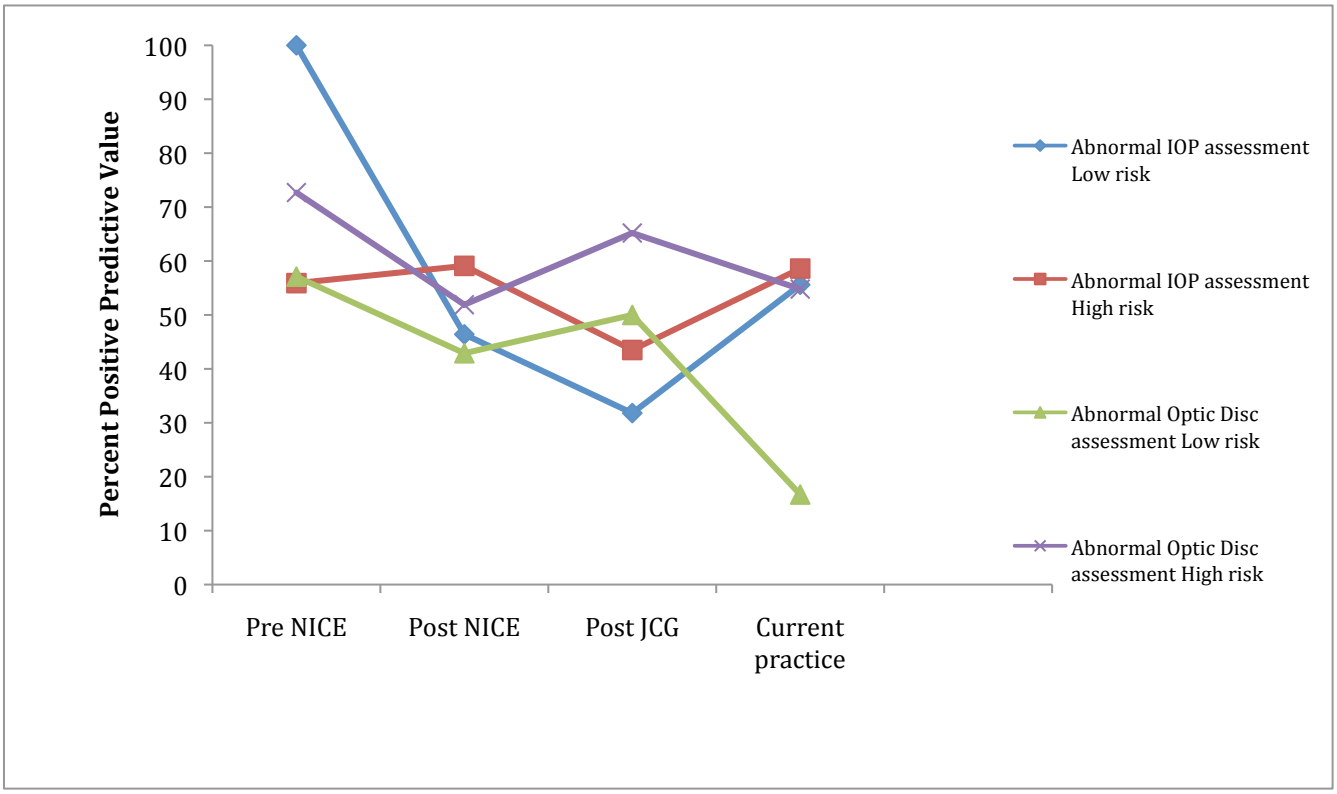
The PPPV for the correct identification of an abnormal optic disc was 70% pre NICE compared to 53% post NICE (p=0.04, Fisher's exact test).

A temporal trend was observed in which the low-risk group demonstrated a larger reduction in PPPV post NICE than the high-risk, with both groups improving post original JCG and declining once more in current practice (these are detailed in Table 3-6 and Figure 3-9).

Table 3-6. Percent positive predictive values for an abnormal IOP and abnormal optic disc assessment for each referral letter risk group by time period.

	Abnormal IOP assessment				Abnormal Optic Disc assessment			
	Low-risk group		High-risk group		Low-risk group		High-risk group	
	PPPV	(n)	PPPV	(n)	PPPV	(n)	PPPV	(n)
All times frames	49	81	56	50	43	53	61	93
Pre NICE	100	6	56	8	57	16	73	24
Post NICE	46	27	59	12	43	5	52	29
Post JCG	31	20	44	12	50	16	65	19
Current practice	56	28	59	18	17	16	55	21

Figure 3-9. Percent Positive Predictive Value for identification of abnormal IOP and optic disc assessment for each time period.



3.4.5. Discussion

A dramatic increase in the number of glaucoma referrals has occurred since the introduction of the NICE guidelines, which has placed an increased burden on ophthalmology out-patient departments nationally (Shah and Murdoch, 2011). This is reflected in the observation of increased scheme activity from a mean of 8.7 patients per month pre NICE to 25.4 per month post NICE, coupled with an increased discharge proportion from 34% to 40%. These changes in referral activity suggest that the NICE guidelines and, more specifically, the response of the AOP to these guidelines has resulted in an increase in the numbers being referred by non-OSIs for suspected glaucoma coupled with a reduction in the diagnostic accuracy of these referrals. The reduction in appropriate referral proportion from an OSI to the hospital reduced (from 70% pre NICE to 61% post NICE) would appear to be a consequence of this change in referral activity.

There was no change in the PPPV for the identification of an abnormal IOP between an OSI and a consultant in the post NICE period compared to pre NICE, explained by the standardisation of techniques employed by both the OSI and the consultant to measure the IOP. It is has been reported that in the period post NICE guideline introduction the total number of referrals for only raised IOP and the FVDP associated with these referrals has increased (Khan et al., 2012, Ratnarajan et al., 2013a, Shah and Murdoch, 2011). The results indicate that the probability of a consultant reproducing the non-OSIs finding of a moderately raised IOP (22-28mmHg) is lower than that of a significantly raised IOP (>28mmHg). This is not unexpected but it demonstrates how stratification of risk on the basis of IOP is an important aspect of this and other referral refinement schemes, with the effect of such a stratification on inter-professional agreement reported for the first time in this study. The finding of improved PPPV for the identification of an abnormal IOP between OSI and consultant, than between non-OSI and OSI can at least in part be explained by the standardisation of IOP measurement technique (Goldmann tonometry)

between OSI and consultant in this scheme. The original JCG did not improve the PPPV for abnormal IOP assessments for both low and high-risk referrals, although the updated JCG, where clearer guidance was given to referring optometrists on how IOP should be measured with both Goldmann and non-contact tonometry, did lead to an improvement in the PPPV in both groups.

PPPV between the OSI and consultant for identification of an abnormal optic disc demonstrated a statistically significant decline post NICE (61% to 43%). This is an interesting finding as dilated disc assessment with indirect slit-lamp based ophthalmoscopy has been used since the introduction of this particular scheme. The lack of legal indemnity for optometrists not complying with the AOP's recommendation to the NICE guidelines may have led optometrists to adopt a more risk averse and medico-legally defensive approach to practice. The above finding suggests this may also be true for the OSI group with respect to optic disc assessment though not for IOP assessment. Agreement levels in the assessment of optic disc are known to variable (Reus et al., 2010, Andersson et al., 2011, Kong et al., 2011, van der Schoot et al., 2013), and may help to explain decline in disc assessment in the post NICE period, although the OSIs in the scheme were unchanged pre and post NICE . In addition, continued education and training of OSI is important to maintain high clinical standards.

The good agreement between OSI and consultant for the sample of discharged patients implies that normal observations are being correctly identified, however a larger sample is needed to make firm conclusions.

There are some limitations that warrant discussion. It has been assumed that the findings of the consultant ophthalmologists with specialist interest in glaucoma are the gold standard and therefore are correct. A similar assumption is made for the OSI in the review of low-risk referrals from a non-OSI. The patient population seen by the OSIs and Consultant is an enriched population with a higher prevalence of glaucoma compared to that of the non-OSIs, who are performing opportunistic surveillance. Additionally, the analysis of non-OSI and OSI agreement for the pre NICE period was based on only 16

patients, which is a smaller sample size than the other 2 month periods analysed. This relatively small sample reflects the lower activity of the CHANGES scheme in this period compared to the post-NICE period. In addition the sample used to calculate agreements for normal examination findings can only be an estimate as information was only gathered from patients that were referred to secondary care, therefore not representative of the total patient population seen by the OSI and non-OSI.

Another potential limitation to the study, but one that does reflect clinical practice is that the examination techniques employed by the non-OSI may differ from that of the OSI or consultant. Typically a non-OSI will not dilate the pupil to perform an examination of the optic disc, whereas the OSI and consultant would always dilate the pupil except in the presence of an occludable anterior chamber angle. By way of a national survey of UK community optometrists, Myint *et* al reported that 25% of optometrists used direct ophthalmoscopy alone and a further 62% used a combination of direct ophthalmoscopy and slit-lamp binocular indirect ophthalmoscopy, whereas the OSI or consultant in the CHANGES scheme only used slit-lamp binocular indirect techniques (Myint et al., 2011). A difference in the method used for measuring IOP also exists, with the OSI and consultant solely using Goldmann applanation tonometry. Therefore the agreement values involving the non-OSI in this report are not necessarily a comparison of two comparable examination techniques.

3.5 The experience of care and awareness of sight testing entitlements in patients referred for suspected glaucoma.

3.5.1 Background

Glaucoma affects more than 67 million people worldwide, and is one of the world's leading cause of irreversible blindness (Quigley, 1996). Up to twenty percent of referrals to ophthalmology clinics in the UK are for suspected glaucoma, with the annual cost for monitoring patients with this chronic, and potentially blinding condition estimated to be £22,469,000 (Davey et al., 2011, National Institute for Health and Clinical Excellence, 2009). Despite this, over fifty percent of patients in the UK with glaucoma are believed to remain undiagnosed (Burr et al., 2007).

It is known that follow-up patients accessing eye care would like to travel a short distance and patients living furthest from hospital or with severe visual disability prefer a minimum of visits to complete a care episode (Bhargava et al., 2008, Gray et al., 1997). In addition, two studies in the UK have shown that patients presenting with advanced glaucoma are more likely to come from areas of greater social deprivation (Day et al., 2010, Fraser et al., 2001).

The NICE guidelines for glaucoma diagnosis and management were published in April 2009 (NICE, 2009a). After an initial scoping exercise it was decided not to include case-finding within the remit of this guidance to prevent the guidance from becoming unmanageably large (Sparrow, 2012). As previously mentioned, the professional representative organizations for optometry practice, the AOP, ABDO and FODO, responded to these guidelines by recommending an ophthalmology referral for all patients with an IOP of greater than 21mmHg irrespective of tonometry method. This resulted in a large and sudden increase in referral numbers to the HES, nearly half of which were discharged after only a single visit (Edgar et al., 2010 , Ratnarajan et al., 2014, Shah and Murdoch, 2011)

Given this rapid transformation of glaucoma referral clinical care pathways there is interest in understanding the outcomes of patients attending both the initial optometrist visit and the hospital visit using a range of clinical and patient reported outcome measures as well as their experience of care and the costs associated with providing it (Sharma et al., 2010, Sharma et al., 2012, Prior et al., 2011). Several frameworks defining important dimensions of patient experience exist (Gerteis M et al., 1993) and instruments to measure the patients' experience of care (patient reported experience measures, PREMs) which provide information about experiences of care have been reported (Schuman, 2008, Somner et al., 2012). Recent qualitative work indicated that both outcomes and experience are of importance to patients and a short combined patient outcomes and experience measure (POEM) instrument was proposed (Somner et al., 2012).

3.5.2 Purpose

The purpose of this study was to explore the reported experience of care of new patients attending a glaucoma clinic appointment as well as their awareness of sight testing entitlements. Factors associated with experience of care in glaucoma have not previously been reported for new patients to a glaucoma clinic.

3.5.3 Methods

Three hundred and thirty five consecutive new patients who attended a glaucoma clinic appointment at Hinchingbrooke Hospital between August 2011 and April 2012 were prospectively reviewed after Trust approval was obtained. All patients were seen by a single consultant ophthalmologist specialising in glaucoma.

After informed consent was obtained, patients completed a two-part non-identifiable anonymised questionnaire after the hospital clinic visit. The first part involved questions related to patient demographics, reasons for attending

the optometrist, awareness at the time of sight testing of eligibility for free sight-tests and what a sight-test entails. The travel arrangements required to attend both the optometrist and hospital visit, including cost, were collected and compared, with a further sub-group analysis in which subgroups were based on the diagnosis made by the hospital. A second part of the questionnaire rated the knowledge, thoroughness, explanation and time spent by the consultant during the hospital visit. A rating of excellent scored 5 points, with ratings of good, average, below average and poor scoring 4,3,2 and 1 respectively. The second part of the questionnaire also asked which of the two appointments, optometrist or hospital, the patient found easier to attend.

The questionnaire addressed several of the dimensions developed by Gerteis (Gerteis M et al., 1993) and the eight Picker principles (Respect for patients values, Preferences and expressed needs, Co-ordination and integration of care, Information, communication and education, Emotional support and alleviation of fear and anxiety, Involvement of family and friends, Transition and continuity, Access to care) (Shaller, 2007) that were recommended by the NICE guidelines on patient experience in adult NHS services (NICE, 2012a).

Social deprivation was estimated from the patient's postcode using the IMD 2010. The national average IMD for 2010 is 21.7, and is calculated using 38 separate indicators, organized across seven distinct domains of deprivation including income, employment, health and disability, education, housing, environment and crime (Communities and Local Government, 2010).

Data Collection and Statistical Analysis:

Data from the questionnaires were entered into Microsoft Excel 2007 whilst statistical analysis was performed in R (version 2.15.1, R Foundation for Statistical Computing). Ninety-five percent confidence limits for differences between means, and P-values for paired and two-sample t-tests were obtained using permutations tests. The comparison of independent percentages was made using Fisher's Exact tests, and the comparison of

correlated percentages was made using McNemar's Test with the exact binomial probability.

3.5.4 Results

3.5.4.1 General Demographics

Three hundred and thirty five patients newly referred to the hospital glaucoma service were included in the analysis of which 48% were male and the median age was 62 years (range, 21 to 89). Ninety six percent of the patients were Caucasian, 2% were African Caribbean and 2% were Asian. Thirty one percent of patients had a known family history of glaucoma, of which 23% were first-degree relatives. 11% of the patients were known to have diabetes. Forty eight percent of patients were retired, 84% were homeowners and 87% car owners.

3.5.4.2 Reasons for Optometrist visit

Patients most commonly attended the optometrist in response to a reminder letter having been seen previously by that practice (44%), but also attended when they felt they needed new glasses (18%), were not able to see clearly (13%). The remaining 25% attended for a combination of the above reasons or specified another reason such as pain or pressure in the eyes. Patients chose to attend a specific optometrist because they had previously been seen by them (51%), they were close to home or work (17%), had been recommended (14%) or a combination of these factors (18%).

3.5.4.3 Patient knowledge

Ninety five percent of patients knew that attending a sight-test appointment involved an examination of the health of the eye. Eighty percent of patients were aware that sight tests are available at no cost to those aged 60 and older and 61% patients were aware that this was also the case for those aged

40 and older with a family history of glaucoma. Additionally 55% of patients were aware that free sight tests are available for patients with a history of diabetes.

3.5.4.4 Travel arrangements for hospital and optometrist appointments

Ninety percent of patients travelled to the hospital appointment by car, 5% by public transport, 3% by foot, 1% by motorcycle and 1% by hospital transport. In comparison 76% of patients travelled to the optometrist appointment by car, 6% by public transport, 15% by foot, and 3% by bicycle. The mean patient reported cost to travel to the hospital was £2.08 and £0.91 to the optometrist (permutation paired t-test, $p < 0.001$).

The mean distance travelled by patients to attend the hospital appointment was 9.4 miles compared to 5.5 miles for the optometrist (permutation paired t-test, $p < 0.001$). The mean time taken to travel to the hospital was 23 minutes compared to 17 minutes for the optometrist (permutation paired t-test, $p < 0.001$). Nineteen percent of patients lived within 5 miles of the hospital compared to 55% for the optometrist (exact McNemar's test, $p < 0.001$). Forty-four percent of patients were accompanied to the hospital while 32% were accompanied when attending the optometrist visit. Overall 62% found travelling to the optometrist easier than the hospital, 25% the hospital easier and 13% reported equal ease of access.

3.5.4.5 Diagnostic outcome at the hospital visit

The FVDP by the Consultant Ophthalmic Surgeon with a specialist interest in glaucoma was 48%. Diagnoses for the entire group were as follows: 5% primary open angle glaucoma, 18% glaucoma suspect, 13% ocular hypertension (OHT) not requiring treatment, 43% normal ocular examination, 21% other. Associations were tested between selected categorical variables from the questionnaire results and two subgroups based on the hospital-based diagnostic outcome (Table 3-7). These two subgroups were patients

with glaucoma/suspect glaucoma (n=79), and patients with no evidence of glaucoma (n=256). This latter group included patients with OHT not requiring treatment. The mean IMD was 9.1 for both glaucoma/suspect glaucoma group as well as the no evidence of glaucoma group (permutation two-sample t-test, p =0.96).

Table 3-7. The association of selected categorical variables from the questionnaire results with the hospital-based diagnostic outcome (represented as two groups: i) patients with glaucoma/suspect glaucoma, ii) patients with no evidence of glaucoma.

Variable and category	Diagnostic group		P- value
	Glaucoma or suspect (G) (n = 79)	No glaucoma (N) (n = 256)	
Median age (years)	66	60	<0.001
% aged over 60 years	72%	50%	< 0.001
% aware free sight test if > 60 years	84%	79%	0.41
% aware free sight test if > 40 years and FH of glaucoma	55%	62%	0.328
% not visited optometrist for at least 12 months prior to referral	78%	76%	0.87
% living within 5 miles from referring optometrist	57%	54%	0.79
% living within 5 miles from hospital	10%	21%	0.030
% paid < £2 for optometrist visit	83%	89%	0.243
% paid < £2 for hospital visit	26%	24%	0.75

For age the P-value was obtained using a two-sample permutation test. For the percentages the P-values were obtained using Fisher's Exact test.

3.5.4.6 Satisfaction score and overall preference

The mean satisfaction score for the hospital consultation was 4.6 out of 5 (4.3 for glaucoma and suspect glaucoma and 4.7 for no glaucoma (permutation two-sample t-test, p = 0.01)) with the overall component satisfaction scores for knowledge, thoroughness, explanation and time spent of 4.8, 4.8, 4.6 and 4.5 respectively. The mean wait to see the consultant was 65 minutes.

3.5.5 Discussion

Reasons for attending a sight-test are complex and multifactorial. Experience from Scotland suggests universal free sight testing does increase attendance although the under-privileged are still under represented (Dickey H, 2012). The Royal National Institute of Blind People (RNIB) Community Engagement project had identified limited community awareness of eye health and symptom-led demand for eye examinations as barriers for uptake of sight testing (Hayden C, 2012); a finding supported by this study. The results of this study highlight the need to increase awareness and promote patient education about free-sight testing, particularly in those with a family history of glaucoma as just over half of those with glaucoma were aware of it. Awareness of free sight testing for those over 60 years of age was higher in the patients diagnosed with glaucoma but this may be a reflection of the higher median age of this group compared to those without glaucoma.

Symptom led demand for sight testing was also evident in this study as 31% waited until they could not see clearly or felt they needed new glasses before attending the optometrist. Optometrists routinely send reminder letters to patients when sight-tests are due, however this was the reason for attendance in only 44% of cases. With 57% of those with glaucoma living within 5 miles of an optometrist and 83% paying less than £2 to travel to the optometrist, other barriers to uptake of sight tests, such as the association of sight testing with buying spectacles, appear to be involved. This highlights the need to further explore cost effective, non-commercial models for sight testing and screening

(Burr et al., 2011, Burr et al., 2007, Hernandez et al., 2008a, Hernandez et al., 2008b, Mowatt et al., 2008, Prior et al., 2012).

Ease of access to health care is important to patients (Gray et al., 1997), and this study clearly shows the statistically significant reduction in costs and travel distance for those attending the community optometrist compared to the hospital. Slightly over half the patients in this study live within 5 miles of their optometrist with no statistically significant difference between those with glaucoma or suspect glaucoma to those with no evidence of glaucoma. However, a statistically significant percentage of patients with glaucoma or suspect glaucoma live greater than 5 miles from the hospital compared to those with no glaucoma. Whilst it may be acceptable for a patient to travel a greater distance and pay more money to attend a new outpatient appointment, it may be more convenient to the patient if long-term review was not carried out in the hospital.

Patients from more deprived areas have been shown to present with more advanced glaucoma (Day et al., 2010, Fraser et al., 2001). In this population, which is more affluent than the national average the IMD was 9.1 in both groups. The severity of glaucoma at diagnosis is unknown in this study.

A FVDP of 48% in this study highlights the need to improve the efficiency of the referral pathway, particularly by reducing inappropriate referrals to the hospital eye service. Enhanced optometry services have been seen as a solution and have been developed in many areas in the UK to both refine referrals as well as provide follow-up care (Bourne et al., 2010, Devarajan et al., 2011, Henson et al., 2003, Local Optical Committee Support Unit, 2012, Parkins and Edgar, 2011, Syam et al., 2010, Ratnarajan et al., 2012). Some studies have reported that patients with stable glaucoma prefer their follow-up in the community, thus supporting the enhanced optometry service model (Bhargava et al., 2008, Gray et al., 1997). However, the preference of new patients with respect to which eye health professional they see and the location is unknown. The results from this study suggest new patients are

satisfied with the current model of care despite the extra distance and cost associated with the hospital visit.

Clinical outcomes in glaucoma take many years to develop while changes to services, have been much more rapid. Patients may want and possibly expect to see a consultant after an optometrist has raised the spectre of glaucoma, and this report has shown high patient satisfaction with this appointment. The Joint College Guidance published in March 2013 has recommended both repeat pressure and glaucoma referral refinement schemes as effective ways to reduce unnecessary referrals to the hospital (Royal College of Ophthalmologists and College of Optometrists, 2013a), however the satisfaction of patients within enhanced optometry services needs to be evaluated using a validated framework.

This is a single-site sample with a lower than average IMD, meaning the results of this paper cannot necessarily be directly applied to other populations, and is a limitation of this study that should be considered. Despite the patient satisfaction component of the questionnaire being anonymous, bias may have been introduced as patients completed the questionnaire at the point of care.

To conclude, the results from this study demonstrate high satisfaction in referred patients with suspected glaucoma although there is a need to increase patient education and awareness of eligibility of free-sight testing to increase attendance in primary care, which will result in more effective glaucoma case-finding. There is also a need to update national guidance to incorporate coherent referral criteria, agreed by both ophthalmologists and optometrists, to reduce the number of inappropriate referrals.

3.6 The Equity profile of an Enhanced Optometry scheme.

3.6.1 Background

Hospital episode statistics indicate there were over 5.5 million Ophthalmology out-patient attendances in England in 2009, of which 1.5 million were new attendances (Hospital Episode Statistics). Up to twenty percent of these attendances were referrals for suspected glaucoma, with the annual cost for monitoring patients with this chronic, and potentially blinding condition estimated to be £22,469,000 (NICE, 2012a).

In the UK, most referrals for suspected glaucoma are generated through opportunistic surveillance during sight tests by primary care optometrists (PCO) (Bowling et al., 2005, Burr et al., 2007, Davey et al., 2011). The location of optometrist practices has been shown to be poorly correlated with service demands with fewer optometrists in areas of higher social deprivation (Day et al., 2010). Individuals from these deprived areas were also shown to present with more advanced disease (Fraser et al., 2001, Day et al., 2010). These studies focused on deprived and urban populations, and may not be a reflection of the problem nationally.

To reduce the burden on the HES caused by the large increase in referrals, enhanced optometry services, such as glaucoma referral refinement, have been increasingly carried out in community practices by OSIs. These services have been shown to deliver safe and reliable ophthalmic care, whilst simultaneously reducing the amount of inappropriate referrals to secondary care by 20% compared to referrals directly from optometrists without specialist interest (Bourne et al., 2010, Ratnarajan et al., 2012, Ratnarajan et al., 2013a, Ratnarajan et al., 2013b).

Glaucoma referral refinement is predominately community-based and has been shown to result in less distance travelled and cost saving to the patient (Ratnarajan et al., 2014). An example of this is the CHANGES scheme that

operates in the semi-rural, predominately Caucasian catchment area of Hinchingbrooke Hospital. In this scheme patients are triaged according to risk factors on the referral form, with low-risk patients directed to OSI review and high-risk patients directly to the hospital.

As stated in 2.5 equity profiling is essential to enable commissioning of effective healthcare that is mapped directly to the needs of the population at a local level (Day et al., 2010). Equity profiling in the ophthalmic literature has focused on socially deprived urban populations (Day et al., 2010). Whilst this is undoubtedly a key demographic, it is by no means representative of the entire population. Therefore, in this study an equity profile was carried out for a semi-rural, relatively affluent population to establish the differences, if any, with respect to the provision and distribution of eye health care. Moreover, this study is the first equity profile of an enhanced optometry scheme. An analysis based on patient proximity to the hospital, OSI or PCO was conducted.

3.6.2 Purpose

The purpose of this study was to perform an equity profile for an enhanced optometry scheme to establish if effective eye health care was being provided to its catchment population.

3.6.3 Methods

After Trust approval, the records of all patients referred under the CHANGES scheme from its introduction in August 2006 until June 2011 were retrospectively audited and analysed.

3.6.3.1 CHANGES scheme

All referral letters for suspected glaucoma from the PCO are categorised by an experienced hospital-based optometrist as either low- or high-risk according to a protocol based on the examination findings listed in the letter. A referral was deemed low-risk if only one of the following risk factors was noted and high-risk if more than one low-risk factor was present, or alternatively if a shallow anterior chamber, IOP >28mmHg, optic disc haemorrhage, pigment dispersion or pseudoexfoliation were detected. Low-risk patients are reviewed by an OSI and high-risk patients are seen directly in the hospital glaucoma clinic. For more details on the organisation of the CHANGES scheme see 3.2.3

3.6.3.2 Data collection

Anonymised demographic data, the reason for referral, final diagnosis and mean deviation of the presenting VF were collated. The road distance from the patients' home postcode to the optometrist, OSI, and Hinchingbrooke hospital was calculated using the Geographical Information System (GIS) package ArcGIS v10. A digital representation of the road network was constructed using the Ordnance Survey Meridian data and network routing algorithms were used in the GIS to identify the most direct route along the road network from each patient's home to each of the health services of interest, and to calculate the total distance for that route (Survey, 2013). All calculations assumed car travel. As a measure of neighbourhood material deprivation the IMD 2010 score was calculated for each individual based on the Census Lower Super Output Area zone that their postcode was allocated to (Communities and Local Government, 2010). The IMD 2010 is calculated using 38 separate indicators, organized across seven distinct domains of deprivation including income, employment, health and disability, education, housing, environment and crime.

3.6.3.3 Data management and statistical analysis

Anonymised patient information from the referral forms of the community optometrist and the OSI, as well as the hospital patient records, was collated on a database in Microsoft Excel; statistical analysis was performed in R (version 2.15.1, R foundation for statistical computing). Categorical variables have been analysed using Fisher's Exact Test, and the means of continuous variables have been compared using permutations tests which do not require the usual distributional assumptions.

3.6.4 Results

A total of 2794 patients were included. The estimated median age was 58 years, and 43% were male. 2078 (74.4%) referrals were classified as high-risk and 716 (25.6%) were low-risk.

Table 3-8 compares high and low-risk patients based on diagnosis, and Table 3-9 compares high and low-risk patients based on distance to PCO or the HES. The location of low-risk patients with glaucoma compared to the surrounding eye health care services is illustrated in Figure 3-10.

3.6.4.1 Low-risk referrals

The median age of low-risk referrals were 54 and 47% were male. The mean IMD was 10.0. The mean distance to the PCO was 9.0 km, to the OSI it was 8.4 km, and to the HES 12.5 km. 31 (4.3%) were diagnosed with POAG and 352 (49.2%) as no evidence of glaucoma, with the remaining classified as glaucoma suspect or OHT.

3.6.4.2 High-risk referrals

The median age of the 2078 high-risk referrals was 60, and 43% were male. The mean IMD was 10.6. The mean distance to the PCO was 8.2 km and to the HES 13.6 km. 236 (11.4%) were diagnosed with POAG and 780 (37.5%) as no evidence of glaucoma, with the remaining classified as glaucoma suspect or OHT.

Table 3-8. Comparison high and low-risk patients based on diagnosis.

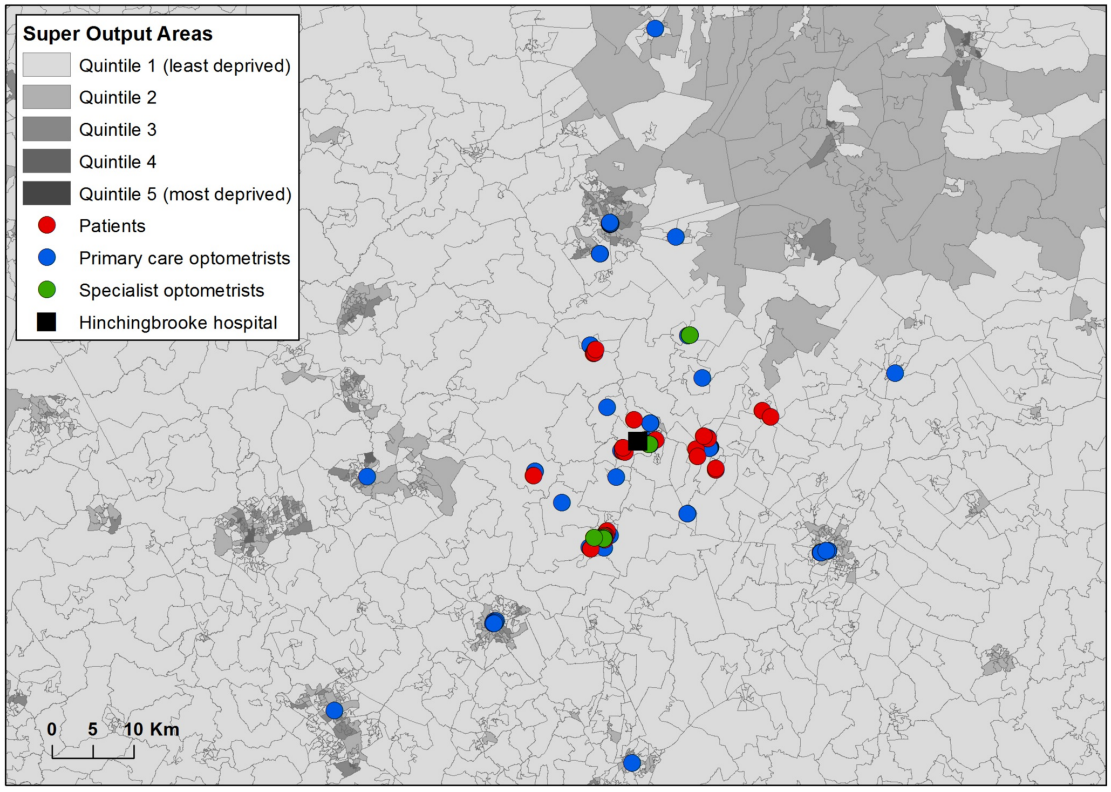
	Low-risk referrals			High-risk referrals		
	Diagnosed with Glaucoma (n = 31)	No evidence of glaucoma (n = 352)	P value for difference	Diagnosed with Glaucoma (n = 236)	No evidence of glaucoma (n = 780)	P value for difference
Mean Age (years)	67	53	< 0.01	68	56	< 0.01
% Male	45	47	1.00	45	42	0.45
Mean IMD	9.6	9.2	0.75	10.7	10.4	0.56
Mean distance to referring optometrist (km)	8.6	8.5	0.96	8.0	8.0	0.97
Mean Distance to specialist optometrist (km)	7.6	8.1	0.72	N/A	N/A	N/A
Mean distance to hospital (km)	11.7	12.6	0.42	13.7	14.1	0.47

Table 3-9. Comparison of high and low-risk patients living closer to the primary-care optometrist with those living closer to the hospital.

	Low-risk referrals				High-risk referrals		
	Closer to optometrist (n = 295)	Closer to OSI (n=192)	Closer to Hospital (n=46)	P-value for difference	Closer to optometrist (n=1405)	Closer to Hospital (n=311)	P-value for difference
Mean distance to service (km)	5.2	6.0	8.0	< 0.01	5.6	10.0	< 0.01
Mean age at audit (years)	55	53	55	0.25	60	57	< 0.01
% Male	44	48	46	0.56	43	48	0.11
Mean IMD	9.8	9.6	8.0	0.15	11.0	8.9	< 0.01
% living in most deprived quartile	21	19	2	< 0.01	30	13	< 0.01
% Glaucoma	4	4	7	0.63	12	11	0.69
% Discharged	40	37	28	0.27	34	34	1.00

Figure 3-10. Map showing location of low-risk patients with glaucoma compared to the surrounding eye health care services.

(Each dot corresponds to a geographic location and not necessarily to single patient or eye health professional)



3.6.4.3 Visual field at presentation analysis

Amongst the 2078 high-risk patients 1884 had visual field measurements of mean deviation, and of these 1651 (87.6%) had a mild VF defect at presentation (defined as a mean deviation of less than or equal to -6dB in the worse eye). 151 (8.0%) had a moderate VF defect at presentation (defined as greater than 6 but less than or equal to -12dB in the worse eye). 82 (4.4%) had a severe VF defect at presentation (defined as greater than -12dB in the worse eye). Table 3-10 compares the access to eye health care based on severity of VF at presentation.

Table 3-10. Comparison of high-risk patient access to eye health care based on visual field loss at presentation.

	MILD VF LOSS (n=1651)	MODERATE VF LOSS (n=151)	SEVERE VF LOSS (n=82)	P-value
Mean IMD	10.5	10.8	11.5	0.36
Distance to primary care optom (km)	8.3	8.6	5.7	0.27
Distance to Hospital (km)	13.7	12.7	13.5	0.40

3.6.5 Discussion

As expected the majority of patients live closer to an optometrist than the HES and this 'care closer to home' is the main driver towards developing quality community based eye health services at a national level. More specifically low-risk patients who are found to have glaucoma after HES review live on average 4.1km closer to the OSI than the HES. In fact the specialist optometrist is often more proximal to the patient's home than even the referring optometrist. This is important as the OSIs in enhanced schemes are distributed according to the service needs of its population rather than economic considerations as demonstrated in figure 3-10.

In this study there is no association between final diagnosis and distance to an eye health professional, in particular the optometrist. The severity of glaucoma at presentation is independent of deprivation and distance to the optometrist or hospital, with patients who were diagnosed with glaucoma and had a severe VF loss actually living closer to the PCO than those with mild or moderate VF loss with no significant differences in deprivation scores. This is in contrast to Fraser *et al* who found deprivation to be linked with late presentation of glaucoma to the hospital (Fraser et al., 2001). The populations from these studies are markedly distinct, with the CHANGES scheme semi-

rural and relatively affluent compared to urban and deprived in the aforementioned studies.

Despite no overall association between diagnosis and distance travelled, there was a highly statistically significant difference in the mean distance travelled by patients living closer to an optometrist (PCO or OSI) compared to those living closer to the HES. High-risk patients living closer to the PCO were older and more likely to be from the most socially deprived quartile of the sample. Low-risk patients living closer to the PCO or OSI compared to the HES also travel a significantly shorter distance, with a larger percentage of patients living in the most socially deprived quartile of the sample. Day *et al* showed a scarcity of optometric service provision in a deprived urban population (Day et al., 2010), whereas optometry services were accessible to the most deprived persons of this semi-rural study. This raises the important question of how to develop glaucoma referral models on a national basis if access to eye health care varies so widely. This study suggests that whilst national standards need to be introduced for glaucoma referral models to address factors such as the level of competency and accreditation of the eye health professional or the time frame in which the patient is seen, it would be wise for details such as number and location of these practices to be decided at a local level.

In chapter 3.5 it has been demonstrated that despite the significantly greater distances travelled to the HES than the optometrist, patients are satisfied with the level of care in the HES and the majority would prefer to see an ophthalmologist after the optometrist has raised the spectre of glaucoma during a sight-test (Ratnarajan et al., 2014).

Equity profiling is a quick and inexpensive way for health professionals and commissioners to understand the need, met or unmet, for their population. This is the first equity profile for an enhanced optometrist service, and only the second equity profile in glaucoma overall. It has demonstrated that the CHANGES scheme does provide a specialist optometric service that is easily accessible to its catchment. Comparison with the first published equity profile

highlights the stark variations that can be observed with regard to patient access to eye health care and the effect of this on the subsequent diagnosis of glaucoma. Further equity profiling studies will better inform future national guidance on referral models in ophthalmology.

This study was not a formal epidemiological survey, but did use an accurate database constructed for the CHANGES scheme. A large number of patients were included in the analysis, and the catchment area of the scheme is free from alternative secondary eye care providers thus eliminating selection bias.

The main weakness is that this is a single site study on a relatively affluent semi-rural population and this might limit the generalisability of the findings to other populations.

3.7 The false negative proportion and the role for virtual review in a nationally evaluated glaucoma referral refinement scheme.

3.7.1 Background

Glaucoma is the world's leading cause of irreversible blindness (Bourne et al., 2013), with a recent study demonstrating a marked increase in disease burden over the last 20 years (measured in disability adjusted life years) in the UK (Murray et al., 2013). Up to twenty percent of referrals to ophthalmology clinics in the UK are for suspected glaucoma, with the annual cost for monitoring patients with this chronic, and potentially blinding condition estimated to be £22,469,000 (National Institute for Health and Clinical Excellence, 2009, Davey et al., 2011).

The number of referrals for suspected glaucoma, particularly those discharged at the first visit to the Hospital Eye Service (HES), has been increasing for many years, though this has been more marked since the publication of the National Institute for Health & Clinical Excellence (NICE) guidelines 'Glaucoma: Diagnosis and management of chronic open angle glaucoma and ocular hypertension' in April 2009 and the response of the Association of Optometrists (AOP), Association of British Dispensing Opticians (ABDO) and the Federation of Ophthalmic and Dispensing Opticians (FODO) (Ratnarajan et al., 2012, Vernon, 1998, NICE, 2009a, Association of Optometrists, 2010).

As previously mentioned; in an attempt to reduce the number of referrals to the HES, the College of Optometrists and Royal College of Ophthalmologists released Joint College Group (JCG) referral guidance recommending additional criteria: that a practitioner may consider not referring a patient aged 80 years and over with an IOP of less than 26mmHg, or patients aged 65 years and older with IOP less than 25mmHg, if the remainder of the ocular

examination is normal, as these patients are not recommended for treatment under the current NICE guidance (College of Optometrists, 2010).

A more recent guideline published by NICE in March 2012, entitled ‘Services for people at risk of developing glaucoma’, was aimed at the commissioning of glaucoma services. It recommends that patients with an IOP of greater than 30mmHg be referred to secondary care without delay suggesting that these patients are not suitable for a community-based refinement of the referral (NICE, 2012b).

GRRS have proliferated across the country over the past decade, often demonstrating marked variation in pathway design, referral criteria as well as the level of competency and training required by the participating optometrists (Ang et al., 2009, Bourne et al., 2010, Devarajan et al., 2011, Henson et al., 2003, Parkins and Edgar, 2011, Syam et al., 2010).

In Chapter 3.3 a multi-site review of GRRS in the UK demonstrated that involving optometrists with a specialist interest (OSI) in glaucoma in the care pathway of patients referred following an initial optometrist assessment for glaucoma risk, can decrease the FVDP as compared with traditional pathways of direct referral of all at-risk patients from primary to secondary care. This reduction in ‘false-positive’ referrals reaching the ophthalmologist-led hospital based glaucoma service reduced the burden on the HES (Ratnarajan et al., 2013b). This paper recommended the triage of referral information from the initial optometrist community-based assessment into two groups of patients, ‘high’ and ‘low’ glaucoma risk, in order to establish much-needed standardization of GRRS across the UK. Our work recommended that referral information involving one of the following criteria would be suitable for assessment by an OSI in advance of (or obviating the need for) a specialist glaucoma hospital-based ophthalmologist assessment (Ratnarajan et al., 2013b):

- Elevated IOP only (but less than 30mmHg)
- Abnormal optic disc only
- Abnormal VF only

- Elevated IOP and abnormal VF

Additionally it was recommended that the OSI subsequently refer to the HES if any of the following observations were made:

- IOP was outside JCG recommendations using Goldmann applanation tonometry (GAT)
- Optic disc pathology found after dilated slit-lamp examination
- Abnormal visual field (ideally using Humphrey visual field machine)

GRRS allows for the OSI to discharge patients in whom the OSI judges there to be no glaucoma risk. The multi-site review and the literature in general, has not been able to comment on the safety of GRRS with respect to patients who may be inappropriately discharged by the OSI. Given that these patients are not seen in the HES there has not been the opportunity to validate the OSI's decision to discharge, hence the first aim of this study, to establish the numbers of patients who may be falsely discharged by community-based specialist optometrists involved in this GRRS. Virtual review of the OSI examination findings in conjunction with an optic disc photograph by a hospital-based specialist optometrist or ophthalmologist has been reported as an effective method to prevent inappropriate discharges by the OSI (Bourne et al., 2010, Devarajan et al., 2011), although its effectiveness compared to physical review in the HES by a consultant ophthalmologist specialising in glaucoma is unknown. The second aim of this work was therefore to compare decision-making between specialist optometrists and consultant ophthalmologist when evaluating optic disc images for the presence of glaucomatous optic neuropathy.

3.7.2 Purpose

The primary purpose of this study was to establish the numbers of patients who may be falsely discharged by community-based specialist optometrists involved in this GRRS. The secondary purpose of this work was to compare decision-making between specialist optometrists and consultant ophthalmologist when evaluating optic disc images for the presence of glaucomatous optic neuropathy.

3.7.3 Methods

Infrastructure of the CHANGES scheme

See 3.2.3

Updated CHANGES scheme

The referral criteria into the CHANGES scheme was updated in December 2013 as per the recommendations of the national multi-site review of GRRS described in chapter 3.3 (Ratnarajan et al., 2013b).

All patients seen, and subsequently discharged by the OSI during the first 8 months of this updated scheme were offered an additional review by a Glaucoma Consultant at the HES to validate the safety of the updated scheme. All examination findings by the OSI were collated on the hospital electronic patient record. This constituted an audit/service review and hence did not require research and ethics approval.

All patients were seen by the same Glaucoma Consultant and had a full ophthalmic examination including IOP measurement using GAT and dilated optic disc assessment. Visual fields were not repeated as all OSIs use the same machine as the HES, the Humphrey visual field machine using 24-2 SITA fast testing. The findings, diagnosis and outcome of the visit were documented on a database. The ‘false negative’ or ‘inappropriate discharge’

proportion was defined as the percentage of these patients in whom the glaucoma consultant judged sufficient glaucoma risk to necessitate a review in the HES. The 'missed glaucoma proportion' was defined as the percentage of patients diagnosed with glaucoma which was initiated on or booked for treatment at that visit.

In addition, a masked virtual assessment of the optic disc images sent by the OSI was performed before the clinic review by both the Glaucoma Consultant as well as the experienced hospital based optometrist who routinely scrutinizes the findings (examination and photographic) of all OSI assessments. The images were assessed non-stereoscopically on a computer screen with resolution of 1600 x 900 pixels for the optometrist and 1280x1024 pixels for the Consultant.

Data management and Statistical Analysis

Data from electronic patient records and paper copies of referral letters were collated on Microsoft Excel; statistical analysis was performed in R (version 3.1.1, R foundation for statistical computing).

3.7.4 Results

3.7.4.1 Study 1

One hundred and twenty patients were seen by OSIs during the first 8 months of the updated CHANGES scheme, of whom 46 were discharged. Thirty-four of the 46 (74%) patients agreed to attend a hospital review by the glaucoma consultant.

All 34 patients discharged by the OSI had documented GAT IOP lower than the threshold for discharge set by the JCG recommendations, normal dilated slit-lamp optic disc assessment and normal 24-2 Humphrey visual fields.

The Glaucoma Consultant also found all 34 patients to have GAT IOP measurement below the JCG threshold for discharge. Five of the 34 (15%) were found by the Consultant to have a suspicious optic disc or peripapillary retinal nerve fibre layer following slit-lamp biomicroscopy through dilated pupils. These five patients were classified as 'glaucoma suspect' and offered a follow-up appointment but none was started on IOP lowering treatment. This translates to a 'missed glaucoma proportion' of 0% and a false negative proportion of 15% for the OSI. It is important to highlight this is the false negative proportion of the OSI's clinical assessment and not the CHANGES scheme as the scheme has a hospital optometrist who virtually reviews the digital images of all optic discs of patients discharged directly by the OSI.

3.7.4.2 Study 2

After virtual review of the optic disc photographs of the 34 patients by the Consultant, 13 patients were felt to be suspicious of glaucoma and 21 patients normal. Comparing this virtual photographic-only review with the clinical findings made independently by the same consultant, virtual photographic review performed with a sensitivity of 80% (95% CI: 38% to 96%) and specificity of 69% (95% CI: 51% to 83%) when compared to the clinic-based assessment (see Table 3-11).

Table 3-11. Comparison of Consultant clinic-based assessment to Consultant virtual review.

	Clinic-based assessment by Consultant	
	Patient with a suspicious optic disc	Patient without a suspicious optic disc
Patient with a suspicious optic disc after virtual review	4	9
Patient without a suspicious optic disc after virtual review	1	20

Virtual review by the hospital optometrist resulted in 5 patients being classified as suspicious and 29 as normal, with a sensitivity of 80% (95% CI: 38% to 96%) and specificity of 97% (95% CI: 83% to 99%) compared to the clinic review by the Consultant (see table 3-12).

Table 3-12. Comparison of Consultant clinic-based assessment to Optometrist virtual review.

	Clinic-based assessment by Consultant	
	Patient with a suspicious optic disc	Patient without a suspicious optic disc
Patient with a suspicious optic disc after virtual review	4	1
Patient without a suspicious optic disc after virtual review	1	28

When comparing the outcomes of the virtual reviewers against each other, there was no difference in the sensitivities, both 0.8. The false positive proportion for the Consultant virtual review was 31.0% (95% CI: 17% to 49%) compared to 3.4% (95% CI: 0.6% to 17.2%) for the optometrist.

3.7.5 Discussion

The CHANGES scheme was updated in December 2013 in accordance with a multi-site review of GRRS. During the first 8 months of the scheme 38% (46/120) of new low-risk referrals from the high street optometrist were

discharged after community based review by the OSI. The majority of these patients were seen by the OSI within 2 to 4 weeks of the initial referral, which is substantially shorter than the waiting time for a HES outpatient appointment. Chapter 3.5.4.4 reports increased convenience and less expense for patients to be seen in a local optometrist practice than the HES; however this must not impinge on patient safety (Ratnarajan et al., 2014).

The findings of Study 1 showed that the OSI did not miss any cases of glaucoma, when comparing the clinical findings of both the OSI and the ophthalmologist. This confirms the safety of the OSIs working in the CHANGES scheme. However, 15% of optic discs that were classified by the OSI as normal were classified by the Consultant Ophthalmologist as being suspicious of glaucoma. There may be a variety of reasons for this disagreement between health professionals. Certainly even among glaucoma specialists there can be considerable disagreement in what constitutes an abnormal optic disc (Reus et al., 2010) and the involvement of only one glaucoma ophthalmologist could be considered a limitation of this study. Additionally the nature of the referral refinement scheme meant that the consultant was being compared with multiple OSIs, some of whom may have been consistently poor at detecting glaucomatous optic neuropathy despite training. A larger study involving larger numbers of eligible patients from each of the OSIs would facilitate this enquiry. The experience of a glaucoma ophthalmologist in optic disc examination, particularly in examination for retinal nerve fibre layer defects, may also part explain the greater number of glaucoma suspects detected by the consultant.

In chapter 3.4 it was reported the positive predictive value between the OSIs and Consultant for the identification of an abnormal optic disc demonstrated a statistically significant decline post NICE guideline publication from 60.6% to 42.7% (NICE, 2009a, Ratnarajan et al., 2012). It was postulated that the lack of legal indemnity for optometrists not complying with the Association of Optometrist's response to the NICE guidelines may have led optometrists to adopt a more risk averse and medicolegally defensive approach to practice

(Association of Optometrists, 2010). The outcome resulted in more false positive referrals to the HES, which resulted in more expense and unnecessary anxiety for the patients. However, the effect of false negative referrals is more serious as patients with glaucoma may not be getting referred to the HES.

Whilst a community based Consultant Ophthalmologist review of every referral for suspected glaucoma may be portrayed an optimal service design, current models of care and infrastructure make this implausible. Virtual review of optic disc photographs by both the Consultant and independently by the hospital-based specialist optometrist showed high sensitivities of 80%, when comparing with ophthalmologist judgment of a suspicious optic disc. However, the hospital-based optometrist displayed higher specificity than the Consultant resulting in a false positive proportion 9 fold lower (3.4% vs 31.0%). It can therefore be inferred that the virtual review of optic disc images of patients thought by an OSI to be normal is a useful adjunct in the infrastructure of a GRRS, resulting in increased patient safety. The results would also suggest a learning curve for virtual review of optic discs exists, with the optometrist who regularly reviews all optic disc images for the CHANGES scheme 9 times less likely to generate a false positive referral compared to the Consultant. It should be remembered however that the virtual review outcomes in this study are based on the findings of only one Consultant and one hospital optometrist, and that the screen used by the optometrist had superior resolution compared to that used by the Consultant, which may be a confounding factor.

The updated CHANGES scheme exhibits safe and effective triaging criteria. Risk stratification ensure patients at higher risk of glaucoma are seen in the HES without the delay of a community based OSI review, and lower risk patients are seen by the OSI, with virtual review acting as an additional step to ensure patients with glaucoma are not being missed. Virtual review in experienced hands can be as effective as clinical review by a Consultant and saves both time and resource.

4 SECTION IV: Discussion and Summary

4.1 The Impact of glaucoma referral refinement criteria on referral proportions and first-visit discharge proportions.

4.1.1. Summary

Referrals involving a raised IOP alone were the most common reason for referrals relating to glaucoma, with an increase in the proportion over time, particularly for the low-risk group. There was a considerable increase in referrals of low-risk patients between 2008 and 2009 (31 to 112) and this is likely to be related to the introduction of the NICE guidelines and the AOP/ABDO/FODO response to these guidelines (Association of Optometrists, 2010).

The high FVDP for referrals based on raised IOP plus abnormal visual fields (54%), coupled with the fact that OSIs in this scheme use equipment that is consistent with that used in the hospital eye services (calibrated Goldmann tonometry and Humphrey visual field analysers), would suggest that re-categorisation of these patients as low-risk rather than high-risk would improve the efficiency of the CHANGES scheme.

The following recommendations from this study aim to reduce the demand on the hospital glaucoma service whilst simultaneously maintaining the quality of care received by patients in the CHANGES scheme.

It is recommended the general organisation of this referral refinement scheme remain unchanged, with risk stratification of the patient based on the referral form into low- and high-risk categories and with low-risk referrals being directed to an OSI and the high-risk referrals being directly assessed by the hospital glaucoma service. However, the criteria for categorisation into low- and high-risk could be adjusted. Referrals deemed low-risk (currently no more

than one of the following: suspicious optic disc, abnormal VF, raised IOP (22-28mmHg) or IOP asymmetry (>5mmHg) could be widened to include patients with:

a. an IOP ≤ 30mmHg (currently ≤28mmHg) in conjunction with a normal optic disc and VF, thus complying with NICE commissioners guidance.
b. an IOP ≤ 30mmHg in conjunction with an abnormal VF
c. an optic disc haemorrhage, evidence of pigment dispersion and pseudoexfoliation in conjunction with a normal IOP, normal VF and no evidence of glaucomatous optic disc cupping.

In addition, the OSI should partially adopt the JCG referral criteria, whereby an OSI need not refer a patient aged ≥ 65 years with an IOP < 25mmHg in both eyes with an otherwise normal ocular examination (current criterion: IOP > 21mmHg). This report found that the JCG suggestion to increase the IOP threshold to < 26 for the over 80's has little impact on further reducing referrals. The role of CCT measurements in GRRS also needs further exploration.

4.1.2. Implications

It is important the referral criteria implemented in GRRS follow national guidance. This study has demonstrated that the lack of legal indemnity for optometrists not complying with the AOP's recommendation has proved to be a really effective way of changing optometry practice, though unfortunately this directly resulted in a higher FVDP of patients seen in the hospital. GRRS must choose entry and referral criteria that comply with the relevant optometry professional guidance or JCG if OSIs are to work with full legal indemnity. It is at national level that evidence-based criteria for GRSS need to be established.

4.1.3. Further work

Based on the findings of this study, amendments to the referral criteria were suggested. The definitive way to test the safety of these recommendations would be for the HES to audit, by way of a HES review, all patients seen by the OSI, both those referred as well as those discharged (see sections 3.7 and 4.6).

The use of electronic referrals forms can help guide the clinical examination of the referring eye health professional and ensure the necessary clinical information is filled in. Electronic referral forms, particularly with digital optic disc images, have been shown to improve the quality of referrals and reduce onward referral to the HES (Cameron et al., 2009). As part of my work with the HIEC, I developed an electronic referrals form that is to be used with OpenEyes electronic health record (see appendix 1).

Clinical decision support software that is integrated into an electronic health record and referral form can further improve the quality of the referral form. Future work to look at clinical decision support and GRRS is in its preliminary stages.

The use of central corneal thickness measurements by OSI to calibrate the IOP measurements, as discussed in section 3.2, is not performed routinely. Whether this entails diagnosis rather than clinical assessment, and the potential impact of purchasing a pachymeter on the cost effectiveness of GRRS should be addressed in future work. Community optometrists have demonstrated a keenness to want to update specialist equipment to be more in line with the HES, as well as move to electronic records and this should be encouraged (Dabasia et al., 2014).

4.2. Multi-site review of glaucoma referral refinement schemes

4.2.1. Summary

In terms of ‘demand management’, review of patients by OSIs can reduce the FVDP of patients subsequently reviewed in secondary care. However, in terms of patient safety, this study also shows that the overemphasis on IOP as a criterion for referral is likely to be having an adverse effect on the ability of non-OSIs, and indeed of OSIs, to detect glaucomatous optic nerve features, a key clinical skill in the detection of this potentially blinding disease. This work has identified the frequency of diagnosed glaucoma in categories based on criteria of single and combined features of the ophthalmic examination by non-OSIs and OSIs. It recommends that referral letters from non-OSIs be stratified for risk using the findings of this report to direct high-risk patients straight to secondary care, and low-risk patients to OSIs for assessment.
The results of this analysis lead to the recommendation that ‘low-risk’ referrals should be defined as those based on abnormal findings in IOP only, optic disc only, VF only and IOP and VF together, with all others, including those with any reference to a shallow anterior chamber angle, better suited to a direct referral to secondary care.

The inclusion of both VF and disc examination is clearly associated with a lower FVDP and, therefore a detailed disc and VF examination should form part of the referral refinement in conjunction with Goldmann/Perkins tonometry for measuring the IOP. Crucially, using the referral criteria of the JCG will allow the optometrist to operate within a professional and legal framework.

4.2.2. Implications

This work has highlighted the large variations in referral criteria and organisational set-up for GRRS nationally. This inevitably leads to variations in the quality and efficiency of care provided and may impact on patient safety.

The safety and efficacy of GRRS needs to be considered. Once a non-OSI has raised the possibility of a diagnosis of glaucoma, the safest option would be for a Consultant to review the patient in the HES. However, as previously described, with current models of care, this is unsustainable and has placed considerable strain on the HES. Alternatives include a Consultant review in the community or the use of a virtual Consultant review in either the community or HES setting as discussed in section 3.7.

The inappropriate discharge proportion following OSI review, i.e. the OSI false negative proportion, would be the most definitive method to establish a GRRS safety. This information is difficult to obtain as the patients are not seen in the HES. Section 3.7 and 4.6 consider the false negative proportion of a GRRS.

4.2.3. Future work

This evidence contributes to the need for a review of national policy on the management of referrals for glaucoma both in terms of referral criteria as well as organisational set-up. The situation is compounded by the fractionation between optometry and ophthalmology. NICE, The Royal College of Ophthalmologists, The College of Optometrists, AOP, ABDO and FODO all have to be involved in the process to ensure compliance with national policy.

4.3. Agreement between eye health professionals

4.3.1. Summary

A dramatic increase in the number of glaucoma referrals has occurred since the AOP's response to the NICE guidelines, which has placed an increased burden on ophthalmology outpatient departments nationally (Shah and Murdoch, 2011). This is reflected in the observation of increased scheme activity from a mean of 8.7 patients per month pre NICE to 25.4 per month post NICE, coupled with an increased FVDP from 33.6% to 40.2%.

The accuracy of examination for detection of an abnormal IOP by the OSI has remained unchanged since 2006, which is likely to be explained by the standardisation of techniques employed by both the OSI and the consultant. However, a decline was observed for detection of an abnormal optic disc by the OSI, which is an interesting finding as dilated disc assessment with indirect ophthalmoscopy has been used since the introduction of this particular scheme.

For the non-OSI, there was a decline in accuracy in detection of both an abnormal IOP and optic disc assessment. The probability of a consultant reproducing the non-OSIs finding of a moderately raised IOP (22-28mmHg) is lower than that of a significantly raised IOP (>28mmHg). This is not unexpected but it demonstrates how stratification of risk on the basis of IOP is important to ensure patient safety for higher IOPs and efficiency of the GRRS with respect to reducing HES FVDP for the lower IOPs. Such a stratification on inter-professional agreement's reported for the first time in this study.

The appropriate referral proportion for an OSI decreased following the publication of the NICE glaucoma guidelines, though the appropriate discharge proportion increased.

4.3.2. Implications

The accuracy for detecting of an abnormal IOP by the OSI has remained unchanged since 2006 largely due to the standardisation of techniques to measure IOP compared with the HES, namely Goldmann applanation tonometry (GAT). The use of GAT or instruments which adjust for the corneal biomechanics should be promoted more among non-OSI to improve the accuracy of IOP measurement. However, the reality of increased equipment costs and decreased patient throughput means that this may not be a popular option for high street optometrists (Myint et al., 2011). The lack of uptake of GAT by non-OSIs has resulted in the introduction of LOCSU's repeat IOP schemes. With this scheme optometrists are remunerated for the extra-time it takes to measure IOP with GAT compared to air-puff tonometry.

The decline in the detection of an abnormal optic disc by the OSI post NICE is interesting. Whether this reflects the variation often seen in studies looking at optic disc agreement is unknown, but seems unlikely as the same OSIs were present throughout the study. Examination techniques used and training remained unchanged throughout the entire study period. The decline may be due to optometrists adopting a more risk averse and medico-legally defensive approach to practice due to lack of legal indemnity following the AOP's recommendation. This, however, remains speculative.

The AOP's recommendation that immediately followed the NICE guideline publication has had significant implications for GRRS, as demonstrated in this study. OSIs may have become more risk averse with respect to optic disc assessment, resulting in more onward referrals to the HES after OSI assessment. Risk stratification of non-OSI referrals and tighter control on GRRS criteria will ensure a more efficient service, with referrals seen by the most appropriate eye health professional.

4.3.3. **Further work**

The decreased agreement between the HES assessment of optic discs to that of the non-OSIs and OSIs suggest an important role for virtual review of disc images. Virtual review is incorporated in the CHANGES scheme, although the majority of GRRS nationally do not employ virtual review. Chapters 3.7 and 4.6 look into this in more detail.

Clinical decision support software in medicine, particularly in General Practice, is well established (Fiks, 2011, Malchow-Moller et al., 1996, Mansell et al., 2011). The evaluation of clinical decisions made by optometrists is an expanding area of clinical research (Corliss, 1995, Myint et al., 2014), however, thus far, this has not translated into the adoption and integration of clinical decision support software in improving the quality of referrals based on guideline adherence, and this is the subject of future planned work. The methods used to train OSIs are changing with a shift towards practice based teaching and active learning rather than didactic teaching, and should be encouraged (Myint et al., 2014).

4.4. The experience of care and awareness of sight testing entitlements in patients referred for suspected glaucoma.

4.4.1. Summary

Reasons for attending a sight-test are complex and multifactorial. The results of this study highlight the need to increase awareness and promote patient education about free-sight testing, particularly in those with a family history of glaucoma. In this study only 55% of patients diagnosed with glaucoma were aware of sight testing entitlements with regard to glaucoma. Symptom led demand for sight testing was also evident as 31% waited until they could not see clearly or felt they needed new glasses before attending the optometrist.

Whilst the cost to the patient to attend the HES is significantly more than visiting the community optometrist, new patients are satisfied with the current model of care despite the extra distance and cost.

4.4.2. Implications

More has to be done to increase awareness of, and promote patient education about, free-sight testing, particularly in those with a family history of glaucoma. In the UK, glaucoma is the second largest cause of both severe sight impairment and sight impairment registrations, 8.4% and 7.4% respectively (Bunce et al., 2010). More effective case-finding will result in less glaucoma associated blindness and its far reaching impact on both the individual as well as the health system.

Ease of access to health care is important to patients (Gray et al., 1997), and this work shows the statistically significant reduction in costs and travel distance for those attending the community optometrist compared to the

hospital. Whilst it may be acceptable for a patient to travel a greater distance and pay more money to attend an outpatient appointment as a new patient, it may be more convenient to the patient if long-term review was not carried out in the hospital.

4.4.3. Future Work

Further promotion of regular sight-testing needs to be carried out. This can be at a national level through government campaigns or more locally by general practitioners, especially if this was built into their Quality and Outcomes Framework.

The RNIB's 'Community Engagement Project' reported the main barriers to accessing sight-tests were the perceived cost of the sight test (even amongst those eligible for free sight-tests) and cost of glasses (Hayden, 2012). Future work to overcome these barriers, especially in socio-economically deprived populations, must be carried out. In conjunction, there is a need to further explore cost effective, non-commercial models for sight testing and screening (Burr et al., 2011, Burr et al., 2007, Hernandez et al., 2008a, Hernandez et al., 2008b, Mowatt et al., 2008, Prior et al., 2012). With new technology case-finding could potentially take place within GP practices and community hospitals, and not necessarily restricted to optometry practices (Dabasia et al., 2015b).

4.5. Equity Profile of an Enhanced Optometry scheme.

4.5.1. Summary

As expected, the majority of patients live closer to an optometrist than the HES and this 'care closer to home' is the main driver towards developing high quality community based eye health services at a national level. More specifically, low-risk patients who are found to have glaucoma after HES review live on average 4.1km closer to the OSI than the HES. In fact, the specialist optometrist is often nearer to the patient's home than even the referring optometrist. This is important as the OSIs in enhanced schemes are distributed according to the service needs of its population, rather than according to economic considerations.

In this study there is no association between final diagnosis and distance to an eye health professional, in particular the optometrist. The severity of glaucoma at presentation was independent of deprivation and distance to the optometrist or hospital; patients who were diagnosed with glaucoma and had severe VF loss actually live closer to the PCO than those with mild or moderate VF loss and there were no significant differences in deprivation scores. This is in contrast to Fraser *et al* who found deprivation to be linked with late presentation of glaucoma to the hospital (Fraser et al., 2001). The populations from these studies are markedly distinct, with the CHANGES scheme semi-rural and relatively affluent compared to urban and deprived.

4.5.2. Implications

Equity profiling is a relatively quick and inexpensive way for health professionals and commissioners to understand the need, met or unmet, for their population.

This study demonstrates that the CHANGES scheme does provide a local, easily accessible enhanced optometry service for its population. This may contrast with the provision of 'high street' optometrists nationally, which are private providers and, therefore, priority is more towards economic viability rather than service needs of its population. The geographic locations of OSIs need to be considered when planning an enhanced optometry scheme.

4.5.3. Future Work

Comparison of this equity profile with the first published equity profile (Day et al., 2010) highlights the stark variations that can be observed with regard to patient access to eye health care and the effect of this on the subsequent diagnosis of glaucoma. Further equity profiling studies will better inform future national guidance on referral models in ophthalmology. These models, however, must be flexible in the delivery of care to allow for the varying demands for the local population and, therefore, must be tailored at a local level to best serve its population.

4.6. The false negative proportion and the role of virtual review of a nationally evaluated glaucoma referral refinement scheme.

4.6.1. Summary

Consultant Ophthalmologist review of patients discharged by the OSIs did not miss any cases of glaucoma, when comparing the clinical findings the OSI and the Ophthalmologist. However, 15% of individuals who were classified by the OSI as normal were classified by the Consultant Ophthalmologist as being suspicious of glaucoma, based on optic disc appearance.

Virtual review of optic disc photographs by either the Consultant or hospital-based specialist optometrist showed a high sensitivity of 80% to identify a suspicious optic disc, when comparing with the reference standard Consultant ophthalmologist clinical slit-lamp examination. However, the hospital-based optometrist displayed higher specificity than the Consultant resulting in a false positive proportion 9 fold lower (3.4% vs 31.0%).

4.6.2. Implications

OSIs working in the CHANGES scheme did not miss any cases of glaucoma as verified by further clinical review by the Consultant. Although this finding cannot be generalised to OSIs nationally as levels of training and accreditation vary, it would suggest that GRRS, in addition to being an effective way of reducing referrals to HES, are also safe. The disagreement between eye health professionals was also demonstrated in chapter 3.4 & 4.3

Virtual review of optic disc images of patients thought by an OSI to be normal is a useful adjunct in the infrastructure of a GRRS, resulting in increased patient safety. The results would also suggest that there is a learning curve for virtual review of optic discs, with the optometrist who regularly reviews all

optic disc images for the CHANGES scheme 9 times less likely to generate a false positive referral compared to the Consultant Ophthalmologist.

4.6.3. Future Work

A standardised and nationally approved framework of competencies for all OSIs wishing to work within GRRS and other enhanced optometry services needs to be established with the help of the College of Optometrists and the Royal College of Ophthalmologists. As chapter 3.4 and 3.7 have shown, even OSIs in possession of a nationally recognised postgraduate certificate in glaucoma shared care (City University London) show significant variation in optic disc assessment.

This variation in optic disc assessment highlights the potential role for virtual review before OSI discharge. This study has highlighted that this can be effective although a learning curve may exist.

Clinical decision support software and telemedicine are also options that can be utilised to improve accuracy and safety of optometry referrals. This is the subject of future planned work.

4.7. Concluding Remarks

Identifying people at risk of glaucoma is important, and is performed largely by opportunistic surveillance by optometrists (Bowling et al., 2005). The increase in the number of referrals to the HES after the AOP response to the NICE guidelines placed unsustainable demands on capacity within the HES. As a result GRRS were developed and the work from this thesis has shown that OSIs working in GRRS have been able to both reduce the FVDP of patients seen in the HES as well as maintain safety with a missed glaucoma proportion for discharged patients of 0%. Whilst efficacy and safety are paramount for a successful GRRS, this thesis has also shown that after the publication of the NICE guidelines both OSIs and non-OSIs have placed an overemphasis on IOP as a criterion for referral and this is having an adverse effect on the detection of glaucomatous optic disc features. The reasons for this are unknown but may be due to optometrists adopting a more risk averse and medico-legally defensive approach to practice due to lack of legal indemnity following the AOP's recommendation. Despite publication of JCG, FVDP remain higher than pre NICE.

The studies addressing equity profiles and patient awareness of sight-testing entitlements in this semi-rural and affluent population show a stark contrast to previously published work looking at urban and deprived populations (Day et al., 2010, Fraser et al., 2001). This highlights the importance of equity profiles and increasing population awareness of sight-testing entitlements, but also demonstrates the need for local level planning and implementation of GRRS.

GRRS should ideally follow nationally agreed guidance with respect to scheme infrastructure and referral criteria and this thesis contributes to the evidence base. There has been much recent attention within the HES given to the development of virtual review of glaucoma patients and this thesis suggests this can be a safe alternative to clinic review in appropriate patients.

My thesis has tried to systematically evaluate and optimise the refinement of glaucoma referrals into the HES, however, with 50% of glaucoma still undiagnosed, a greater emphasis is needed in increasing case detection. The barriers to attending sight-tests remain and a cost-effective screening test remains elusive. Alternative models of care for case detection and screening need further exploration. As GP surgeries expand in both size and the services they offer, it would be interesting to evaluate a GP-based, technician-led screening programme and compare this to optometrist-based and -led care. Increased case detection would mean the role of GRRS will become even more important.

There is a drive by commissioners to transfer the care of stable glaucoma and OHT patients out of the hospital and into the community setting, often described as ‘shared care’. My work with the HIEC and the studies within this thesis has shown to me that GRRS is not only an effective way to reduce the FVDP to the HES but serves as a crucial intermediary step to the development of ‘shared care’ in terms of identifying and training OSIs.

Ophthalmologists, optometrists, GPs, commissioners of services, glaucoma charities and patient representative groups must continue to work closely and synergistically with one another to continue to improve the care we provide to patients with glaucoma or at risk of developing glaucoma.

5 SECTION V: Summary of Publications

5.1 Published papers

RATNARAJAN, G, COOMBES E, JONES A, PARKER M, BOURNE R. 2015. The equity profile of an enhanced optometry scheme. *Ophthalmic Physiol Opt,* 35**,** 243-4.

RATNARAJAN, G., KEAN, J., FRENCH, K., PARKER, M. & BOURNE, R. 2015. The false negative rate and the role for virtual review in a nationally evaluated glaucoma referral refinement scheme. *Ophthalmic Physiol Opt*, 35, 577-81.

RATNARAJAN, G., NEWSOM, W., FRENCH, K., KEAN, J., CHANG, L., PARKER, M., GARWAY-HEATH, D. F. & BOURNE, R. R. 2013a. The effect of changes in referral behaviour following NICE guideline publication on agreement of examination findings between professionals in an established glaucoma referral refinement pathway: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways project. *Br J Ophthalmol,* 97**,** 210-4.

RATNARAJAN, G., NEWSOM, W., FRENCH, K., KEAN, J., CHANG, L., PARKER, M., GARWAY-HEATH, D. F. & BOURNE, R. R. 2013b. The impact of glaucoma referral refinement criteria on referral to, and first-visit discharge rates from, the hospital eye service: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways project. *Ophthalmic Physiol Opt,* 33**,** 183-9.

RATNARAJAN, G., NEWSOM, W., VERNON, S. A., FENERTY, C., HENSON, D., SPENCER, F., WANG, Y., HARPER, R., MCNAUGHT, A., COLLINS, L., PARKER, M., LAWRENSON, J., HUDSON, R.,

KHAW, P. T., WORMALD, R., GARWAY-HEATH, D. & BOURNE, R. 2013c. The effectiveness of schemes that refine referrals between primary and secondary care--the UK experience with glaucoma referrals: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways Project. *BMJ Open,* 3.

RATNARAJAN, G., SOMNER, J., COOMBES, E., JONES, A. & BOURNE, R. 2014. Awareness of sight-testing entitlements in patients referred for suspected glaucoma. *Eye (Lond),* 28**,** 504-5.

RATNARAJAN, G. & WORMALD, R. 2013. Peep into policy, politics, Parliament. *Perspect Public Health,* 133**,** 7.

RATNARAJAN, G., WORMALD, R. & ASTBURY, N. 2013. The NHS Act of 1951; is it time to re-act? *Eye (Lond),* 27**,** 685-7.

5.2 Abbreviations

ABDO - Association of British Dispensing Opticians
AOP - Association of Optometrists
CVI – Certificate Visual Impairment
CCT – Central Corneal Thickness
CG – Congenital Glaucoma
CHANGES - Community and Hospital Allied Network Glaucoma Evaluation Scheme
CIGTS - Collaborative Initial Glaucoma Treatment Study
CNTGS - Collaborative Normal Tension Glaucoma Study
COAG – Chronic Open Angle Glaucoma
EMGT - Early Manifest Glaucoma Trial
FODO - Federation of Ophthalmic and Dispensing Opticians
FVDP - First-visit discharge proportion
GAT – Goldmann Applanation Tonometry
GOS - General Ophthalmic Services
GP – General Practitioner
GRRS – Glaucoma Referral Refinement Scheme
HES – Hospital Eye Services
HIEC – Health Innovation and Education Cluster
HTG - High Tension Glaucoma
IMD - Index of Multiple Deprivation
IOP - Intra-ocular pressure
JCG – Joint College Guidance
LOCSU – Local Optical Committee Support Unit
LoGTS - Low-pressure Glaucoma Treatment Study
LOXL1 - Lysyl oxidase-like 1
MREH - Manchester Royal Eye Hospital
MYOC - Myocilin
NCT – Non Contact Tonometry
NHS – National Health Service
NICE - National Institute for Health and Clinical Excellence
Non-OSI – Optometrist with no Specialist Interest in glaucoma
NTG - Normal Tension Glaucoma

OHT - Ocular Hypertension

OPTN - Optineurin

OSI – Optometrist with Specialist Interest in glaucoma

OHTS - Ocular Hypertension Treatment Study

PACG - Primary Angle Closure Glaucoma

POAG - Primary Open Angle Glaucoma

PCO – Primary Care Optometrists

RNIB – Royal National Institute for Blind People

TIGR - Trabecular meshwork-inducible glucocorticoid response factor

UKGTS – United Kingdom Glaucoma Treatment Study

VF – Visual Field

6 SECTION VI: References

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7 SECTION VII: Appendices

7.1 Appendix 1: Electronic referral form

OPENEYES REFERRAL FORM

Patient's Details	Optometrist / Practice
First name:	Optometrist name:
Last name:	GOC/GMP number:
NHS number:	Practice Name and Address:
DOB:	
Address:	Phone:
Phone:	**Patient's GP**
Mobile:	GP name:
	Address:

PRESCRIPTION DETAILS FROM CURRENT SIGHT TEST

	Uncorrected VA	Sph	Cyl	Axis	Prism	VA	Add	Near VA	Previous VA	
RE										Date:
LE										

HOSPITAL REFERRAL SENT TO: E mail:				☐ 18 YEARS OR YOUNGER
☐DIRECT REFERRAL	☐VIA/TO-GP	☐URGENT	☐ROUTINE	☐INFO-ONLY

Please select a suitable clinic type for your main referral condition.

☐AMD	☐EXTERNAL/CORNEA	☐MED RETINA DIABETES	☐ONCOLOGY	☐ STRABISMUS/MOTILITY
☐CATARACT	☐ GLAUCOMA	☐MED RETINA OTHER	☐ ORBIT/LACRIMAL/PLAST	☐VITREO-RETINA
☐CAPSULOTOMY Yag Laser	☐LOW VISION	☐NEURO-OPHTH	☐ORTHOPTICS	☐GENERAL OPHTH

ABOVE IS THE GENERIC COMPONENT TO THE REFERRAL FORM.

BELOW IS THE GLAUCOMA SPECIFIC REFERRAL FORM WHICH WILL OPEN IF GLAUCOMA CLINIC IS TICKED AS THE MOST SUITABLE CLINIC.

HISTORY AND SYMPTOMS

Risk factors: Family History of Glaucoma ☐ Diabetes ☐ Myopia ☐ Hypertensive ☐ Afro-Caribbean ☐ Smoker ☐

CLINICAL EXAMINATION	RIGHT EYE	LEFT EYE
ANTERIOR CHAMBER FINDINGS THAT CARRY GLAUCOMA RISK eg pseudoexfoliation, pigment dispersion	YES / NO comment:	YES / NO comment:
VAN HERICK GRADE (shallow equates to a limbal chamber depth of ≤16% of corneal thickness)	SHALLOW / DEEP	SHALLOW / DEEP

INTRAOCULAR PRESSURE (mmHg)	**@ hrs**		**@ hrs**	
LENS	**CLEAR / CATARACT / IOL**		**CLEAR / CATARACT / IOL**	
TONOMETER USED	**GOLDMANN / NCT / OTHER Specify:**			
MYDRIASIS	**YES / NO**			
OPTIC DISC FEATURES	**VERTICAL C:D RATIO**		**VERTICAL C:D RATIO**	
(tick if present)		**ISNT RULE BROKEN**		
		NOTCH		
		FLAME HAEMORRAHGE		
		PERI-PAPILLARY ATROPHY		
		NERVE FIBRE LAYER DEFECT		
OVERALL OPTIC DISC STATUS	**NORMAL / ABNORMAL**		**NORMAL / ABNORMAL**	
MACULA / RETINA	**NORMAL / ABNORMAL**		**NORMAL / ABNORMAL**	
VISUAL FIELDS **(copies must be enclosed)**	**NORMAL / ABNORMAL / SUSPECT** **RELIABILITY GOOD / BAD**		**NORMAL / ABNORMAL / SUSPECT** **RELIABILITY GOOD / BAD**	
Signature of optometrist:			Date:	

STATEMENT: The reason for this referral has been explained to the patient or guardian who agrees to it. The patient or guardian also consents to information being exchanged between the Hospital Eye Service, their General Medical Practitioner, and optometrist or ophthalmic medical practitioner **(delete any not consented to).**

7.2 Appendix 2: HIEC Glaucoma Pathways Project Summary

Glaucoma Referral Refinement Project Summary

April 2011 – April 2012

Gokulan Ratnarajan

Rupert Bourne

David Garway-Heath

Peng Khaw

Robyn Hudson

Introduction:

THE BURDEN OF GLAUCOMA IN THE UK

Approximately 10% of UK blindness registrations are attributed to glaucoma. Approximately 2% of people older than 40 years have primary open angle glaucoma (POAG), which rises to 10% in people older than 75 years in white Europeans [REF 1]. The prevalence is higher in people with risk factors such as black African or black Caribbean descent or in those with a family history of glaucoma. Approximately 480,000 people are currently affected by POAG in England though this number is expected to increase significantly with changes in population demographics.

There are over a million glaucoma-related outpatient visits to the hospital eye service annually in the UK. This places an unsustainable demand on Ophthalmology out patient departments. Consequently, patients already under review for glaucoma often do not receive their follow-up clinic visits in the time frame specified by their Ophthalmologist. This can and has already resulted in avoidable visual loss. National Patient Safety Agency figures from June 2009 revealed that 44 patients lost part of their sight as a result of delayed follow-up appointments and a further 13 were rendered blind [REF 2].

CURRENT SERVICE PROVISION FOR PATIENTS REFERRED AS GLAUCOMA SUSPECTS

The National Institute of Clinical Excellence (NICE) guidelines for patients suspected of having glaucoma and ocular hypertension (published in April 2009 [REF 1] and the subsequent advice by the Association of Optometrists [REF 3] have resulted in a marked increase in patients referred with a suspicion of glaucoma or ocular hypertension (a risk factor for glaucoma). Approximately 40% of these referrals made directly to the hospital service (the 'traditional pathway') are subsequently found to not have glaucoma and are subsequently discharged ('false positive referrals'). This inefficient system constitutes a waste of resources and is less than ideal for patients where a provisional diagnosis of glaucoma or ocular hypertension can provoke considerable anxiety.

In December 2010 a joint college guidance (JCG) was provided by the Royal College of Ophthalmologists and College of Optometrists in relation to ocular hypertensive patients with low-risk of significant visual field loss in their lifetime. It was recommended that optometrists consider not referring patients aged over 80 years with an IOP of less than 26mmHg with an otherwise normal ocular examination. For patients aged between 65 and 80 this IOP recommendation was 25mmHg, as this subset of patients does not qualify for treatment under the current NICE guidance. For the latter group, it was recommended that these individuals be reviewed annually by a community optometrist [REF 4].

The most recent guideline published by NICE (March 2012) was aimed at the commissioning of glaucoma services and was titled ‘Services for people at risk of developing glaucoma [REF 5]. It recommends patients with an IOP 30mmHg or greater should be referred to secondary care without delay suggesting that these patients are not suitable for a community-based refinement of the referral.

ORGANISATIONAL INTERVENTIONS TO MANAGE OR DIVERT REFERRALS OF PATIENTS SUSPECTED TO HAVE GLAUCOMA.

The UK Government has an ambition for community care, enabling of health, independence and well being, better access to community services, support for people with longer term needs, and care closer to home [REF 6]. The NICE Guidelines for glaucoma stated Service Provision as one of its research recommendations. Within the UK there are several examples of glaucoma referral refinement schemes (GRRS) [REF 7-13] where an accredited optometrist will examine the patient that was referred from the original optometrist and according to pre-determined criteria and protocol may either discharge the patient back to the original referring optometrist or refer the patient to the hospital eye service. if there is a genuine cause for concern. GRRS offers a different pathway to the traditional pathway in which an optometrist refers all patients suspected of glaucoma direct to the hospital service. GRRS carry potential advantages in terms of reducing 'false positive' referrals, possible cost savings to hospitals and patients, and potentially improved access to care for patients.

However, there is much variation in how GRRS are organised within the UK and much of the basis for shared care of glaucoma with the community lacks a scientific evidence base. Little is also known about the cost-effectiveness, access to care and patient satisfaction with such schemes, which offer an alternative to the traditional hospital-based pathway for managing glaucoma.

National Multi-site Glaucoma Referral Refinement Analysis:

The North East, North Central London and Essex Health Innovation and Education Cluster (NECLES HIEC) Eyes and Vision work stream has conducted a review of 4 established organisationally and clinically distinct GRRS in England to establish a national framework for glaucoma referral refinement in terms of pathway design and patient safety [REF 14,15].

The four chosen schemes were Manchester, Nottingham, Gloucestershire and Huntingdon. Each scheme is organisationally distinct and reflects the range of variation between schemes nationally.

Overview of the schemes:

Manchester

The Manchester glaucoma referral refinement scheme was established in 2000. All referrals to Manchester Royal Eye Hospital (MREH) for patients who are registered with a GP in central Manchester Primary Care Trust are reviewed by one of 12 optometrists with specialist interest in glaucoma (OSIs). The current criteria necessitating referral to MREH after referral refinement are a modification of the original criteria to reflect the JCG. This includes single referral criteria consisting of IOP ≥30mmHg confirmed at a second visit, unequivocal pathological cupping of the optic disc noted after pupil dilation or

visual field loss consistent with a diagnosis of glaucoma confirmed at a second visit. Combined referral criteria include IOP ≥22 mmHg plus a suspicious optic disc appearance or optic disc asymmetry. An abnormal optic disc and corresponding visual field defect irrespective of the IOP necessitates a referral. Additional referral criteria include anterior segment signs of secondary glaucoma with IOP >22 mmHg on two occasions, or suspected angle closure (symptoms of sub-acute attacks or occludable angle and IOP >22 mmHg).

Nottingham

The glaucoma referral refinement scheme based at Queens Medical Centre was established in 2009. All new referrals for suspected glaucoma are assessed by one of 3 hospital-based optometrists. Patients found to have a normal ocular examination by these optometrists are discharged. Those patients that are found to have glaucoma and who require urgent treatment or who are identified as having occludable anterior chamber angles are discussed with a consultant on the same day with a treatment plan established and an appropriate prescription issued if necessary. Patients diagnosed as ocular hypertensive or in whom glaucoma is suspected are offered a review in an ophthalmology clinic.

Gloucestershire

The Gloucestershire glaucoma referral refinement scheme was established in 2008, after a successful 5-year pilot from 2003 to 2008. Patients who are registered with a Gloucestershire GP practice and are seen by one of 77 local OSIs may have their referral refined by this same optometrist. The pilot was conducted in the Forest of Dean. In 2008, all community optometrists with no specialist interest in glaucoma (non-OSIs) were offered the opportunity to participate and become accredited to the scheme. Patients who are registered with a Gloucestershire GP practice are seen by one of 103 (85%) accredited community optometrists and have their referral refined by the same accredited optometrist (for consistency in nomenclature accredited community optometrists will subsequently also be referred to as OSI). The optometrist is only reimbursed for referral of those patients who meet the following NICE compliant, referral criteria: patients younger than 65 years with IOP in either eye of ≥ 22mmHg, patients aged 65 years or older with an IOP ≥ 25mmHg, measured twice on each of 2 separate patient visits with a Goldmann or Perkins tonometer. If initial measurement is ≥ 30mm Hg and/or angle closure is suspected, repeated IOP measurements on one occasion are sufficient for referral. Regardless of IOP,

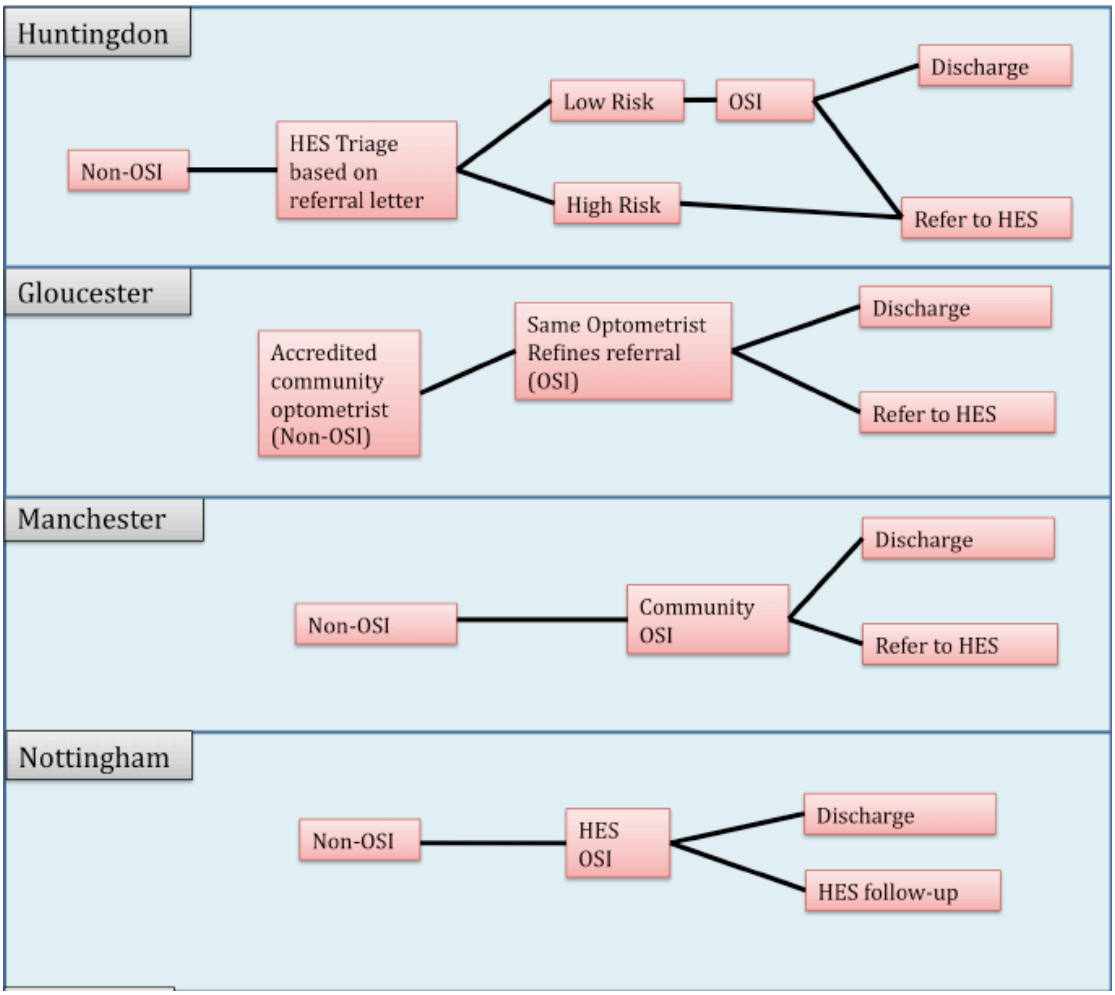
patients are referred if the optic disc appearance is glaucomatous and/or a reproducible visual field defect (evident on two separate occasions) is noted with automated perimetry. When a patient attends a non-accredited optometrist, a referral is made in the usual way, without refinement, via the patient's GP to the hospital glaucoma clinic.

Huntingdon

The Community and Hospital Allied Network Glaucoma Evaluation Scheme (CHANGES) was established in 2006 and involves an initial triage of the referral letter by a hospital based optometrist into either low or high-risk according to a protocol. A referral is deemed low-risk if only one/none of the following risk factors were noted for either eye: abnormal optic disc, abnormal visual field, abnormal IOP (22-28mmHg or IOP asymmetry). All other referrals were deemed high-risk (including any reference to a shallow anterior chamber). Low-risk patients are seen by one of 8 community based OSIs and high-risk patients are seen directly in the hospital's specialist glaucoma clinic. Only those low-risk patients with a normal ocular examination (IOP less than 22mmHg, normal optic disc and visual fields) are discharged.

Each of these schemes requires participating optometrists to gain accreditation through a hospital approved training scheme. A diploma in glaucoma is not a prerequisite. All patients seen by an OSI in these schemes have IOP measured using Goldmann or Perkins tonometry, optic disc assessment with slit-lamp binocular indirect ophthalmoscopy recommended and visual field assessment using a perimeter with a supra-threshold algorithm. Patients who fulfill predetermined criteria are subsequently referred to the hospital, and the others are discharged with feedback to the original referring optometrist.

Schematic diagram of each scheme



Data Collection:

The outcomes of GRRS in Huntingdon, Manchester, Gloucestershire and Nottingham were retrospectively analysed. A two month time period based on date of a patient's hospital appointment was used for both pre NICE (March and April 2009) and post JCG (March and April 2011) time frames. A total of 4 months were collected for the post NICE data; a two-month time period soon after the implementation of the NICE guidance (November and December 2009) and a 2 month period later following implementation (August and September 2010). These time frames were chosen to allow an analysis of temporal changes in scheme activity in a timeframe of significant alteration in national policy.

In Huntingdon and Nottingham the data from the non-OSI who initiated the referral as well the subsequent findings from the next eye health professional in the pathway were collected. In Manchester and Gloucestershire the data from the findings of the OSI and that of the subsequent hospital visit were analysed. The pathway of a patient through each of these schemes differed with respect to the eyecare professional involved therefore the activity of OSI and non-OSI could be compared with respect to reason for referral as well as the unnecessary referral rate of these referrals during a period of changing national policy.

In addition the outcomes of all low and high-risk referrals to Hinchingbrooke Hospital in Huntingdon since the CHANGES scheme was implemented in 2006 was collected and analysed as an additional component to the HIEC work. The primary outcome measures from this work were to establish the number of unnecessary referrals generated by OSI and non-OSI for each reason for referral as well as assessing the accuracy of the examination findings of these optometrists with respect to a consultant ophthalmologist in glaucoma which is deemed as the gold standard.

Summary of the Main Findings from the multi-site review:

Data relating to 1086 patients were analysed: 434 from Huntingdon, 179 from Manchester, 204 from Gloucestershire and 269 from Nottingham.
By time period, 190 (17.5%) attended their hospital appointment in the pre NICE time period, 338 (35.7%) early post NICE, 287 (26.4%) later post NICE and 271 (25.0%) post JCG.

Of the 1086 patients, 521 were male. 56.1% of patients referred from an OSI were male as compared to 43.7% of non-OSI referrals. Mean age of patients seen by the OSIs was 63.2 years compared to 62.0 years by non-OSIs.

Reason for Referral for non-OSI and OSI

The reason for referral can be based on an elevated IOP, abnormal optic disc or visual field (VF) appearance, or any combination of these. The most common reason for a non-OSI referral was an elevated IOP only (accounting for 36.1% of non-OSI referrals). In the pre NICE timeframe IOP only referrals accounted for 19.0% of referrals, increasing to 45.1% in the early post NICE period. This reduced in the post NICE period to 32.0% and rose again post JCG to 41.3%. This general rise over time was coupled with a decrease in many other reasons for referral by the non-OSI, particularly for referrals not involving IOP. This is exemplified by disc only referrals which dropped from 15.9% pre NICE to 6.1% early post NICE. A more detailed breakdown of the temporal trend for reason for referral by non-OSIs (Huntingdon and Nottingham schemes) is found in the table below.

Reason for non-OSI referral by time period: Huntingdon and Nottingham

Reason for referral	Guideline period								Total	
	Pre NICE		Early post NICE		Later post NICE		Post JCG			
	Count	%	Count	%	Count	%	Count	%	Count	%
IOP only	24	19.0	96	45.1	58	32.0	76	41.3	254	36.1
Disc only	20	15.9	13	6.1	34	18.8	22	12.0	89	12.6
VF only	8	6.3	6	2.8	10	5.5	13	7.1	37	5.2
IOP+Disc	20	15.9	33	15.5	19	10.5	18	9.8	90	12.8
IOP+VF	5	4.0	9	4.2	8	4.4	6	3.3	28	4.0
Disc+VF	14	11.1	13	6.1	21	11.6	22	12.0	70	9.9
IOP+Disc+VF	9	7.1	28	13.1	7	3.9	5	2.7	49	7.0
Other	26	20.6	15	7.0	24	13.3	22	12.0	87	12.4
Total	126	100.0	213	100.0	181	100.0	184	100.0	704	100.0

The most common reason for referral by the OSIs was for raised IOP and it accounted for 28.8% of OSI referrals. IOP only referrals by the OSI demonstrated a less marked increase post NICE than the non-OSI, 10.9% to 28.0%. The proportion of referrals not involving a raised IOP demonstrated an increase in the early post NICE period again mainly on account of disc only referrals which accounted for 18.8% of referrals pre NICE to 20.0% post NICE. A more detailed breakdown of the temporal trend for reason for referral by OSIs (Manchester and Gloucestershire schemes) is found in the table below.

Reason for OSI referral by time period: Gloucestershire and Manchester

Main reason for referral	Guideline period								Total	
	Pre NICE		Early post NICE		Later post NICE		Post JCG			
	Count	%	Count	%	Count	%	Count	%	Count	%
IOP only	7	10.9	35	28.0	44	41.5	24	27.6	110	28.8
Disc only	12	18.8	25	20.0	16	15.1	16	18.4	69	18.1
VF only	3	4.7	3	2.4	6	5.7	5	5.7	17	4.5
IOP+Disc	13	20.3	27	21.6	17	16.0	18	20.7	75	19.6
IOP+VF	4	6.2	8	6.4	4	3.8	2	2.3	18	4.7
Disc+VF	8	12.5	19	15.2	12	11.3	14	16.1	53	13.9
IOP+Disc+VF	17	26.6	8	6.4	4	3.8	6	6.9	35	9.2
Other	0	0.0	0	0.0	3	2.8	2	2.3	5	1.3
Total	64	100.0	125	100.0	106	100.0	87	100.0	382	100.0

Unnecessary referral rate

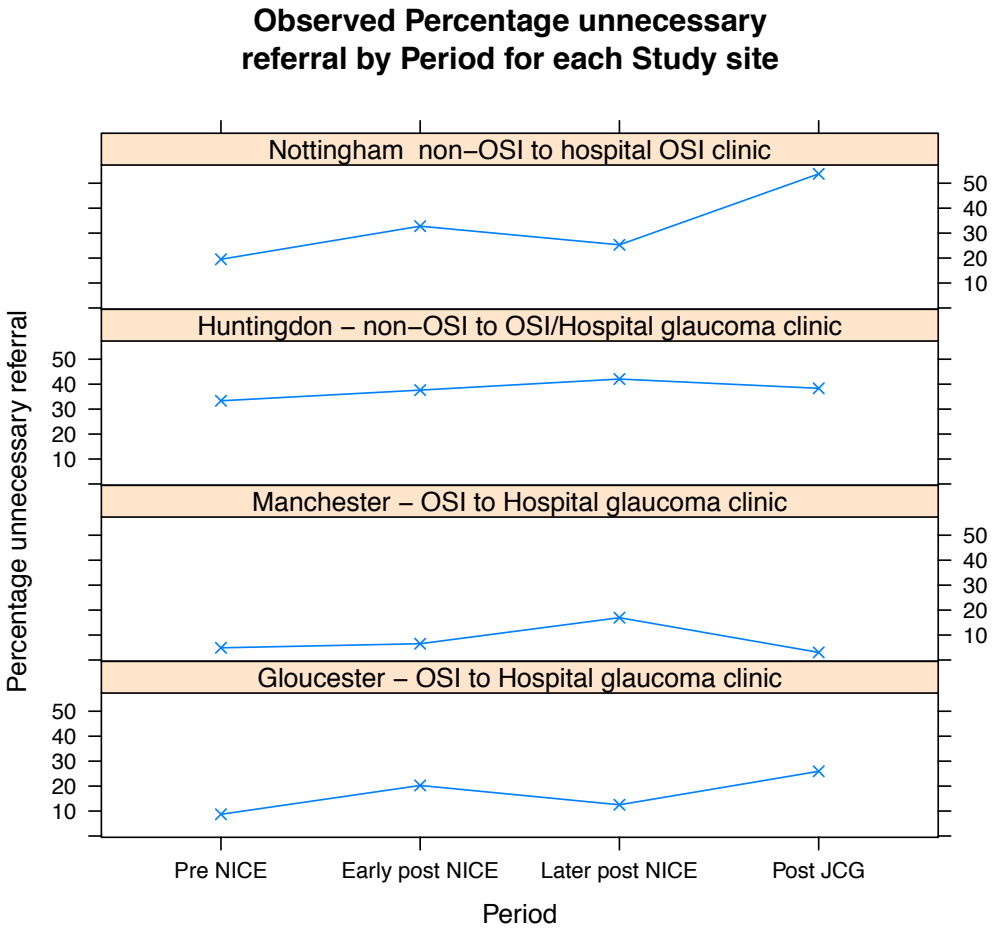
The overall unnecessary referral rate (URR) for non-OSI referrals was 36.1%, with a pre NICE URR of 29.2%, early post NICE of 35.0%, later post NICE of 34.7% and post JCG of 43.9%. The overall URR for OSI referrals was 14.1%, with pre NICE URR of 15.2%, early post NICE of 15.0%, later post NICE of 17.2% and post JCG of 14.1%.

The URR for each site for each time period is given in the table and figure below. When interpreting this graph it is important to note that for Nottingham and Huntingdon the graph represents the URR for the non-OSI and for Manchester and Gloucestershire the URR is representative of the OSI.

Unnecessary Referral Rate by site and by time period

Site (professional initiating referral)	Period				Overall
	Pre NICE	Early post NICE	Later post NICE	Post JCG	
Nottingham (non-OSI)	19.5	32.8	25.3	53.7	33.5
Huntingdon (non-OSI)	33.3	37.6	42.1	38.3	38.0
Manchester (OSI)	4.9	6.5	16.9	3.0	8.9
Gloucestershire (OSI)	8.7	20.3	12.5	25.9	18.6
Non-OSI overall	29.2	35.0	34.7	43.9	36.1
OSI overall	6.3	15.2	15.0	17.2	14.1
Overall	21.9	27.8	27.6	35.4	28.6

Temporal trends in Unnecessary Referral Rate by site



Summary of Main Findings from Huntingdon data:

The analysis of the Huntingdon database included 2912 patients (average age, 63.6 years; 1623 men) referred by primary care. Of these referrals, 2154 (74%) were categorised as at high-risk (average age, 63.6 years; 941 men) and 758 (26%) were deemed low-risk (average age, 59.5 years; 348 men).

The number of patients seen in both low and high-risk had increased since 2006. The total number of low-risk referrals involving IOP was 467 (61.6%) with a sharp rise in these numbers since 2009. The numbers of high-risk referrals involving IOP was 1558 (72.3%) with a steady increase in numbers since 2006. The highest unnecessary referral rates were for referrals due to an IOP between 22 and 27mmHg (45.4%), IOP asymmetry (52.8%), VF defect (46.3%) and IOP and VF (54.0). Modelling of the JCG may have resulted in 65 less referrals and the NICE commissioning guidance 28 less referrals.

The agreement between an OSI and a non-OSI to a consultant ophthalmologist in determining whether the IOP in either eye was normal (<22mmHg) or abnormal (>21mmHg), expressed as a percent positive predictive value (PPPV), was 61.2% for the OSI and 49.4% for the non-OSI. For high-risk IOP referrals (IOP > 28mmHg) the PPPV between a non-OSI and consultant was 75.0%. OSI in the Huntingdon scheme do not review patients with high-risk referral letters and thus this corresponding value for an OSI is not known.
The PPPV for the identification of an abnormal optic disc for an OSI and non-OSI was 51.3% and 43.3% respectively.

OSIs and to a lesser extent non-OSIs were substantially better at identifying normal IOPs and normal optic discs.

Summary of Main Conclusions and Recommendations:

This report of activity from four established referral refinement schemes of differing design has demonstrated that OSIs can successfully refine the referrals from non-OSIs for suspected glaucoma leading to a reduction in the unnecessary referral rate of patients being reviewed in secondary care. This work has also highlighted the key role the secondary care provider, particularly the consultant ophthalmologist, plays to ensure patients with glaucoma are correctly diagnosed and also in preventing missed cases of glaucoma from inappropriate discharge. It is therefore recommended that patients with a high-risk of being diagnosed with glaucoma based on the examination findings of the non-OSI should be referred directly to secondary care and those at lower risk could effectively and safely be reviewed by an OSI, ideally in the community setting. The results of this analysis lead us to recommend that it would be effective and safe to define the low-risk category as referrals based on IOP only, optic disc only, VF only and IOP and VF, with all other referrals including any reference to a shallow anterior chamber angle better suited to a direct referral to secondary care.

Advantages of referral refinement that utilises OSIs may include better access for patients and less anxiety experienced by patients awaiting a referral to the hospital service. The additional numbers of clinicians specialising in glaucoma care as a result of training OSIs, added to feedback to non-OSIs about the result of their referral has been demonstrated to result in a general improvement in quality of referrals by the non-OSI community. Higher quality referrals to the hospital service result in a more efficient utilisation of a consultant ophthalmologist's time in a service which is usually pressured by the demand for follow-up appointments for this chronic disease. The numbers of OSIs involved in a glaucoma referral refinement scheme will be governed by local factors, but it is important that close communication and a collective work ethic is created and maintained by the OSI, secondary care provider and commissioner for a scheme to be successful. Education and training of all optometrists, not only OSIs, should be encouraged to further reduce the unnecessary referral rate, particularly as high-risk referrals from a non-OSI would bypass the refinement stage and be referred directly to secondary care.

The referral criteria in the Manchester scheme resulted in the lowest unnecessary referral rate. It is advised to implement referral criteria that are based on national policy and College guidance if a national framework for glaucoma referral refinement is to be established. It is therefore the recommendation from the authors that OSIs utilise the referral criteria of the JCG which crucially allows the OSI to operate with professional and legal support. In addition, further modifications to the original NICE guidance to allow optometrists to use more discretion for borderline IOP levels in younger patients, especially if the IOP was measured using non-contact tonometry is required. This has been successfully piloted in Gloucestershire.

It is the recommendation of the authors that a full comprehensive eye examination should be carried out by all OSIs in a glaucoma referral refinement scheme. This should involve Goldmann/Perkins tonometry as the sole method for measuring IOP, anterior chamber depth evaluation using Van Herick or gonioscopy, detailed (ideally dilated) indirect slit-lamp based ophthalmoscopy for disc assessment, and visual field testing using a suprathreshold visual field machine (ideally the same as that use by the local secondary care provider). The results have highlighted the potential for missed pathology if IOP is measured alone.

Glaucoma Referral Refinement Activity in North London and Essex

There is a relative paucity of GRRS in operation in north London and Essex when the HIEC Glaucoma Pathways project began in April 2011.

Multiple meetings with Local Optical Committees (LOC), Consultant Ophthalmologists, Cluster and GP commissioning leads in these regions has resulted in a general increase in the awareness GRRS, and how implementation of these schemes can successfully result in many more patients being reviewed in a community setting in keeping with the Care Closer to Home initiative, as well as reducing the considerable burden new glaucoma out-patients appointments are placing on Ophthalmology departments nationwide. It is anticipated that these meeting will serve as a platform for continued

communication between all stakeholders and hopefully result in the implementation of GRRS for which the HIEC multi-site research project will provide a framework and evidence base.

In the 12 months from April 2011 – April 2012 a new glaucoma referral refinement scheme has been agreed upon in Islington. The majority of glaucoma referrals to Moorfields Eye Hospital are generated by optometrists working within Islington and this scheme should successfully reduce the number of referrals for suspected glaucoma to Moorfields Eye Hospital by 25% in keeping with the recent NICE commissioning guidance on glaucoma [REF 5].

Through close collaboration with the HIEC, the GRRS in Barnet has been successfully updated to reflect national and College guidance. Education and training has been provided to both participating specialist optometrists as well as non-participating optometrists in an endeavour to raise the awareness and skills of optometrists in this region.

GRRS serves as an efficient and safe alternative to the traditional referral pathway for patients with suspected glaucoma. There is a need for a national framework and guidance on glaucoma referral refinement to ensure equity of care and safety is afforded to all patients. It is hoped the work from the HIEC can serve as evidence base on which this guidance can be developed.

Acknowlegements:

The HIEC Glaucoma Referral Refinement Project was a multi-site project and the HIEC would like to thanks and acknowledge all those involved from Manchester, Nottingham, Gloucestershire and Huntingdon.

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