

The Clinical Skills of Optometrists in Assessing the Anterior Chamber Angle

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Abstract

Introduction

The number of cases of glaucoma is predicted to increase considerably over the next few decades. The current reference standard method used to distinguish between primary open angle and primary angle closure glaucoma is gonioscopy, but there is a lack of evidence on anterior chamber angle (ACA) assessment methods outside Asia. Optometrists who show competence at gonioscopy are well placed to play an important future role in glaucoma care provision in the UK.

Aims:

- To investigate the impact of the NICE guideline on glaucoma on the clinical practice of optometrists.
- To investigate the ability of optometrists and other healthcare professionals (HCPs) at gonioscopy.
- To assess the intra-observer repeatability and agreement between gonioscopy, van Herick method and anterior segment Optical Coherence Tomography (AS-OCT).

Methods

Optometrists were invited to complete an online questionnaire investigating clinical practice before and after the introduction of the NICE guideline. Gonioscopy findings for optometrists and other HCPs were compared to those of a consultant ophthalmologist. Sensitivity and specificity were calculated, weighted kappa (κ_w) was used to assess inter-observer repeatability.

Gonioscopy, van Herick method and AS-OCT were performed on two occasions. Sensitivity and specificity of van Herick method and AS-OCT were calculated, using gonioscopy as the reference standard. Kappa (κ) was used to measure the intra-observer repeatability.

Results

A significant increase in the use of applanation tonometry ($p < 0.01$) but no significant change in gonioscopy usage ($p=0.47$) was found after the introduction of the NICE guideline. Sensitivity and specificity values for HCPs' gonioscopy findings compared to a consultant ophthalmologist were good: 92% and 92% respectively. The repeatability of gonioscopy was fair $\kappa=0.29$, while that of the van Herick method ($\kappa=0.54$) and AS-OCT ($\kappa=0.47$) were better. The van Herick method showed good sensitivity (visit 1: 82%, visit 2: 75%) and very good specificity (visit 1: 88%, visit 2: 95%). The sensitivity of AS-OCT was fair (visit 1: 46%, visit 2: 25%), specificity was high (visit 1: 87%, visit 2: 89%).

Discussion

In this thesis new evidence is presented comparing ACA assessment tests. There has been no change in gonioscopy practice since the guideline on glaucoma was issued. Optometrists along with other HCPs, are able to perform gonioscopy accurately and competently. The van Herick method and AS-OCT have better repeatability than gonioscopy. The van Herick method showed good agreement with gonioscopy but AS-OCT agreement with gonioscopy was less. The van Herick method would therefore appear to be a more useful test than AS-OCT for optometrists assessing patients at risk of glaucoma.

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List of terms used in this report

Anterior Chamber Angle	The junction between the back of the cornea and the front of the iris (Burr <i>et al.</i> , 2007).
Anterior Segment Optical Coherence Tomography	See Optical Coherence Tomography.
Aqueous humour	Clear, colourless fluid that fills the anterior and posterior chambers of the eye. It contributes to the maintenance of the intraocular pressure. It is formed in the ciliary processes, flows into the posterior chamber, then through the pupil into the anterior chamber and leaves the eye through the trabecular meshwork passing to the canal of Schlemm (Millodot and Laby, 2002, p. 126).
Closed Angle Glaucoma	See Glaucoma.
False Positive	When a screening test incorrectly tests positive but the patient does not have the condition.
False Negative	When a screening test incorrectly tests negative but the patient does have the condition.
Glaucoma	A progressive optic neuropathy (damage to the optic nerve) characterized by structural changes in the optic nerve head with corresponding functional changes in the visual field (Salim, 2012, p.1).
Primary Closed Angle Glaucoma	The angle of the anterior chamber is blocked by the root of the iris which is in apposition to the trabecular meshwork (Millodot and Laby, 2002, p.115)
Primary Open-Angle Glaucoma	Glaucoma which follows a chronic time course and occurs in the presence of an open anterior chamber angle (the trabecular meshwork is visible on gonioscopy) (NICE, 2009).
Gold Standard	The best result that may be currently achieved so it provides a basis for assessing the quality of all other judgements (Gilchrist, 1992).
Gonioscopy	A clinical test where a mirrored contact lens (or gonioscope) is used in conjunction with slit lamp bio-microscopy to observe angle structures and estimate the depth of angle, allowing the examiner to determine whether the angle is open or closed (NICE, 2009).
Inter Observer Repeatability	A measure of an instrument's variability when used by two or more observers.
Intra Observer Repeatability	A measure of the variability in repeated measures by one observer when all other factors are assumed constant (McAlinden <i>et al.</i> , 2010).
Intra-Ocular Pressure	The internal pressure of the fluid contained within the eye (NICE, 2009).

Limbus	The junction of the cornea and sclera in the eye.
Occludable Angle	An eye with narrow anterior chamber angle at risk of angle closure.
Ocular Hypertension (OHT)	Raised intraocular pressure (IOP) in the presence of open angles and absence of visual field or optic nerve damage (Kotecha 2009).
Open Angle Glaucoma (OAG)	See Glaucoma.
Ophthalmologist	A medically qualified specialist with expert knowledge of conditions affecting the eye and orbit, including diagnosis, management and surgery.
Ophthalmoscopy	The examination of the optic nerve, retinal, ocular media using an ophthalmoscope or with slit lamp bio-microscopy (Walters, 2006).
Optical Coherence Tomography	Device that uses the principle of low-coherence interferometry to produce cross sectional images of ocular tissues (Brezinski and Fujimoto, 1999).
Anterior Segment Optical Coherence Tomography	The principle of low-coherence interferometry to produce a cross-sectional image of the anterior segment of the eye.
Optometrist	A healthcare professional with specialist training and expertise in conditions of the eye, especially measurement of vision and refractive error, prescription and dispensing of spectacles and contact lenses.
Orthoptist	A healthcare professional with specialist training and expertise in the care of conditions of the eye, especially measurement of vision in children and binocular function in children and adults (NICE, 2009).
Pachymetry	Measurement of the central corneal thickness.
Peripheral Anterior Synechiae (PAS)	Adhesions between peripheral cornea and peripheral iris that obstruct access to the drainage angle (Spry and Harper, 2010).
Repeatability	See Inter and Intra –Observer repeatability.
Primary Glaucoma	Glaucoma that occurs in the absence of any underlying ocular or medical condition (Kotecha 2009).
Scleral Spur	Part of the corneal-scleral portion of the trabecular meshwork (Kanski, 2007, p.234).
Schlemm’s canal	A circumferential channel through which aqueous humour leaves the eye after travelling through the trabecular meshwork (Kanski, 2007, p.234).
Sensitivity	The effectiveness of a test at finding disease positives (i.e. those with a certain condition).It is the proportion of disease

	positives that are correctly identified by the test (Bland, 2000).
Secondary glaucoma	Glaucoma that develops as a consequence of an ocular or medical co-morbidity (Kotecha 2009).
Slit Lamp Bio-microscope	The fundamental tool in the clinical examination of the eye, consisting of a moveable light source and binocular microscope that is used to illuminate and view the eye (Spalton <i>et al.</i> , 1998).
Specificity	The effectiveness of a test at excluding disease negatives (i.e. those who do not have a certain condition). It is the proportion of disease negatives that are correctly identified by the test (Bland, 2000).
Tonometry	A test to measure intraocular pressure using an instrument called a tonometer (NICE 2009).
Trabecular Meshwork	A sieve-like structure through which aqueous humour leaves the eye (Kanski, 2007, p. 234).
Van Herick method	A non-contact approach for estimating angle width using the slit-lamp beam to compare the depth of the peripheral anterior chamber depth to the thickness of the cornea (Van Herick <i>et al.</i> , 1969).
Visual Field	The total area that can be seen including central and peripheral vision for each eye is called the visual field (Walters, 2006, p. 20).

Abbreviations

ACA	Anterior Chamber Angle
ACG	Angle Closure Glaucoma
AOP	Association of Optometrists
AS-OCT	Anterior Segment Optical Coherence Tomography
CACG	Chronic Angle Closure Glaucoma
CI	Confidence Interval
COAG	Chronic Open Angle Glaucoma
GAT	Goldmann Applanation Tonometry
HES	Hospital Eye Services
IOP	Intra-ocular Pressure
NICE	National Institute for Health and Care Excellence
NHS	National Health Service
OCT	Optical Coherence Tomography
OHT	Ocular Hypertension
PACG	Primary Angle Closure Glaucoma
PAS	Peripheral Anterior Synchia
POAG	Primary Open-Angle Glaucoma
ROC	Receiver Operating Characteristic
SD	Standard Deviation
SPAC	Scanning Peripheral Anterior Chamber Depth Analyzer
SPSS	Statistical Package for the Social Sciences
SS	Scleral Spur
VH	Van Herick
VF	Visual Field

1 INTRODUCTION

1.1 Background

Healthcare in the United Kingdom is currently undergoing radical change (Grosios *et al.*, 2010). One of the challenges healthcare provision faces is the rise in the ageing population. The number of people over 65 years old is set to increase by fifty per cent in 20 years and then double to around 19 million by 2050 (Cracknell, 2013). The treatment and management of age related health conditions is likely to become more challenging over the next few decades. Within ophthalmic healthcare, community optometrists traditionally play a key role in the detection of eye disease (Bell and O'Brien, 1997). They are increasingly involved in the long term care of patients with chronic eye conditions such as diabetic eye disease and glaucoma.

The trend towards providing more “patient-centred” care over the past decade has meant a greater emphasis is placed on meeting the expectations of the patient (Department of Health, 2000). In 2007, the health minister Lord Darzi recommended that patient choice should be at the centre of NHS provision (Darzi, 2007). In ophthalmic care, convenience of the location for healthcare appointments has been described as an important factor in patient satisfaction by glaucoma patients (Bhargava *et al.*, 2008).

Glaucoma is a group of eye conditions more prevalent in an older population (Coleman and Miglior, 2008). It is the second most common cause of blindness in the UK (Bunce *et al.*, 2010). Due to the ageing population and increasing life longevity, the number of people with glaucoma in the UK is set to increase in the coming decades. Currently there are over a million glaucoma related outpatient visits in the hospital eye service annually in England (NICE, 2009). Optometrists are becoming more involved in glaucoma management in hospital and community settings (Marks *et al.*, 2012), in part due to the overburdened hospital resources. Community optometrists in convenient locations are well placed to play a greater role in the provision of future glaucoma care.

This thesis will look at certain aspects of glaucoma detection and management. The effect that the National Institute for Health and Clinical Excellence (NICE) guideline on glaucoma (NICE, 2009) has had on optometrist clinical behaviour will be investigated. The ability of optometrists and of other healthcare professionals to carry out certain clinical tests used in glaucoma diagnosis will be assessed and these results will be compared to those of consultant ophthalmologists. Comparison between certain tests used in glaucoma diagnosis and management will be investigated.

This Chapter will provide an introduction to testing for glaucoma and the role optometrists and other healthcare professionals play in glaucoma detection and management. The different types of glaucoma will be explained and management of glaucoma patients will be outlined. Certain aspects of glaucoma screening will be discussed.

1.2 Glaucoma

1.2.1 The Eye

Figure 1-1 shows a schematic diagram of the eye. Light rays enter the eye through the cornea, they are refracted by the cornea and lens to focus on the retina. Retinal photoreceptors transduce this light into neuronal signals, photochemical reactions take place in the outer retina when photons of light are absorbed by the photoreceptors. A neuronal signal cascade is then initiated. Signals are relayed from the retina to an area of the brain called the lateral geniculate nucleus. They are then relayed to the Primary Visual Cortex and subsequently to the extra-striate cortex. The region of space perceived by the eye is called the visual field (Spalton *et al.*, 1998).

The eye contains three chambers, see Figure 1-1. The anterior and posterior chambers are filled with aqueous humour and the vitreous chamber is filled with

vitreous humour. The function of the aqueous humour is to keep the eye inflated, provide nutrients to the iris, lens, and cornea (Weinreb and Khaw, 2004). It also permits inflammatory cells and mediators to circulate in the eye in pathological conditions (Goel *et al.*, 2010). Aqueous humour is formed by active secretion in the non-pigmented epithelium layer of the ciliary body, located behind the iris. Active secretion involves selective trans-cellular movement of ions and other molecules across a concentration gradient in the blood-aqueous barrier (Goel *et al.*, 2010). The aqueous then travels through the pupil into the anterior chamber. Ninety percent of the aqueous drains through a meshwork (called the “trabecular meshwork”) located between the root of the iris and the cornea, see Figure 1-1. This drainage junction is called the anterior chamber angle or “drainage angle”. The remaining ten percent of aqueous leaves via the “uveal-scleral” pathway (Hitchings, 1998), through the anterior ciliary body, between muscle bundles and out through the sclera (Bill, 1977).

The intra-ocular pressure (IOP) is regulated by a balance between the secretion and drainage of aqueous humour (Walters, 2006). Small variations in the production or outflow of aqueous humour are known to have a large influence on the intraocular pressure (IOP) (Weinreb and Khaw, 2004).

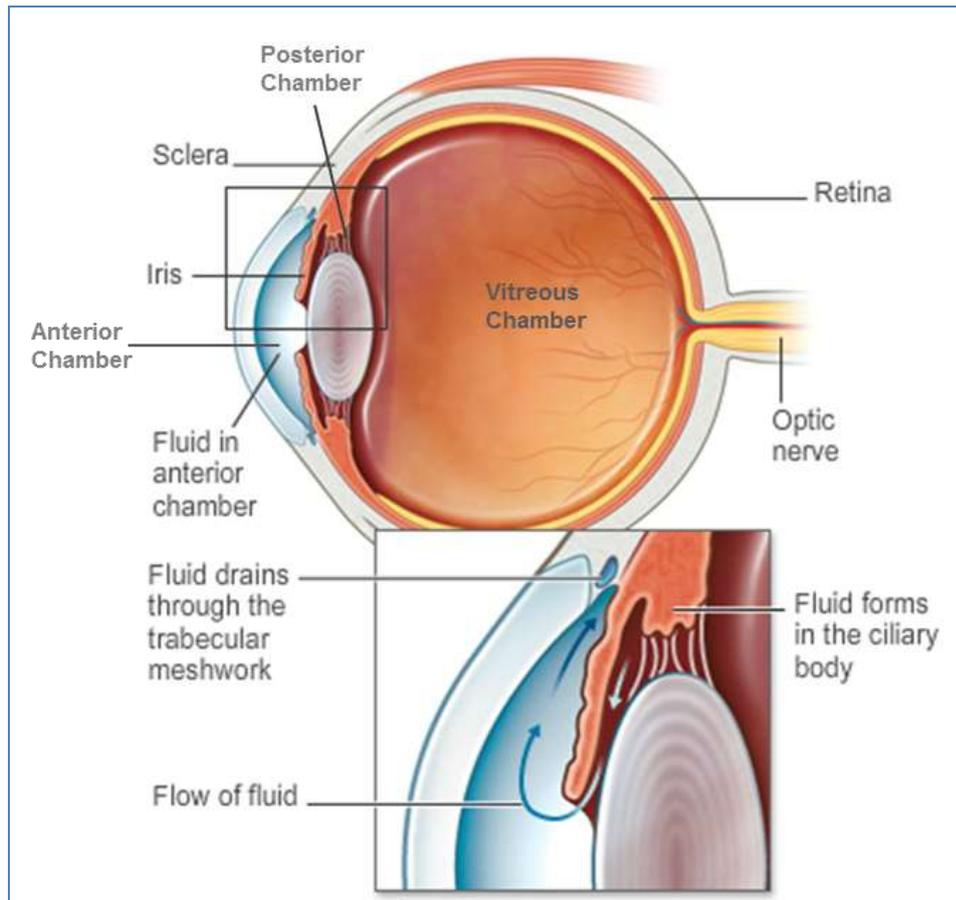


Figure 1-1 Artistic drawing showing the main components of the eye (courtesy of <http://www.nhs.uk/Conditions/Glaucoma/Pages/Causes.aspx>; accessed 16 January 2014).

1.2.2 Definition of Glaucoma

Glaucoma is the leading cause of irreversible blindness worldwide (Quigley, 1996). It is defined as a progressive optic neuropathy (damage to the optic nerve) characterized by structural changes in the optic nerve head with corresponding functional changes in the visual field (Salim, 2012). Raised IOP is the main ocular risk factor for developing glaucoma (Weinreb and Khaw, 2004). Other risk factors include increasing age, African ethnicity, family history of glaucoma, myopia, vascular disease and history of steroid use (Kotecha, 2009).

1.2.3 Glaucoma Classifications

Glaucoma is classified as either primary (in the absence of any underlying ocular or medical condition) or secondary (as a consequence of an ocular or medical condition), and further subdivided into open and closed-angle glaucoma. Primary open angle glaucoma (POAG) occurs when there is no obvious physical occlusion to the drainage of aqueous fluid at the front of the eye, but changes can occur within the functioning of the trabecular meshwork (Spry and Harper, 2010). Primary angle closure glaucoma (PACG) occurs when the position of the peripheral iris causes a significant obstruction to aqueous outflow. This can lead to an increase in IOP and subsequent optic nerve damage (Kotecha, 2009). Figure 1-2 shows the difference in appearance between open angle and closed angle glaucoma.

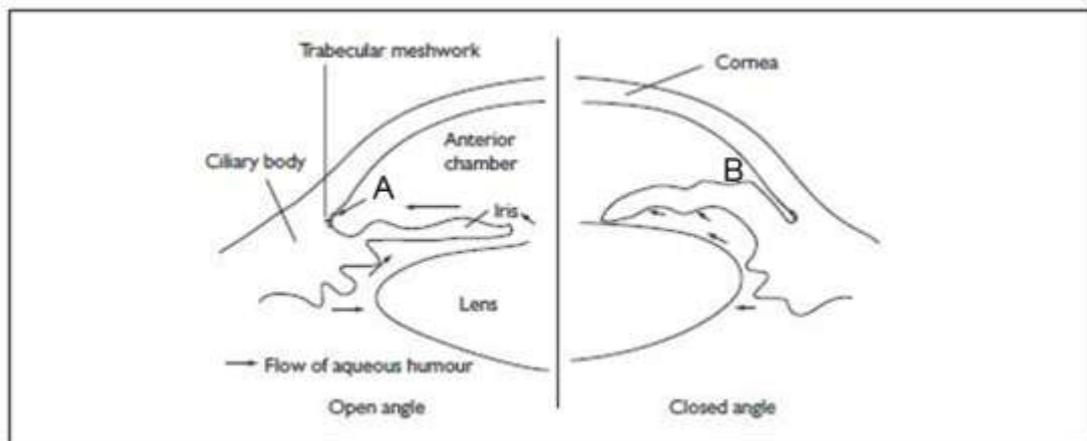


Figure 1-2 Anterior chamber of the eye showing an open angle (A) and closed angle (B). The arrows represent the flow of aqueous fluid (courtesy of Burr *et al.*, 2007).

The differential diagnosis of open angle glaucoma and angle closure glaucoma is normally made by examination of the anterior chamber angle (ACA) using a mirrored contact lens placed on the cornea; this technique is called “gonioscopy” (Figure 1-3).

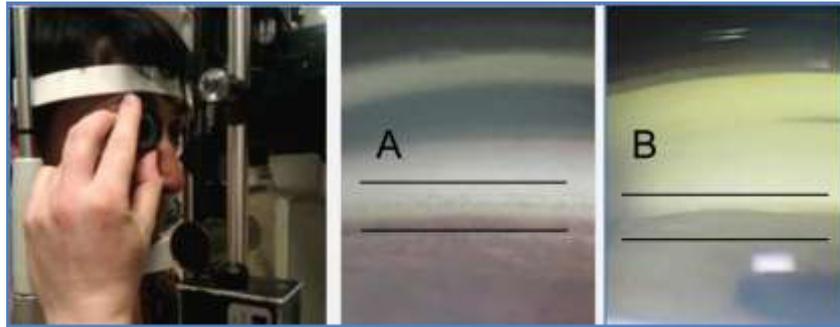


Figure 1-3 Gonioscopy: a contact lens is placed onto the cornea (left image). The ACA is shown between the two horizontal lines. Figure A: open angle Figure B: closed angle (images reproduced courtesy of www.gonioscopy.org, accessed 10 January 2013).

Primary angle closure is subdivided into three categories (Weinreb and Friedman, 2006):

1. *Primary angle closure suspect (PACS)*: the iris is in contact with the trabecular meshwork for at least 270 degrees of the anterior chamber angle but IOP, optic nerve and visual field are normal.
2. *Primary angle closure (PAC)*: Iris is in contact with the trabecular meshwork with either raised IOP and/or evidence of adhesion between the peripheral cornea and peripheral iris. Optic nerve and visual field are normal.
3. *Primary angle closure glaucoma (PACG)*: Iris-trabecular contact plus evidence of glaucomatous damage to the optic nerve.

In the UK, the estimated prevalence of POAG in people over 40 years is 2.1% (Burr *et al.*, 2007). This rises to almost 10% in people older than 75 years. The risk of developing open angle glaucoma is four times higher in those of African ethnicity (Burr *et al.*, 2007). POAG is a chronic condition and visual loss occurs gradually over many months.

The prevalence of PACG is estimated at 0.4% in people over 40 years in a European population (Day *et al.*, 2012). The prevalence of PACG is higher in Asia, ranging from 1.26% in China, 1.20% in South East Asia and 0.80% in India (Quigley and Broman, 2006). The higher prevalence in Asian eyes is believed to be due to smaller anterior

segment dimensions (Foster *et al.*, 2000), where the iris is inserted more anteriorly, (He *et al.*, 2006). The higher prevalence is not believed to be associated with refractive status; myopes, who typically have longer axial lengths (the distance from anterior to posterior poles), have been found to have similar anterior segment characteristics to hypermetropes and emmetropes in an East Asian population (Yong *et al.*, 2014).

The prevalence of PACG is also higher in females (Alsbirk, 1974) due to a shallower anterior chamber depth. This higher prevalence of PACG is of relevance to optometrists in the UK who work in areas with high levels of Asian ethnicity (College of Optometrists, 2013a).

PACG can be acute or chronic, sometimes causing vision loss in the space of a few days. It is believed to be more asymptomatic in Asian eyes (He *et al.*, 2006). In part due to the fact that angle closure can cause loss of vision quickly, nearly half of all blindness caused by glaucoma is from closed angle glaucoma (Quigley and Broman, 2006).

Ocular hypertension (OHT) is defined as elevated IOP with open angles in the absence of visual field loss or glaucomatous optic nerve damage. It is estimated that up to 10% of people over 40 years in the UK have ocular hypertension and that between 4% and 10% of these individuals will eventually develop glaucoma (Kotecha, 2009).

Strategies for the treatment of open and closed angle glaucoma differ. Initial therapeutic options for open angle glaucoma involve the use of intra-ocular pressure lowering glaucoma medications (eye drops) and/or laser trabeculoplasty (laser burns in the trabecular meshwork to reduce aqueous outflow). Angle-closure glaucoma normally requires initial treatment with laser peripheral iridotomy (a laser burn in the peripheral iris) to enable improved drainage of the aqueous humour due to a change in the iris profile (Spry and Harper, 2010).

Individuals with glaucoma or OHT require lifelong monitoring for disease control and detection of possible progression of visual damage (Hitchings, 1995). At present more than half of glaucoma cases are thought to be undetected in the UK (Bunce *et al.*, 2010). With the ageing population as well as improved glaucoma detection rates, the number of cases of open angle glaucoma in England and Wales was previously predicted to increase by a third from 2003 to 2021, and then continue upwards at a similar pace to 2031 (Tuck and Crick, 2003). The number of cases of angle closure glaucoma is expected to increase by 19% in the UK over the next decade (Day *et al.*, 2012).

1.3 Tests used in the detection and diagnosis of glaucoma

In the UK, optometrists are responsible for up to 96% of referrals of patients with suspected glaucoma to the Hospital Eye Service (HES) (Bell and O'Brien, 1997). Optometrists are trained to “*evaluate glaucoma risk factors, to detect glaucoma and refer accordingly*” (College of Optometrists, 2013b).

Glaucoma is a multifactorial condition (Jamous *et al.*, 2014) and optometrists carry out a myriad of tests when screening for glaucoma. These comprise measuring the intraocular pressure (IOP), assessing the appearance of the optic nerve head, assessing the visual field and assessing the anterior chamber angle (Kotecha, 2009). Patients suspected of having glaucoma are traditionally referred to an ophthalmologist within the Hospital Eye Service for diagnosis and subsequent management.

1.3.1 Tonometry: measuring the IOP

The intra-ocular pressure (IOP) is regulated by a balance between the secretion and drainage of aqueous humour (Weinreb and Khaw, 2004). Raised IOP is the main risk factor in the progression of vision loss caused by glaucoma. The Ocular Hypertension Treatment Study (OHTS) showed that subjects with higher IOP had a greater risk of developing glaucoma (Kass *et al.*, 2002).

Tonometry involves the measurement of the IOP in a clinical setting. Manometry measures the “true IOP” when the eye is canulated in a surgical setting (Okafor and Brandt, 2015). Contact or applanation tonometry is the reference standard method to measure IOP, in a clinical setting (Kotecha *et al.*, 2010). Goldmann applanation tonometry, carried out at the slit lamp bio microscope as shown in Figure 1-4, is based on the Imbert-Fick Law. This states that the force required to deform a given area of the cornea is proportional to the IOP (Spalton *et al.*, 1998). Anaesthetic drops are instilled, and an estimation of the IOP is based on the force required to applanate the corneal apex to an area of 7.35mm^2 (Okafor and Brandt, 2015).

Perkins applanation tonometer, a handheld alternative method, has been shown to be comparable to Goldmann applanation tonometry (Arora *et al.*, 2014). Myint *et al.*, (2011), in a survey carried out in 2008, reported that 11% of UK community optometrists perform Perkins tonometry and 5% perform Goldmann tonometry.

Traditionally community optometrists measure the IOP with an “air puff” or non-contact tonometry (NCT), see Figure 1-4. Myint *et al.*, (2011) reported that in 2008, 79% of optometrists use NCT. A pulsed jet of air is projected onto the cornea and the time taken to applanate the corneal apex is proportional to the IOP (Shields, 1980). This method requires no anaesthesia and can be carried out by trained technicians. However, NCT devices have been shown to be influenced by biomechanical factors such as corneal thickness and ocular rigidity (Tonnu *et al.*, 2005). They are also influenced by ocular pulse amplitude and multiple measurements are needed (Okafor and Brandt, 2015). The age of the machine has also been shown to affect its accuracy (Atkinson *et al.*, 1992).



Figure 1-4 Left image: contact tonometry at the slit lamp bio-microscope. Right image: Non-contact (air-puff) tonometry.

Newer methods of measuring IOP include rebound tonometry (iCare, Tiolat Oy, Helsinki, Finland). This handheld contact method fires a probe onto the cornea. The probe rebounds from the anterior corneal surface and the motion and impact of the probe is measured to obtain the IOP (Kontiola, 2000). This method does not require anaesthesia and has been shown to compare well with Goldmann applanation tonometry (Fernandes *et al.*, 2005), although it overestimates the IOP at higher IOP values (Beasley *et al.*, 2013). Myint *et al.* (2011) found that four years after its introduction in 2008, 4% of UK optometrists were routinely using rebound tonometry. The use of rebound tonometry has however increased in optometry practice in more recent years (Optometry Today, 2012) and from the present author's anecdotal evidence, more community optometrists have recently changed from non-contact to rebound tonometry.

The mean IOP in normal eyes is estimated between 15–16 mmHg, with a standard deviation (SD) of 2.5–2.8 mmHg (Colton and Ederer, 1980; Hollows and Graham, 1966). Accuracy of IOP measurement has been shown to be significantly influenced by corneal properties, such as thickness, curvature, rigidity, viscosity, elasticity and hydration (Whitacre and Stein 1993; Doughty and Zaman 2000).

1.3.2 Pachymetry

Measurement of corneal thickness is called pachymetry. Ultrasound-based pachymetry was introduced into clinical practice in the 1970s and 1980s replacing

earlier optical methods (Doughty and Zaman, 2000). The thickness of the cornea is measured in micrometres, using an ultrasonic transducer on the cornea. The measurement of IOP can be by affected central corneal thickness (Kotecha, 2009); a thicker cornea requires greater force to applanate and, conversely, a thinner cornea is more easily flattened (Tonnu *et al.*, 2005). Ocular hypertension patients with thinner corneas are at greater risk of developing POAG (Gordon *et al.*, 2002). With modern instrumentation, this is a quick, simple procedure to carry out. It is not routinely carried out in community optometry practice (Myint *et al.*, 2011), however it is a relatively easy test for optometrists to learn.

1.3.3 Assessing the Optic Nerve

Examination of the optic nerve head is essential in assessing patients at risk of glaucoma (College of Optometrists, 2013b). Glaucoma can cause changes in the optic nerve head appearance. Figure 1-5, shows progressive damage to an optic nerve over a five year period from glaucoma. The arrows show the change in the optic nerve “cupping” caused by glaucoma. This shows a quite obvious change but in many cases the difference can be quite subtle or even indistinguishable.

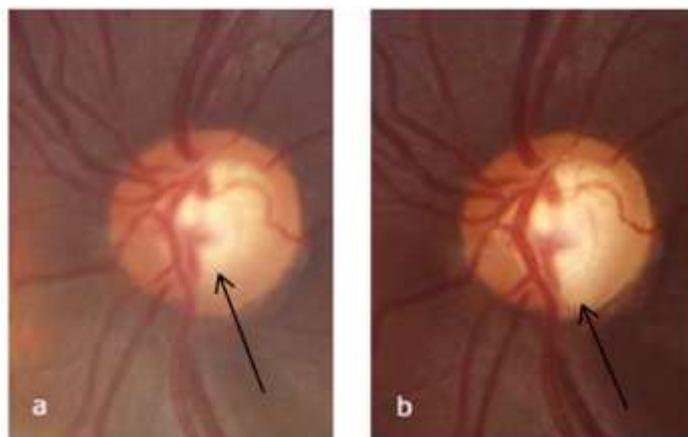


Figure 1-5 Optic Nerve Head images. The arrows denote the change in the optic nerve neuro retinal rim tissue caused by progressive glaucoma damage over a five year period. Courtesy of Kotecha (2009).

Other changes that can occur with glaucoma include asymmetric optic nerve heading cupping, optic nerve haemorrhages, acquired “pit” of the optic nerve and retinal nerve fibre layer loss around the optic nerve (Weinreb and Khaw, 2004).

Optometrists have traditionally used the hand held ophthalmoscope to examine the optic nerve and retina but are increasingly using the binocular indirect method with the slit lamp bio microscope (College of Optometrists, 2008). This gives a more detailed stereoscopic (three-dimensional) view of the optic nerve. More recently, imaging methods such as Optical Coherence Tomography (OCT) have allowed more quantitative assessment of the optic nerve head and nerve fibre layer analysis (Hood and Kardon, 2007).

1.3.4 Assessing the Visual Field

The visual field is the total area that can be seen including central and peripheral vision for each eye (Walters, 2006). Standard automated perimetry refers to the standardised method to measure the visual field using fixed sizes and intensities of stimuli. Detection of visual field defects is important when screening for glaucoma damage. Figure 1-6 shows a visual field test being carried out along with an example of a characteristic visual field defect caused by glaucoma. The blacked out area in the superior part of the visual field plot in the right image represents the loss of vision caused by optic nerve damage from glaucoma.

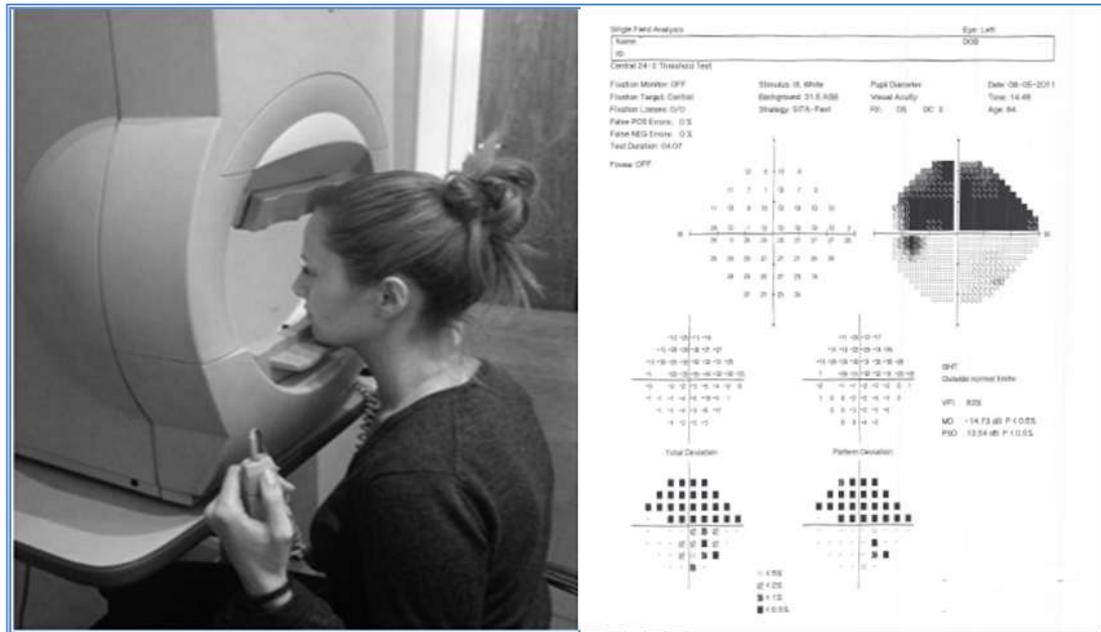


Figure 1-6 The visual field test, the patient clicks the button each time they see a stimulus. Right image is an example of visual field loss caused by glaucoma.

1.3.5 Assessing the Anterior Chamber Angle

Assessing the ACA is important in assessing a patient at risk of PACG, prior to onset of the disease. The “van Herick method” (Van Herick *et al.*, 1969) is a quick and easy test commonly used by optometrists to assess the anterior chamber angle (Figure 1-7). It is recommended by the College of Optometrists (the UK Optometrists professional body) when examining patients at risk from glaucoma (College of Optometrists, 2013b) in order to screen for patients at risk of PACG.

The ACA is graded as narrow if the anterior chamber depth thickness is less than or equal to one quarter the thickness of the cornea. This technique is described in further detail in Section 2.2.2.

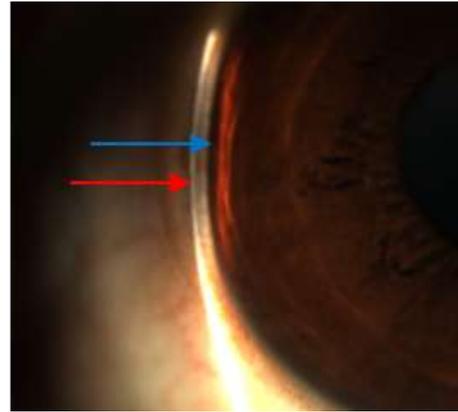


Figure 1-7 The van Herick method using the slit lamp bio microscope -the thickness of the cornea is compared to the anterior chamber gap. The red arrow points to the white slit of the corneal section, the blue arrow points to the dark strip of anterior chamber “gap”.

1.4 The Role of the Optometrist in Glaucoma Detection and Management

Glaucoma detection is typically opportunistic when patients attend for a routine eye examination based on optometrist case finding (Burr *et al.*, 2007). Patients suspected of open angle glaucoma or ocular hypertension are referred to an ophthalmologist clinic or a referral refinement clinic (see section 1.4.1) for further investigation and diagnosis. Patients who present with angle closure glaucoma signs and/or symptoms are referred urgently for an assessment.

1.4.1 Glaucoma Referral Refinement

Due to the low prevalence of glaucoma in the UK (2.1% for open angle glaucoma in people over 40 years), there has traditionally been a relatively large number of patients referred from optometrists who in turn do not have the condition (Henson *et al.*, 2003). This “false positive rate” has been reported as between 26% and 46% (Bowling *et al.*, 2005; Pierscionek *et al.*, 2009). This places considerable strain on overstretched NHS resources and also causes unnecessary anxiety for the patient. In recent years, new schemes have been introduced in an attempt to reduce the false positive referral rate. The simplest type of scheme is where certain measurements are repeated by a more accurate method, for example, a raised

reading of IOP using non-contact tonometry is checked again with Goldmann appplanation tonometry. If the IOP is found to be above 21 mmHg then the patient is referred on to the Hospital Eye Service.

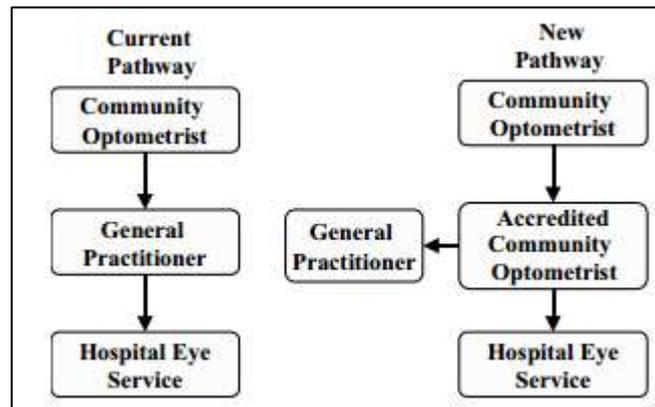


Figure 1-8 Referral Refinement Pathway, courtesy of Henson *et al.*, (2003).

A referral refinement scheme is where “an initial suspicious finding is validated by a subsequent enhanced assessment which adds value beyond that achieved through a simple repeat measures scheme” (College of Optometrists and Royal College of Ophthalmologists, 2013, p. 6).

Patients with suspected glaucoma are referred to one of a group of specially trained community optometrists working to an agreed set of referral criteria. Patients are assessed and subsequently referred back to their GP/Optomertist or to the hospital eye service as appropriate, see Figure 1-8. These schemes have been shown to help reduce the number of false positives by 40% (Henson *et al.*, 2003).

1.4.2 Glaucoma Shared Care

Shared care schemes, in ophthalmology, have been defined as the use of “paramedical personnel” either within the eye department or outside it to manage some patients with chronic ophthalmic disease (Hitchings, 1995). In 1995 the College of Optometrists and the Royal College of Ophthalmologists discussed the future use of clinical optometric expertise to relieve the predicted burden of overloaded hospital eye departments (Royal College of Ophthalmologists *et al.*,

1995). Various glaucoma shared care schemes now exist with optometrists, nurses and orthoptists working alongside ophthalmologists in a hospital setting or independently within a community setting (Vernon and Adair, 2010). Optometrists are well placed to take on this role as they possess many of the skills required to examine a glaucoma patient (Marks *et al.*, 2012).

These schemes have been shown to operate safely. Gray *et al.*, (2000) reported on the findings of a randomised control trial on 405 patients with either stable or suspect glaucoma who were reviewed either in the hospital eye service or by a trained community optometrist in the Bristol area over a two year period. Community optometrists were shown to take measurements of comparable accuracy to those made by hospital ophthalmologists. A scheme comparing decision making between optometrists and ophthalmologists in Grampian, Scotland showed that community optometrists trained in glaucoma provided satisfactory decisions regarding glaucoma diagnosis and treatment (Azura-Blanco *et al.*, 2007). Optometrists are therefore well placed to relieve the strain on increasingly over stretched hospital-based glaucoma clinics.

1.5 The NICE guideline on the diagnosis, treatment and monitoring of chronic open angle glaucoma (COAG) and ocular hypertension (OHT)

The NICE guideline on Glaucoma published in April 2009 (NICE, 2009) provided a series of recommendations on the diagnosis, treatment and monitoring of chronic open angle glaucoma (COAG) and ocular hypertension (OHT).

The guideline highlighted the fact that:

“There are not enough ophthalmologists at present so the work needs to be shared” (NICE, 2009, p. 239).

The guideline states that patients should be offered a series of tests in order to confirm diagnosis of COAG or OHT, including testing to exclude primary closed angle glaucoma (PACG):

- Intra-ocular pressure measurement using Goldmann applanation tonometry
- central corneal thickness (CCT) measurement/pachymetry
- peripheral anterior chamber configuration and depth assessments using gonioscopy
- visual field measurement using standard automated perimetry
- optic nerve assessment, with dilatation, using stereoscopic slit lamp biomicroscopy with fundus examination

The introduction of the guideline had a considerable impact on optometric practice. Prior to the NICE publication, optometrists often used their clinical judgement on patients with normal ocular examination and borderline IOP based on risk factors such as age and a family history of glaucoma (Ratnarajan *et al.*, 2013). The publication of the guideline meant that these patients should be referred for further assessment. The Association of Optometrists (the leading UK optometrist membership organisation) issued a statement after the publication of the guidance advising that:

“OHT should be formally diagnosed using gonioscopy before continued monitoring”

They also advised optometrists to:

“Refer all patients with intraocular pressure over 21 mm Hg to an ophthalmologist”

(Association of Optometrists *et al.*, 2010, p. 1)

There was a surge in referrals by optometrists for suspect glaucoma after the release of the guideline (Shah and Murdoch, 2011). However further clarification was made in a joint statement by the Royal College of Ophthalmologists and the College of Optometrists, recommending that IOP measurements should be repeated prior to referring a patient. In addition, patients aged 80 years and over

with IOPs < 26 mmHg and otherwise normal ocular examinations as well as patients aged 65 years and over with IOPs < 25 mmHg and otherwise normal ocular examinations need not be referred (College of Optometrists and Royal College of Ophthalmologists, 2010).

1.5.1 NICE guideline and Gonioscopy

NICE reviewed the available evidence on methods of anterior chamber angle assessment and concluded that gonioscopy was the preferred method for angle assessment and should be carried out at diagnosis of COAG and OHT and repeated when clinically indicated:

“Gonioscopy allows comprehensive visualisation of the interior anterior chamber angle and related structures in a way which is not possible using any of the other tests....No technique was considered a suitable alternative to gonioscopy in describing the status of the drainage angle. For exclusion of angle closure and accurate diagnosis the reference standard is therefore required” (NICE, 2009, p. 82).

Gonioscopy is acknowledged to be a clinically demanding skill and semi-subjective in nature (Gazzard and Nolan, 2009). NICE recommends the use of the van Herick method when gonioscopy is not possible for example with wheelchair patients (NICE, 2009).

The NICE guideline highlighted the fact that gonioscopy is not routinely carried out in UK optometric practice. A national survey of community optometrists in 2008 investigating clinical practice showed that only twelve per cent of optometrists had access to a gonioscopy lens (Myint *et al.*, 2011). The lack of optometrist experience in gonioscopy could potentially pose a problem for optometrists involved in referral refinement schemes and glaucoma shared care clinics where gonioscopy may be required. The publication of the guideline has however provided an opportunity for

optometrists along with other healthcare professionals to learn new skills and improve competency in management of glaucoma and OHT patients.

1.6 Summary and Thesis Outline

Glaucoma is the second most common cause of blindness within the UK (Bunce *et al.*, 2010). Due to an ageing population the number of people with glaucoma is set to increase significantly over the next decades. Optometrists play an important role in glaucoma diagnosis and have been shown to provide safe and accurate care to glaucoma patients (Azuara-Blanco *et al.*, 2007; Gray *et al.*, 2000).

This chapter has provided information on the types of glaucoma and the tests involved in glaucoma detection and diagnosis. The role of optometrists in glaucoma management and the implications of the NICE guideline on chronic open angle glaucoma and ocular hypertension have been discussed. Assessment of the ACA is important in the diagnosis of POAG, PACG and OHT. In the next chapter, the methods to assess the ACA will be investigated. In Chapter Three a literature review will investigate the evidence on comparing ACA methods. Literature comparing gonioscopy results by different clinicians will be highlighted. Based on this literature review, the aims of the thesis will be outlined.

2 CLINICAL TECHNIQUES FOR ASSESSING THE ANTERIOR CHAMBER ANGLE

2.1 Introduction

As discussed in Chapter One, due to the ageing population in the UK, the treatment and management of age related health conditions such as glaucoma is likely to become more challenging over the next few decades. In an attempt to relieve the predicted burden of overloaded hospital eye departments, optometrists along with other healthcare professionals are becoming more involved in the management of glaucoma patients. This means that over time they are likely to take on more clinical roles previously performed by ophthalmologists.

The NICE guidance on the diagnosis and monitoring of patients with chronic open angle glaucoma (COAG) and ocular hypertension (OHT) advised that a number of tests including gonioscopy should be carried out at diagnosis of COAG and OHT (NICE, 2009). Gonioscopy is seen as the gold standard method for assessing the ACA (Friedman and He, 2008). It allows the clinician to directly visualise the angle structures. Other methods to directly visualise the ACA include Anterior Segment Optical Coherence Tomography (AS-OCT), see Section 2.2.3. In this chapter, gonioscopy along with alternative methods of ACA assessment will be discussed. Statistical methods to compare clinical tests will also be reviewed.

2.1.1 Anterior Chamber Angle

The normal ACA structures are shown in Figure 2-1, the inset shows an artistic impression of how these structures may appear when viewed by a clinician during gonioscopy. The ciliary body (A) is the most posterior structure and typically appears pigmented in colour. The scleral spur (B) appears as a whitish band. The trabecular meshwork consists of a posterior pigmented part (C) adjacent to the scleral spur and an anterior non-pigmented part (D). The posterior part overlies the canal of Schlemm and is active in the aqueous drainage. Schwalbe's Line (E) is the most anterior structure and appears as an opaque line (Salmon, 2009).

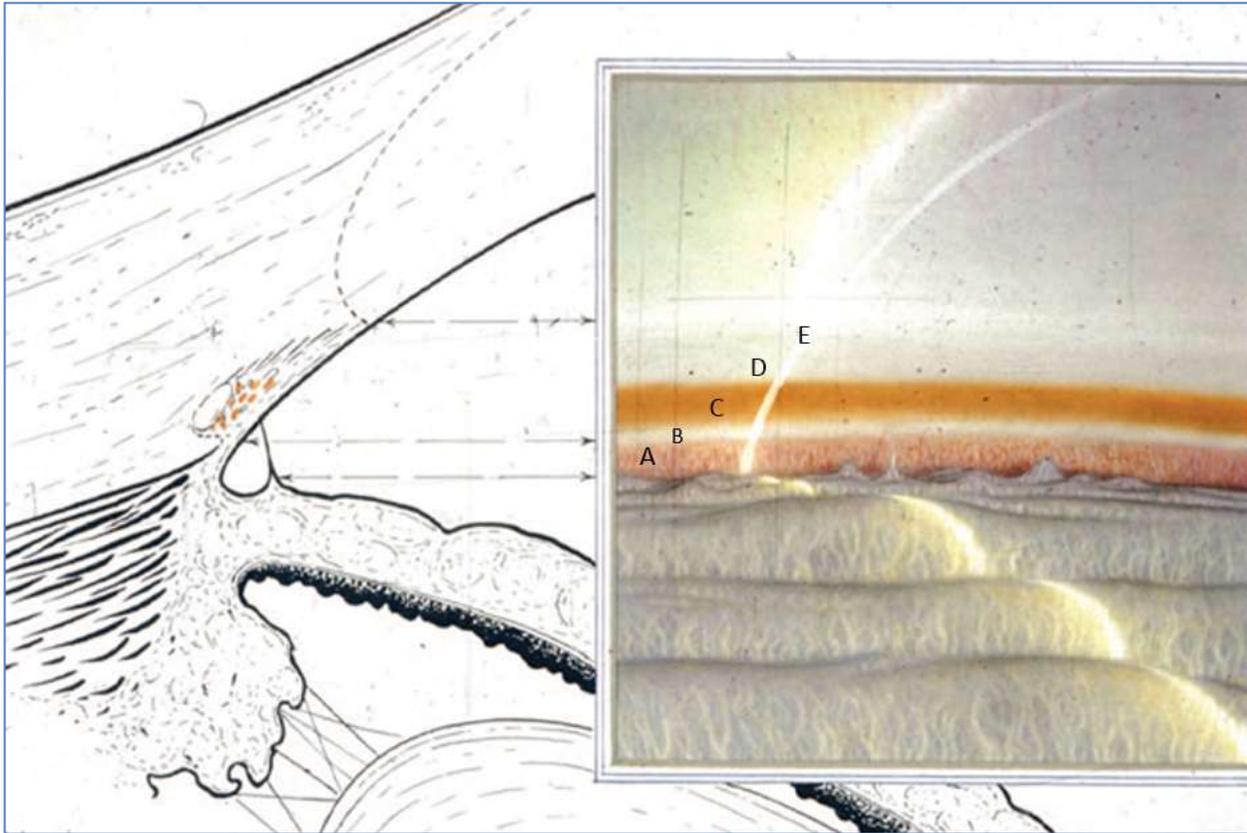


Figure 2-1 Normal angle structures: A=ciliary body-(pinkish band), B=scleral spur (white band), C=posterior trabecular meshwork (orange band) D=non-pigmented trabecular meshwork (gray-ish band), E=Schwalbe's line-(faint line). Courtesy of E Lee Allan, University of Iowa (Alward, 2011).

As discussed in Section 1.2.1, ninety per cent of the aqueous humour drains out of the eye primarily through the trabecular meshwork into the canal of Schlemm. If the iris is in contact with the trabecular meshwork, the aqueous humour is unable to drain out of the eye and this can lead to PACG.

2.2 Methods used in ACA assessment

The ideal method of angle assessment should be clinician independent, rapid, non-invasive, allow easy visualisation of the angle and easily be able to quantify the risk of closure (Baskaran *et al.*, 2007).

2.2.1 Gonioscopy

Gonioscopy was first developed in 1898 by Alexios Trantas, a Greek ophthalmologist who discovered that he could see the ACA with a direct ophthalmoscope while indenting the sclera with his finger (Alward, 2011). He coined the term “gonioscopy” - meaning observation of the angle, in his native Greek (Dellaporta, 1975). In 1914, Salzman introduced the first gonioscopy contact lens for indirect viewing of the ACA (Smith *et al.*, 2013) and was the first person to study the angle in detail (Alward, 2011).

There are two methods of gonioscopy. Direct gonioscopy involves placing a lens on the cornea that alters the approach of the light from the ACA, thus overcoming total internal reflection, in the cornea, and allowing a direct view of the ACA (Alward, 2011). It is difficult to carry out and is now normally limited to the operating theatre for examining infants under general anaesthesia and during glaucoma surgery. Modern indirect gonioscopy was introduced in 1938 by Goldmann and is the more widespread method (Alward, 2011). The practice of gonioscopy did not become popular within ophthalmology until the 1960s when slit lamp bio-microscopes and gonioscopy lenses became more widely available (Fisch, 1993).

Indirect gonioscopy should be undertaken in a dark room using a 1mm slit lamp beam with adequate illumination to visualise the structures clearly (Weinreb and Friedman, 2006). The patient should be instructed to look straight ahead (primary position). Figure 2-2 shows indirect gonioscopy being performed and the view of the ACA obtained.

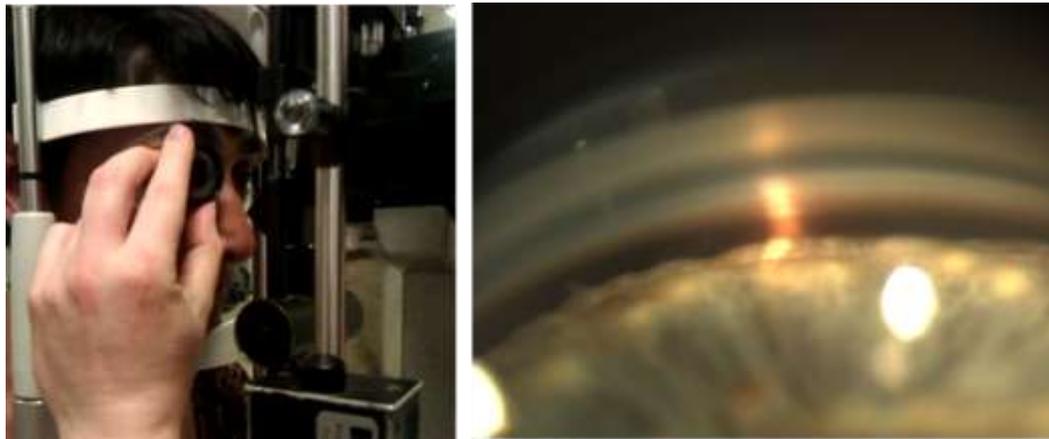


Figure 2-2 Gonioscopy technique. A gonioscopy lens is placed onto the cornea after the instillation of anaesthetic drops. A view of the ACA is shown on the right.

Gonioscopy Grading Schemes

The grading of the ACA is an essential part of gonioscopy. The aims of grading are to evaluate the functional status of the ACA, the degree of angle closure and the risk of further angle closure (Salmon, 2009). There are several different schemes in place.

Scheie System

This system, developed in 1957, is a grading scheme based on the visible angle structures (Alward, 2011). The Scheie system is not however commonly used today (Salmon, 2009). Grade I is the widest angle in which the ciliary body is visible. Grade II is an open angle where the scleral spur is identified. Grade III is moderately narrow where only the anterior trabecular meshwork is visible. Grade IV is closed. No studies have been published documenting inter or intra-observer repeatability of this grading scheme (Friedman and He, 2008).

Shaffer System

The Shaffer grading system, introduced in 1960, uses the opposite numerical approach to Scheie grading. Closed is grade 0 and wide open is grade 4, see Figure 2-3. The clinical interpretation of each grade is described in Table 2-1. The angle is often graded according to the visibility of the various angle structures (Salmon, 2009).

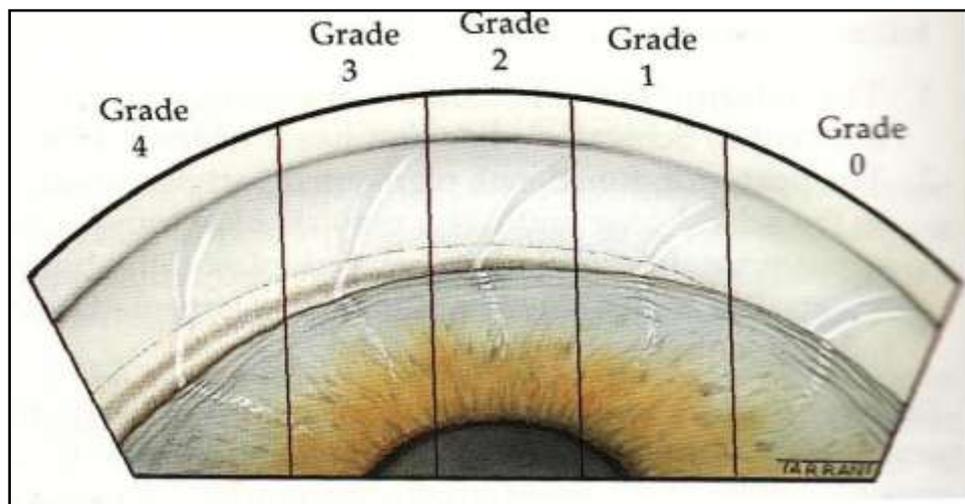


Figure 2-3 Shaffer Grading system – each section in the image shows the typical appearance for each Grade, reproduced courtesy of Kanski (2007).

Table 2-1 Shaffer Grading interpretation (adapted from Salmon, 2009)

Shaffer angle	Grade	Structures visible	Clinical interpretation
35-45°	4	Ciliary body	Closure impossible at present
25-35°	3	Scleral Spur	Closure impossible at present
20°	2	Pigmented TM	Closure possible but unlikely
10°	1	Non-Pigmented TM	Closure not inevitable but risk is high
0°	0	None	Closed

This system is widely used today clinically and in research (Friedman and He, 2008). It is a quick and simple method to classify the status of the ACA for each quadrant. It may be confusing if the angle width and structures visible do not appear to match

(Friedman and He, 2008). Also this scheme does not describe the iris shape or the level of the iris insertion (Alward, 2011). The Spaeth system, a modification of the Shaffer system; provides information on the iris insertion angle, iris approach and the configuration of the iris (Spaeth, 1971). This system is more complex and is not used often in practice (Salmon, 2009).

Following gonioscopy, the eye can be graded as “occludable” (at risk of developing PACG) or “open” (no risk of developing PACG). Different criteria exist in the literature for defining an occludable eye. Foster *et al.*, (2000) state an eye is occludable when the posterior trabecular meshwork is only visible in one quadrant or none of the angle circumference (at least three quadrants with Grade 0 or 1). Lavanya *et al.*, (2008), using a more lenient definition, state an eye is defined as occludable if the posterior trabecular meshwork is visible for two quadrants or less (at least two quadrants with Grade 0 or 1). Nolan *et al.*, (2007), grade an eye as occludable if the posterior trabecular meshwork is visible for three quadrants or less (at least one quadrant with Grade 0 or 1). This latter definition offers the greatest sensitivity when screening eyes at risk of PACG at the expense of lower specificity.

Advantages of Gonioscopy when assessing ACA

Gonioscopy allows direct visualisation of the ACA and this permits the clinician to determine the presence of primary open angle or primary angle closure glaucoma (POAG or PACG). It is also used to monitor changes in the ACA over time (Friedman and He, 2008). In addition, it is used to investigate any new blood vessels in the angle in diabetic patients and to assess for any evidence of ocular trauma (Cockburn, 1981).

Disadvantages of Gonioscopy

Gonioscopy has substantial inter-observer variability and relies on subjective assessment of ACA findings (Friedman and He, 2008). It is not always well tolerated by patients and the examiner has to make a decision relatively quickly when viewing the ACA in order to minimise the discomfort to the patient.

It involves direct contact with the eye. Inadvertent pressure on the cornea may lead to distortion to the ACA and this may affect the visibility of the angle. The interpretation of the findings requires considerable skill and experience (Lavanya *et al.*, 2008). It may be time consuming in a busy clinic (Foster *et al.*, 2000). A survey carried out in 2008 showed that only 8% of UK community optometrists had access to a gonioscopy lens (Myint *et al.*, 2011).

2.2.2 Van Herick Method

The van Herick method was developed as a non-contact alternative to gonioscopy (Friedman and He, 2008). It is commonly used by optometrists to assess the ACA and is recommended by the College of Optometrists (the UK Optometrists professional body) when examining patients at risk from glaucoma (College of Optometrists, 2013b).

In this method, the thickness of the peripheral cornea is compared to the depth of the peripheral anterior chamber adjacent to the edge of the cornea (called the limbus), see Figure 1-7. It is normally carried out only for the temporal quadrant as this has been shown to be shallower than the nasal quadrant (Alsbirk, 1986). However this quadrant may not always correspond to the narrowest angle and this may result in an under estimation of angle closure when only the temporal quadrant is chosen (Gispets *et al.*, 2013). In addition the superior quadrant is normally narrower than the inferior quadrant. Many optometrists grade both the temporal and nasal quadrants (Spry and Harper, 2010).

Van Herick Grading

Van Herick introduced a four point grading scheme in 1969 to assess the angle (Table 2-2). This scale remains widely used, however it is non-linear, with the range between grade 3 and 4 covering 50 per cent whereas the range between grade 1 and 2 is less than 25 percent. A decimal system using 0.1 intervals from 0.0 to 1.0 was introduced in 1982 (Cockburn, 1982) and a grade less than 0.3 was seen as an indication of an eye at risk of PACG. Foster *et al.* (2000) further increased the

precision by adding more grades for a narrow angle, using a percentage scale (fourth column Table 2-2). An eye with a grading < 25% is classified as occludable using this grading system.

Table 2-2 The original van Herick grading system compared to the modified grading system

Van Herick Original Grading	Estimation of AC depth compared to corneal thickness	Risk of angle closure	Modified Grading System (Foster et al, 2000)
Grade 4	> 0.50:1	Unlikely	≥100% 75%
Grade 3	> 0.25 to 0.50:1	Unlikely	40%
Grade 2	0.25	Capable	25%
Grade 1	<0.25	Likely	15% 5% 0%

Figure 2-4 shows an example of an eye with a 100% (open) grading and a 15% (narrow) grading.

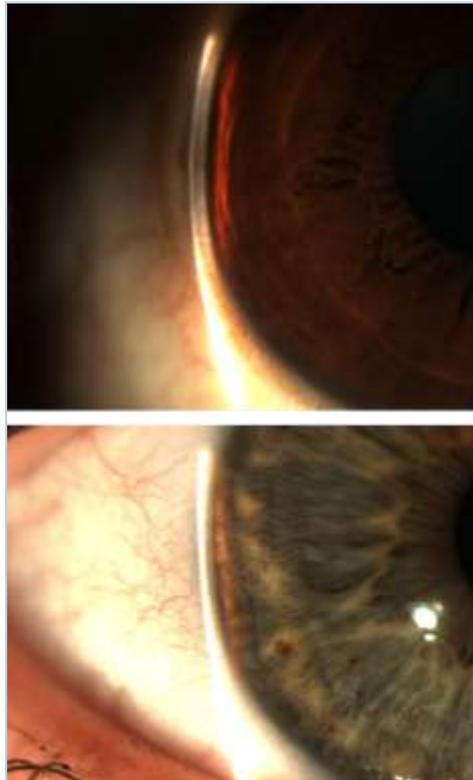


Figure 2-4 The van Herick method. Grading for top image=100%, bottom image=15%.

Advantages of van Herick method

It is a non-invasive test and is quick and easy to perform. It is the most widely adopted method for evaluating the ACA in community optometric practice. It employs the slit-lamp bio-microscope, commonly used by optometrists in the UK (Debasia *et al.*, 2013).

Disadvantages of van Herick method

It is a subjective test and requires the observer to have experience in the technique (Gispets *et al.*, 2014). It does not allow direct visualisation of the ACA and has been shown to be sensitive to alignment of the slit lamp (Leung *et al.*, 2012). It can only be performed when the limbus is clear, so eyes with scarred temporal corneas cannot be graded (Friedman and He, 2008). In addition, it is unsuitable for certain clinical conditions such as plateau iris syndrome (Alward, 2011), where a “hump” in the peripheral iris alters the estimation of the ACA (Gispets *et al.*, 2013).

2.2.3 Anterior Segment-Optical Coherence Tomography (AS-OCT)

Optical Coherence Tomography (OCT) is a relatively new approach to imaging the structures within the eye. It was first described in 1991 (Huang *et al.*, 1991) and was developed for ophthalmology in the late 1990s. It uses the principle of low coherence interferometry to produce cross sectional images of ocular tissues (Brezinski and Fujimoto, 1999). Interferometry is where waves of light in phase with each other will amplify each other and waves of light out of phase will cancel each other out (Friedman and He, 2008).

OCT devices traditionally use an infra-red super luminescent diode (SLD) laser operating between 820 to 870 nanometres (Huang *et al.*, 1991). These devices produce high resolution images of the posterior segment structures of the eye (the vitreous, retina and choroid). They also can image the anterior segment although this wavelength fails to penetrate the sclera, causing light scatter and resulting in poor visualisation of the ACA (Friedman and He, 2008). Standalone anterior segment OCTs operating at a longer wavelength (1300-1310 nm), available since 2001, allow deeper penetration of the anterior segment structures and better visualisation of the ACA.

The scleral spur is an anatomical landmark at the junction between the inner wall of the trabecular meshwork and the sclera used as a reference point in grading the ACA with an AS-OCT device. It is observed as an inward protrusion or change in curvature at the inner angle surface. An angle is graded “occludable” or at risk of developing PACG if there is any contact seen between the iris and the angle wall anterior to the scleral spur (Lavanya *et al.*, 2008).

Figure 2-5 shows an example of two AS-OCT images. The left hand image is taken using the posterior segment OCT: Topcon OCT-2000 (Topcon Europe Medical B.V, Netherlands) operating at 840 nm. The right image is from using a standalone AS-OCT (Visante; Carl Zeiss Meditec, Dublin, California). The figure demonstrates the superior quality of the standalone AS-OCT for visualising the scleral spur (SS).

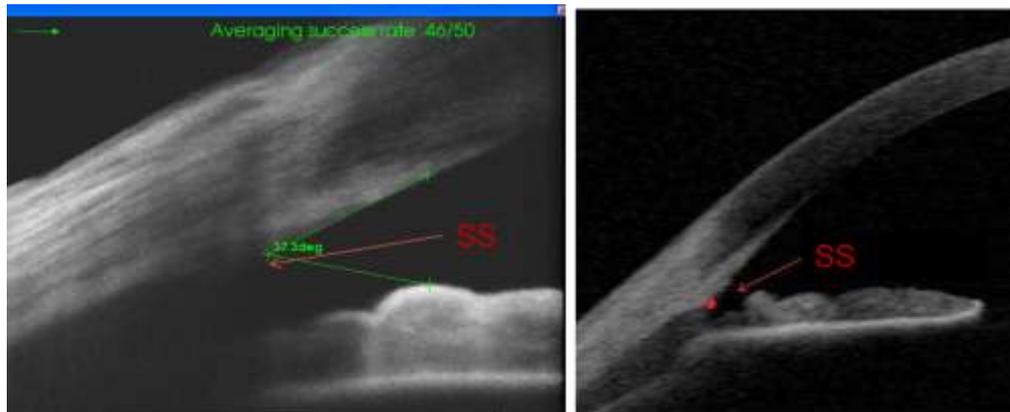


Figure 2-5 Anterior Segment Imaging. Left image Topcon OCT (wavelength 840 nm.) Right image Visante AS-OCT wavelength 1310 nm) SS=scleral spur (courtesy of <http://www.askdrash.com>, accessed 12 January 2014).

Advantages of AS-OCT

AS-OCT is considered a more objective method of assessing the ACA than both gonioscopy and van Herick (Gazzard and Nolan, 2009). It is quick and easy to carry out, requires minimal training and is comfortable for the patient (Park *et al.*, 2011). It can be carried out by non-clinical staff and has the potential to become a rapid, diagnostic screening tool for the detection of PACG (Nolan *et al.*, 2007).

Disadvantages of AS-OCT

The device is not very widely used in optometry practice. In 2008, only two per cent of community optometrists reported having access to an OCT machine (Myint *et al.*, 2011). Imaging of the superior angle quadrant is difficult and requires manipulation of the upper eyelid. This manipulation may introduce the possibility of distortion of the ACA (See, 2009) and this may affect the ability to correctly grade this quadrant. It does not provide reliable imaging of structures posterior to the iris (Smith *et al.*, 2013) and this excludes the evaluation of cases where the cause of angle closure is posterior to the iris (See, 2009).

The location of the scleral spur may also be difficult to visualise particularly in cases of angle closure (Sakata *et al.*, 2008b). The location of this important landmark is

vital in classifying the status of the angle so any difficulty in visualising it has a deleterious effect on its use as a screening tool for angle closure. Finally this device is expensive and this limits its availability in less wealthy countries particularly in Asia where the prevalence of PACG is high (See, 2009).

2.2.4 Other ACA Assessment Techniques

Other objective methods of ACA assessment include ultrasound bio-microscopy (UBM), Scheimpflug Photography and Scanning Peripheral Anterior Chamber Depth Analyzer (SPAC) see Table 2-3. UBM allows high resolution imaging and deep penetration of the optical structures including the ciliary body. This technique is time consuming and inconvenient to perform in a routine clinical setting. It is normally carried out in a hospital setting and requires a skilled practitioner (Smith *et al.*, 2013). Scheimpflug photography systems such as the Pentacam (Oculus, Wetzlar, Germany) use a rotating camera to image the anterior segment from the cornea to the posterior surface of the lens (See, 2009). The Pentacam device does not allow any angle assessment in detail and this limits its usefulness in detecting occludable angles. The Scanning Peripheral Anterior Chamber Depth Analyzer (SPAC) is an optical system that takes consecutive slit-lamp images and analyses them by comparison with a normative database. These techniques are not commonly used in optometry practice. The different methods of ACA assessment are summarised in Table 2-3. Not all techniques can directly measure/view the ACA but they are still included in the table as they can provide an indirect method of assessing the ACA.

Table 2-3 Methods of Angle Assessment

Test	Description	Advantages	Disadvantages
Anterior Segment Optical Coherence Topography (AS-OCT)	A non-contact device that uses low coherence interferometry to obtain cross-sectional images of ocular tissues (See, 2009).	This image acquisition is rapid and the instruments are easy to operate.	Difficulty visualising the superior angle quadrant due to the upper eyelid obstructing the view.
Flashlight	A flashbeam light is directed parallel to the eye from the temporal side. The crescent iris shadow formed is graded according to the area between the limbus and the papillary edge. An eye with a shallow ACA is expected to have a more protruding iris which will cause a shadow across the nasal iris. The eye is graded as occludable or open depending on the extent of shadow formed on the nasal iris (Thomas <i>et al.</i> , 1996)	This quick procedure can be carried out by non-medical staff.	No direct viewing of the angle.
Gonioscopy	A mirrored contact lens is used in conjunction with slit lamp bio-microscopy to observe angle structures and estimate the depth of angle	Direct viewing of the angle possible. Relatively inexpensive method.	Requires considerable skill, uncomfortable for the patient.
Orbscan	A scanning slit topography imaging system that uses slit-beam images (the eye is scanned limbus-to limbus) to derive three-dimensional anterior segment topography (Eperjesi and Holden, 2011).	This quick non-contact procedure can be carried out by non-medical staff.	Expensive to buy.
Scanning peripheral anterior chamber depth analyzer (SPAC)	A rapid non-contact device that uses a slit-lamp based photographic technique to take images and assess the peripheral anterior chamber depth (Friedman and He 2008)	A rapid non-contact device.	Expensive and can only assess the temporal angle of the eye (See, 2009).
Smith's Technique	A slit lamp based optical technique where the length of the slit beam when the two images are touching is multiplied by a constant to give an estimate of the Anterior Chamber Depth in millimetres (Smith, 1979).	Quick non-contact method,	Required experience in using the slit lamp.
Ultrasound Bio microscopy (UBM)	A contact imaging device that uses ultra-sonic waves delivered to the eye through saline solution to allow high resolution real time imaging of the angle (See, 2009).	Allows deep penetration of the optical structures including the ciliary body.	Expensive. Causes discomfort to the patient Requires a skilled operator.
Van Herick Method	A non-contact slit lamp based method compares the depth of the peripheral anterior chamber depth to the thickness of the cornea (Van Herick <i>et al.</i> , 1969).	Quick procedure. Routinely carried out in optometric practice.	Does not allow direct viewing of the ACA. Sensitive to slit lamp alignment.

2.3 Method comparison studies for ACA Assessment

As shown above in Table 2-3, there are a variety of different methods available to assess the ACA. Method comparison studies can provide important information on how well diagnostic tests agree with each other and whether one test could replace the other (Altman, 1990). This section will outline the methods that can be used when comparing ACA assessment tests.

2.3.1 Sensitivity and Specificity

Many clinical tests in optometry as well as other healthcare professions, involve the use of diagnostic tests to assign patients into two categories, those who pass or fail a certain test (Gilchrist, 1992). The terms test positive and test negative can be used to classify those patients (Altman, 2000).

In ACA assessment for example, when screening patients at risk of PACG, a van Herick method grading of 15% or less, could be classified as **test positive**. A van Herick method of 25% or more could be classified as **test negative**. Comparing these diagnostic test results with the gold standard method, in this case gonioscopy, will give a measure of the effectiveness of the screening test. The **sensitivity** of a clinical test refers to the ability of the test to correctly identify these patients with the disease. The **specificity** refers to the ability of the test to correctly identify those without the disease.

A **true positive** is when the patient has the condition and is correctly identified by the screening test. A **true negative** is where the patient does not have the condition and is correctly classified by the screening test (Bland, 2000). A **false positive** is when the patient does not have the condition but is incorrectly identified positive by the screening test. A **false negative** is where the patient does have the condition but is incorrectly classified negative by the screening test. The proportion of people in a population who are known to have a condition at a given time is called the **prevalence**. The **positive predictive value (PPV)** is the probability that a patient

who is test positive will be a true positive and the **negative predictive value (NPV)** is the probability that a patient who is test negative will be a true negative. Table 2-4 outlines the formulae used to calculate sensitivity, specificity PPV and NPV.

Table 2-4 Summary of the evaluation of a screening test

		Gold standard test	
		Positive	Negative
Screening test	Positive	TP (true positive)	FP (false positive)
	Negative	FN (false negative)	TN (true negative)
Sensitivity = $TP/TP+FN$ Specificity = $TN/FP+TN$ Positive Predictive Value = $TP/TP+FP$ Negative Predictive Value = $TN/FN+TN$			

Diagnostic tests used in screening should ideally minimise the number of false negatives in order to maximise the sensitivity of the test (Gilchrist, 1992).

2.3.2 Repeatability and Agreement

Repeatability and reproducibility give information on the precision of a test or device (McAlinden *et al.*, 2011). Two measurements (or more) by the same test for the same group of patients gives information on its repeatability. A test with poor repeatability is unlikely to agree with another test (Altman, 1990).

Intra-observer repeatability is defined as a measure of the variability in repeated measures by one observer when all other factors are assumed constant (McAlinden *et al.*, 2011). Inter-observer repeatability is defined as a measure of the variability when measurements are compared between one or more observers. **Reproducibility** refers to the variability in repeated measurements when one or more factors, such as observer, test, environment or time is varied (McAlinden *et al.*, 2011).

Cohen’s kappa “κ” (Cohen, 1960) is the simplest way to measure *agreement* between tests or between observers. It measures the level of agreement beyond that expected by chance alone (Altman, 2000). It is used to measure agreement for categorical data such as in the case of diagnostic tests where there is either a positive or negative outcome (McAlinden *et al.*, 2011).

Kappa is calculated as follows:

$$\kappa = \frac{p_o - p_e}{1 - p_e}$$

p_o = the observed agreement or proportion of samples for which both observers agree.

p_e = the expected proportion of agreement.

Kappa has a maximum of 1.00 indicating perfect agreement, and zero indicating no agreement better than chance. While no absolute definitions exist, Altman (1990) provides some guidelines on interpreting values (see Table 2-5).

Table 2-5 Kappa Agreement definitions (Altman, 1990, p. 404)

Value of κ	Strength of agreement
< 0.20	Poor
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Good
0.81-1.00	Very good

With the kappa statistic, all disagreements are treated equally. The weighted kappa statistic “κ_w”, allows greater importance to be placed on certain differences found in the results. This is used when there may be implications if certain disagreement in results may be more serious than others (Gilchrist, 1992).

Fleiss (1981, p. 223) defined weighted kappa as:

$$\kappa_w = \frac{p_{o(w)} - p_{e(w)}}{1 - p_{e(w)}}$$

$p_{o(w)}$ = the observed weighted proportional agreement.

$p_{e(w)}$ = the expected weighted proportion of agreement.

$$p_{o(w)} = \sum_{i=1}^k \sum_{j=1}^k w_{ij} p_{ij}$$

$$p_{e(w)} = \sum_{i=1}^k \sum_{j=1}^k w_{ij} p_{i.} p_{.j}$$

Weights: $W_{ij} i=1, \dots, k; j=1, \dots, k;$

$0 \leq W_{ij} \leq 1$

Values for weights can be chosen between 0 and 1, where $W=0$ represents the least weight and $W=1$ represents the greatest weight.

ACA assessment tests produce categorical results on the nature of the angle and therefore the kappa and weighted kappa are valid tools to measure repeatability of tests and agreement between different methods.

2.4 Summary

This chapter outlines the different methods of ACA assessment and introduces methods used to measure agreement between clinical diagnostic tests. The literature review in the next chapter will investigate the evidence comparing gonioscopy seen as the gold standard method for ACA assessment with other methods. Evidence looking at optometrists' skills at gonioscopy will also be investigated. The aims of this thesis will then be outlined.

3 LITERATURE REVIEW

Assessment of the anterior chamber angle (ACA) is an important part of investigating patients at risk of glaucoma. Gonioscopy is seen as the gold standard method of assessing the ACA. The NICE guideline on diagnosis and management of chronic open angle glaucoma and ocular hypertension states that from the available evidence, gonioscopy has the highest accuracy and is required at diagnosis of patients with COAG and OHT (NICE, 2009). This is primary in order to rule out primary closed angle glaucoma (PACG).

3.1 Aims of Literature Review

The purpose of a literature review is to *“find evidence within the published literature to answer clinical questions identified”* (NICE, 2009, p.41). The aim of this literature review is to investigate the evidence assessing how gonioscopy compares to other methods of angle assessment. Emphasis will be given to evidence on inter and intra observer repeatability for ACA assessment tests. A secondary aim is to investigate how optometrists perform gonioscopy compared to other clinicians. Any areas where there is a lack of published evidence will be highlighted. The literature will be critically appraised using the Critically Appraisal Tools developed by Oxman *et al.* (1993).

3.2 Literature Search

Searches of peer-reviewed literature were conducted on 16 November 2009 and again on a bimonthly basis up to 1 August 2014 using PubMed and Cochrane Library databases. The search strategy used the following medical subject heading (Mesh) and text terms:

- Anterior chamber angle assessment
- Gonioscopy AND van Herick
- Gonioscopy AND AS-OCT
- Gonioscopy AND Anterior Segment Optical Coherence Tomography

- Gonioscopy AND repeatability
- Gonioscopy AND reproducibility
- Gonioscopy AND optometrist
- Gonioscopy AND optometry
- NICE Guideline AND Glaucoma

The “related citations” option in PubMed was also used to capture any additional articles.

In addition, the following links were also utilized:

- National Institute for Health and Clinical Excellence (NICE) (<http://www.nice.org.uk>)
- National Library for Health Eyes and Vision Specialist Library (<http://www.library.nhs.uk/eyes/>)
- NICE guideline (NICE, 2009)
- Optician Online (<http://www.opticianonline.net/>)
- Optometry Today (<http://www.optometry.co.uk>)

Ophthalmology and optometry text books were also consulted for references to gonioscopy and ACA assessment.

Papers written in English only were reviewed published from 1960. Emphasis was given to papers that focussed on comparison between different ACA methods and comparison of ACA assessment results between different professional groups. Papers were selected which had the most relevance to UK optometrists. This was based on ACA tests that optometrists are familiar with and are likely to use in practice. Papers investigating the use of software measurement tools for standalone anterior segment OCTs (operating between 1300-1310 nm) were excluded due to their lack of relevance to UK optometrists who are unlikely to use these functions when screening patients at risk of PACG. The results of the searches are shown in Table 3-1. There was some degree of overlap from the different

sources, the eleven Cochrane papers had already been found from the PubMed search.

Table 3-1 Results of Literature Search

Search Engine	Key Words	Papers	Relevant Papers
PubMed	Anterior chamber angle assessment	149	62
	Gonioscopy van Herick	1	1
	Gonioscopy AS-OCT	42	10
	Gonioscopy Anterior Segment Optical Coherence Tomography	113	20
	Gonioscopy van Herick AS-OCT	1	1
	Gonioscopy repeatability	7	2
	Gonioscopy reproducibility	84	25
	Gonioscopy Optometrist	3	1
	Gonioscopy Optometry	23	9
	NICE glaucoma	14	6
NICE	Gonioscopy	4	4
	Anterior chamber assessment	4	4
www.library.nhs.uk/eyes	Gonioscopy	4	2
Optician Online/ Optometry Today	Gonioscopy Anterior chamber angle assessment Anterior Segment Optical Coherence Tomography	38	4
Cochrane Library	Gonioscopy Anterior chamber angle assessment AS-OCT Van Herick	94 1 8 5	5 0 2 4

3.3 Results of the literature review

Papers were screened for appropriateness by title and abstract. The evidence cited by the NICE guideline committee will first be appraised followed by a review of additional relevant papers on how gonioscopy compares to other methods of angle assessment. Literature relating to optometrists and gonioscopy will be highlighted.

3.3.1 NICE guideline on the diagnosis and management of chronic open angle glaucoma and ocular hypertension

NICE is a Department of Health public body that produces evidence based guidance for health, public health and social care practitioners (NICE 2014). The aims of the guidance are:

- to provide recommendations for the treatment and care of people by health professionals in terms of best clinical effectiveness and cost effectiveness
- to be used to develop standards to assess the clinical practice of individual health professionals
- to be used in the education and training of health professionals
- to help patients make informed decisions
- to improve communication between patients and health professionals (NICE, 2009).

A NICE guideline on COAG and OHT was issued in 2009. A quality standard was issued in 2011 which clarified some issues relating to case finding and screening for glaucoma (NICE, 2011).

NICE recognised that there are wide variations across the NHS in terms of management of COAG and that this may be due to a reflection of the uncertainties and sometimes conflicting reports in the scattered literature. When deciding on the best method to assess the ACA, the NICE committee asked:

“Are other methods of assessing anterior chamber angles suitable as alternatives to gonioscopy?” (NICE, 2009, p. 38)

Following a review of the literature NICE recommend that gonioscopy is the preferred method. They state that the van Herick method should be offered as an alternative if clinical circumstances rule out gonioscopy (for example when people with physical or learning disabilities are unable to participate in the examination). The van Herick method should also be carried out at every monitoring visit for patients with COAG and OHT. NICE based this recommendation on gonioscopy on three studies (Thomas *et al.*, 1996, Nolan *et al.*, 2007, and Baskaran *et al.*, 2007).

In the first study, Thomas *et al.*, (1996) measured the sensitivity and specificity of the flashlight test and van Herick method at detecting occludable ACAs on 96 subjects in Vellore, India. Details of the flashlight are given in Table 2-3. Figure 3-1 shows an example of a flashlight grading.

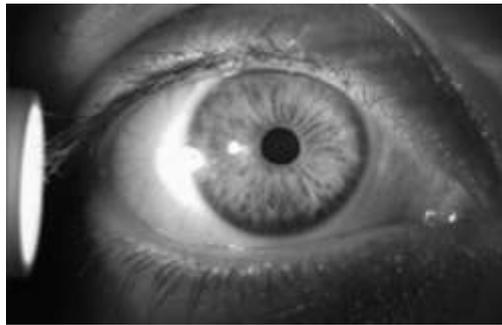


Figure 3-1 Flashlight test. A light is directed parallel to the eye from the temporal side and the practitioner observes the consequent shadow on the iris. Courtesy of Debasia *et al.*, (2014).

The flashlight, van Herick method and gonioscopy were carried out by one examiner and then gonioscopy was carried out by a second examiner. The inter observer agreement between the two examiners was calculated using the weighted kappa statistic (κ_w). Details of the weighting used is not discussed. Sensitivity and specificity values were calculated for the van Herick method and the flashlight test (see Table 3-2).

Table 3-2 : Flashlight Test and van Herick Method compared to Gonioscopy

Test	κ_w	Sensitivity	Specificity
Flashlight Test (half shadow)	0.74	46%	83%
Flashlight Test (one third shadow)	0.74	86%	71%
Van Herick method (< 25%)	0.73	62%	89%

Agreement in gonioscopy results between the two examiners was also calculated ($\kappa_w=0.81$). Due to the somewhat poor sensitivity values the authors conclude that the flashlight test and the van Herick method are of limited use when screening for PACG.

The flashlight test does not require any specialist optical equipment and is therefore seen as an inexpensive method of screening for PACG. A more recent paper (Gracitelli *et al.*, 2013) comparing the flashlight test to gonioscopy in 45 eyes in Brazil, did however find better sensitivity results (92-97%) than this study. However its use as a screening test for PACG has limited relevance to UK optometrists who generally have access to slit lamp bio microscopes allowing them to undertake more detailed examination of patients at risk of PACG. The van Herick sensitivity results from this paper would suggest that it also is of limited use when screening for PACG.

The study is biased as the flashlight and van Herick method were carried out in the same order by the same examiner and therefore the findings of the prior test could influence the subsequent test findings. The prevalence of PACG in this outpatient clinic (21.9%) is higher than in the UK optometry practice making the findings less relevant to a UK audience.

In the second study cited by NICE, Nolan *et al.*, (2007) measured the sensitivity and specificity of an anterior segment optical coherence tomography (AS-OCT) device at detecting PACG compared to gonioscopy. Subjects were recruited from a glaucoma clinic in Singapore. A prototype Anterior Segment Optical Coherence Tomography (AS-OCT) device, operating at a wavelength of 1310 nm, was used (Figure 3-2).

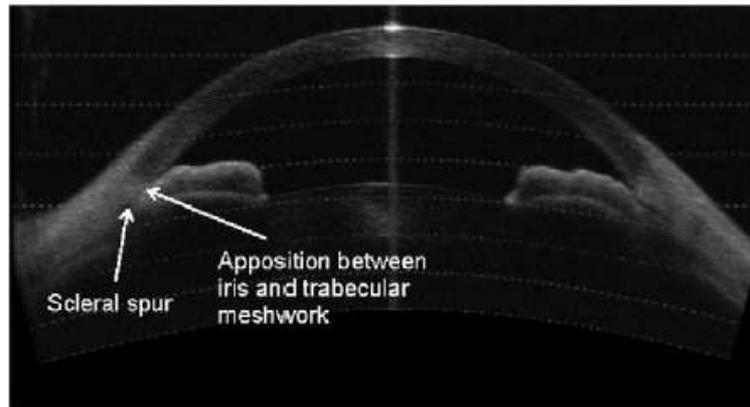


Figure 3-2 AS-OCT image of nasal and temporal angles (courtesy of Nolan et al, 2007).

Subjects underwent imaging using the AS-OCT by a single observer followed by gonioscopy by a second independent observer who was masked to the AS-OCT findings. Results were given for 342 eyes from 200 subjects (Chinese ethnicity 87%). The sensitivity for AS-OCT was very good (98%) but the specificity was poor (55%), indicating that more subjects appeared to have closed angles with AS-OCT than with gonioscopy.

The main strength of the paper is the significant number of subjects recruited with occludable angles (44.4%). The use of a single observer for gonioscopy and AS-OCT does somewhat bias the results. In addition results for both eyes are included. As there is a correlation in using results for a subject's right and left eye (Ray and O'Day, 1985) the statistical power of the findings is therefore reduced (Armstrong, 2013).

From the low specificity value, the authors conclude that AS-OCT is unlikely to replace gonioscopy as a method to detect PACG. However they argue that AS-OCT and gonioscopy use different landmarks to detect occludable angles and AS-OCT is likely to detect more eyes with angle closure than gonioscopy. The high sensitivity for AS-OCT means that AS-OCT could be a useful tool in initial screening in clinical practice (Friedman and He, 2008), provided that it is followed by a more specific test for those patients who screen positive.

Baskaran *et al.*, (2007) measured the sensitivity and specificity of the van Herick method and the scanning peripheral anterior chamber depth analyzer (SPAC) compared to gonioscopy, in 120 subjects recruited from Singapore glaucoma and ophthalmology clinics. SPAC is an optical system similar to AS-OCT that takes consecutive slit-lamp images and analyses them by comparison with a normative database. Subjects initially had gonioscopy and van Herick grading carried out by one observer, followed by SPAC grading by a different observer masked to the results of gonioscopy and van Herick grading.

SPAC had a sensitivity and specificity of 85% and 73% respectively. Van Herick (in this case with cut off $\leq 25\%$) had a sensitivity and specificity of 85% and 90% respectively. If van Herick cut off was changed to $\leq 15\%$, then sensitivity and specificity was 60.4% and 100% respectively. However this sensitivity is too low to be used in screening. The specificity results for van Herick method are better than SPAC and also better than the values found by Thomas *et al.*, (1996). It would seem that, from this study, the van Herick method (with a cut off $\leq 25\%$) would appear to be more accurate than SPAC at screening for PACG. One weakness of this study is that the van Herick method was carried out by the same observer at the same time as gonioscopy, potentially introducing systematic bias into the results.

All three studies cited by NICE were based in Asia; this limits their relevance to UK optometrists. The anatomical structure of the eye is known to be different between Asians and non-Asians (Foster *et al.*, 2000) and these differences may result in different mechanisms being responsible for PACG in Asian and non-Asian eyes (Wang *et al.*, 2013). Their findings therefore have problems when considering tests for a European population. The tests used to detect PACG may perform differently in different populations so any conclusions on how different ACA tests compare to each other should be read with caution.

The NICE committee highlight the fact that there is paucity of evidence on angle assessment in non-Asian populations. They recommend that new research

comparing gonioscopy to other methods of ACA assessment should be carried out across different populations.

Other relevant papers found from the literature search, not included by NICE, as well as papers published since NICE on methods of ACA assessment will now be reviewed.

3.3.2 Comparing van Herick method to gonioscopy

In a study on 1717 subjects, Foster *et al.*, (2000) compared the van Herick method to gonioscopy in Mongolia. It is not clear why these findings are not cited in the NICE guidance. In this study the van Herick method was carried out (as described in Section 2.2.2) followed by gonioscopy by one of two ophthalmologists. Occludable angles were identified in 140 subjects (8%). The sensitivity and specificity values for van Herick ($\leq 15\%$) compared to gonioscopy for all subjects were 84% and 86% respectively. If the van Herick cut off point was changed to $\leq 25\%$ the sensitivity and specificity values change to 99% and 65% respectively. In addition inter-observer repeatability of gonioscopy and van Herick method was measured in 55 eyes of 28 subjects using the weighted kappa statistic; $\kappa_w = 0.80$ for gonioscopy and $\kappa_w = 0.76$ for van Herick method.

The high sensitivity and specificity values for van Herick method from this study would suggest that it is a useful tool when screening patients at risk of PACG. Inter-observer agreement appears to be good for the van Herick method and gonioscopy in the subset of patients. The high sensitivity and specificity for van Herick method might suggest it could be carried out as an alternative method to gonioscopy in certain situations. However the NICE committee do not mention this in their guidance. This may be because the van Herick method does not allow visualisation of the ACA and therefore the committee do not consider it a suitable alternative to gonioscopy.

Kashiwagi *et al.*, (2005) reported the results from a large study in Japan where the van Herick method was performed on 14,770 subjects. Five hundred and five subjects were graded by an ophthalmologist as occludable (van Herick \leq 25%). Three hundred and eighty-three of these subjects (75.8%) were then followed up for gonioscopy by a glaucoma specialist. The sensitivity for these subjects was 70.7% (van Herick \leq 25%) but the specificity was only 9.7%. The main strength of this paper is the large sample size. Limitations of the study include the following:

- only 75.8% of the subjects found occludable with van Herick method went on to have a gonioscopy examination
- none of the subjects who had open angles with van Herick went on to have gonioscopy
- both eyes were included in the analysis thus affecting the validity of the results

Because of these limitations, it is likely that this paper is of too poor quality for consideration by the NICE committee.

More recently, Bourne *et al.*, (2010) looked at decision making by eight optometrists working in a glaucoma referral refinement scheme in Cambridgeshire. Patients with van Herick grading \leq 15% were referred to the consultant ophthalmologist who then carried out gonioscopy. Sensitivity and specificity values of optometrists carrying out the van Herick method compared to gonioscopy, for 21 patients, were 69% and 88% respectively.

The authors highlight the fact that at that time (2006-2008) community optometrists were not trained in gonioscopy. The sensitivity of 69% would imply that the van Herick method is not a very accurate method of angle assessment. Changing the definition of an occludable angle by van Herick to say \leq 25% rather than \leq 15% may have a positive effect on sensitivity but at the expense of specificity. The authors conclude that since the publication of the NICE guideline there may have been a change in the clinical practice of this group and further work

is needed to investigate this, particularly if gonioscopy practice is becoming more widespread amongst optometrists.

3.3.3 AS-OCT comparison studies

There is a large number of studies (35 as of September 2013) looking at how the anterior segment OCT compared to other methods of angle assessment. Papers will be discussed based on studies where the AS-OCT is used to screen eyes for PACG as this criteria bears most relevance to UK optometrists. Most of the evidence is based on standalone AS-OCT devices such as the Visante-OCT (Carl-Zeiss Meditec, Dublin, CA, USA), and the SL-OCT (Heidelberg Engineering, Heidelberg, Germany) operating at a wavelength 1300 nm. These specialist instruments (typical cost over £25,000) are currently only found in some Hospital Eye Departments.

In a pilot study, a prototype standalone AS-OCT device, operating at wavelength 1310 nm (Carl Zeiss, Meditec, Dublin, CA), was used to compare gonioscopy and Ultrasound Bio microscopy (UBM) to AS-OCT in 14 eyes of 7 subjects with primary angle closure and 17 normal subjects (Radhakrishnan *et al.*, 2005). Sensitivity and specificity for AS-OCT compared to gonioscopy were reported as 62.5% and 100%, respectively. The authors concluded that AS-OCT is a promising new method for screening occludable angles.

Lavanya *et al.*, (2008) compared SPAC and AS-OCT-1310 nm (Visante AS-OCT, Carl Zeiss Meditec, Dublin, CA, USA) to gonioscopy, in a large cross sectional, observational, community based study. Gonioscopy was carried out by an observer who was masked to the imaging findings. Data were collected for 2052 subjects (90% of whom were of Chinese ethnicity). The sensitivity values for SPAC and AS-OCT, compared to gonioscopy, were 90% and 88%, the specificity values were 76.6%, 63%, respectively. The relatively low specificity of AS-OCT agrees with the findings by Nolan *et al.*, (2007) and questions the usefulness of AS-OCT in screening for angle closure.

Sakata *et al.*, (2010) compared the results for two different AS-OCT models (Visante-OCT, Carl-Zeiss Meditec, Dublin, CA, USA and SL-OCT, Heidelberg Engineering, Heidelberg, Germany) for 83 eyes in a Singapore glaucoma clinic. Gonioscopy was performed by a second examiner masked to the OCT results. One eye was randomly selected for analysis. Figure 3-3 show a Venn diagram displaying the agreement between the three methods. The agreement in detecting eyes with at least one closed ACA was greater for SL-OCT than Visante OCT when compared to gonioscopy. Agreement between the two devices was found to be good. Intra-observer repeatability, calculated using the kappa statistic, was found to be good ($\kappa = 0.71$ for both Visante-OCT and SL-OCT). The authors conclude that both devices perform well at detecting occludable angles but that the results from each device are not interchangeable.

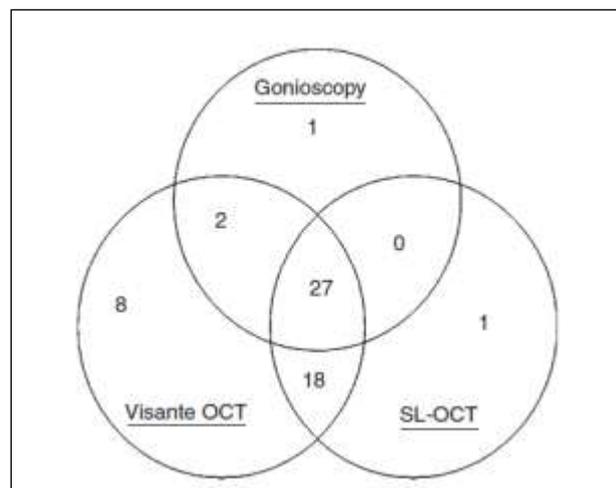


Figure 3-3 Agreement between gonioscopy, Visante-OCT and SL-OCT in detecting an occludable angle (Courtesy of Sakata *et al.*, 2010).

Interestingly, Figure 3-3 also shows that eighteen out of the fifty seven subjects (31.5%) were classified as occludable with both OCT devices, but were found to be open with gonioscopy. Both AS-OCTs would therefore appear to produce a lot of false positives. However, is it possible that this subset go on to develop angle closure later and therefore this risk is detected earlier with AS-OCT than with gonioscopy? This potential disadvantage of labelling gonioscopy as the “gold standard” is discussed further in Sections 3.3.7 and 7.3.

In addition the intra-observer repeatability for gonioscopy in grading the ACA as open or occludable, was measured in a subset of 20 eyes; $\kappa = 0.80 - 1.00$ for the four quadrants.

There are three papers looking at the performance of posterior OCT devices at assessing the ACA. Hoerauf *et al.*, (2000) examined the anterior segment for sixty subjects using a slit lamp adapted OCT system operating at wavelength 830 nm (Schwind, Kleinostheim, Germany and Medical Laser Centre). They found the device allowed visualisation of the ACA which facilitated determination of the anterior segment structures however they concluded it was difficult to completely visualise the angle due to the scatter of light from the sclera.

Leung *et al.*, (2005) used a posterior segment Stratus OCT 830 nm light source (Carl-Zeiss Meditec, Dublin, CA, USA) to examine the anterior segment. Three subjects with occludable angles had anterior segment imaging before and after receiving treatment with laser peripheral iridotomy (LPI). The authors show the capability of imaging the ACA using a posterior OCT. They do however highlight the lack of details of the structures visible when operating at this shorter wavelength.

Kalev-Landoy *et al.*, (2007) carried out anterior segment images in 26 eyes using the Stratus OCT (Carl-Zeiss Meditec, Dublin, CA, USA) in an ophthalmology clinic in London, UK. The authors showed this device was able to visualize the anterior chamber configuration in sufficient detail in most cases to assist with the everyday clinical assessment of glaucoma patients. The inability of this device to provide good visualisation in all cases was explained by the failure of the device to penetrate the sclera at 840nm wavelength.

3.3.4 Comparing gonioscopy, van Herick and AS-OCT

Park *et al.*, (2011) evaluated agreement between gonioscopy, van Herick and AS-OCT in 148 subjects recruited from a glaucoma clinic in Seoul, Korea. All three methods were performed independently by three different examiners. A

standalone anterior segment OCT (Visante; Carl Zeiss Meditec, Dublin, California) was used in this study. An occludable angle was defined with van Herick as $\leq 15\%$ and with AS-OCT if any contact was visible between the iris and angle wall anterior to the scleral spur. Agreement in detecting an occludable angle was measured using the kappa statistic. Results for the nasal and temporal quadrants were analysed separately, see Table 3-3.

Table 3-3 Van Herick method and AS-OCT compared to gonioscopy (Park *et al.*, 2012)

n=93	Agreement (κ)		Sensitivity		Specificity	
	Temporal	Nasal	Temporal	Nasal	Temporal	Nasal
van Herick method	0.80	0.80	92%	96%	90%	100%
AS-OCT	0.16	0.15	100%	98%	41%	55%
Van Herick vs. AS-OCT	0.11	0.11	-	-	-	-

Agreement between van Herick and gonioscopy was excellent, but agreement between gonioscopy and AS-OCT and between van Herick and AS-OCT was poor. Sensitivity and specificity were good for van Herick, sensitivity was good AS-OCT but specificity was poor. The authors agree with previous researchers Nolan *et al.*, (2007) and argue that AS-OCT is inherently different to gonioscopy in determining an occludable angle and this may explain the discrepancy between the results. They conclude however that due to the high levels of sensitivity, the AS-OCT is a useful method to screen for PACG.

3.3.5 Literature Synthesis

The majority of published evidence investigating how gonioscopy compares to other methods of ACA assessment takes place in Asia where the prevalence of PACG is higher. These studies also have taken place mostly in ophthalmology clinics and/or glaucoma clinics rather than in the community so they are likely to have higher levels of occludable angles. This review highlights the increasing use of new devices such as AS-OCT and SPAC and how the results compare to gonioscopy. A

summary of the sensitivity and specificity values from the literature for van Herick method and AS-OCT are shown graphically in Figure 3-4 and Figure 3-5, respectively.

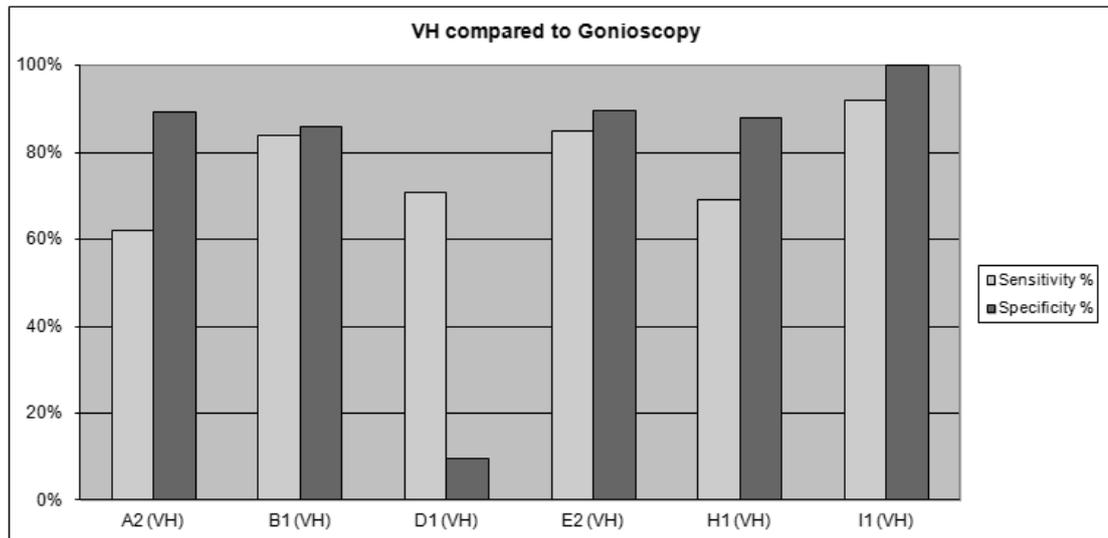


Figure 3-4 Sensitivity and Specificity for van Herick results compared to gonioscopy. Code: A: Thomas *et al.*, (1996) FL=Flashlight (1/3 shadow), VH=Van Herick $\leq 25\%$ B: Foster *et al.*, (2000) $VH \leq 15$ D Kashiwagi *et al.*, (2005). E: Baskaran *et al.*, (2006) $VH \leq 25\%$; H: Bourne *et al.*, (2010) $VH \leq 15\%$, I: Park *et al.*, (2012) $VH \leq 15\%$

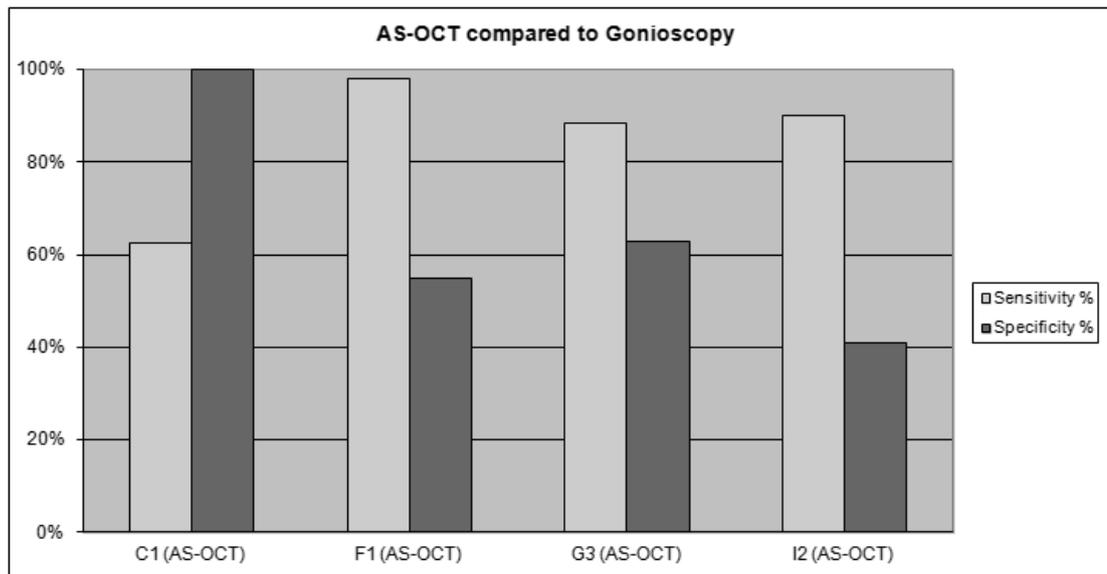


Figure 3-5 Sensitivity and Specificity for AS-OCT results compared to gonioscopy
 Code: C: Radhakrishnan *et al.*, (2005) F: Nolan *et al.* (2007) G: Lavanya *et al.*, (2008).
 I: Park *et al.*, (2012) VH≤15%

The graphs show the degree of variation in the findings. Park *et al.*, (2011) report the highest sensitivity and specificity for van Herick [I1], whilst the values are lowest in A1 (Kashiwagi *et al.*, 2005). In the latter study only subjects with a narrow angle by van Herick method were referred on for a gonioscopy assessment and this may explain the low value found for specificity.

Sensitivity results for AS-OCT were good (greater than 80%) in three out of the four studies (F1, G3, I2), but specificity varied from 40% to 100% across the different studies. Sensitivity was lower in one study (C1), and this may in part be explained by the small sample size (n = 24).

3.3.6 Optometry and gonioscopy

There was no published evidence comparing gonioscopy between optometrists or other healthcare professionals and other clinicians. Gonioscopy is currently not a General Optical Council-mandated core competency for UK optometrists (General Optical Council, 2011). The present author has noticed however an increase in gonioscopy training at optometry continuing professional development events in

recent years. A survey sent to community based optometrists in 2008, showed that 12% of the respondents possess a gonioscopy lens in their practice (Myint *et al.*, 2011). In a College of Optometrist survey in 2007, six percent of College Members reported they use a gonioscopy lens (College of Optometrists, 2008), although in both studies there was no mention of frequency of use of the lens.

Outside the UK, several authors have been published articles describing gonioscopy for an optometry audience. Cockburn argued that gonioscopy should form part of diagnostic workup when optometrists are investigating patients for glaucoma:

“Optometrists are becoming increasingly aware of the value of gonioscopy as a method of estimating the risk of angle closure” Cockburn (1981, p.706).

Prokopich and Flanagan (1997) in Canada argue that for optometrists, gonioscopy is essential to master when assessing patients at risk of PACG.

In the UK, investigation of optometrists and gonioscopy has been limited to a review of glaucoma shared care schemes carried out in 2006 (Vernon and Adair, 2010). Eight out of the twelve hospital-based optometrist schemes reported that gonioscopy was performed but only three out of twelve community optometry schemes reported they were carrying out gonioscopy

Figure 3-6 shows the range of schemes in England. In total, gonioscopy was carried out in twenty-six (40.6%) of the sixty-four schemes. Hospital based optometrists schemes (code=A) appear to have the highest percentage practicing gonioscopy. In order to become compliant with the NICE guideline, it is likely that more of these schemes will adapt to include a gonioscopy assessment. The authors stated that they intended to repeat the study again to investigate any change in behaviour after the introduction of the NICE guideline. However this did not occur due to lack of funding (Vernon, 2014).

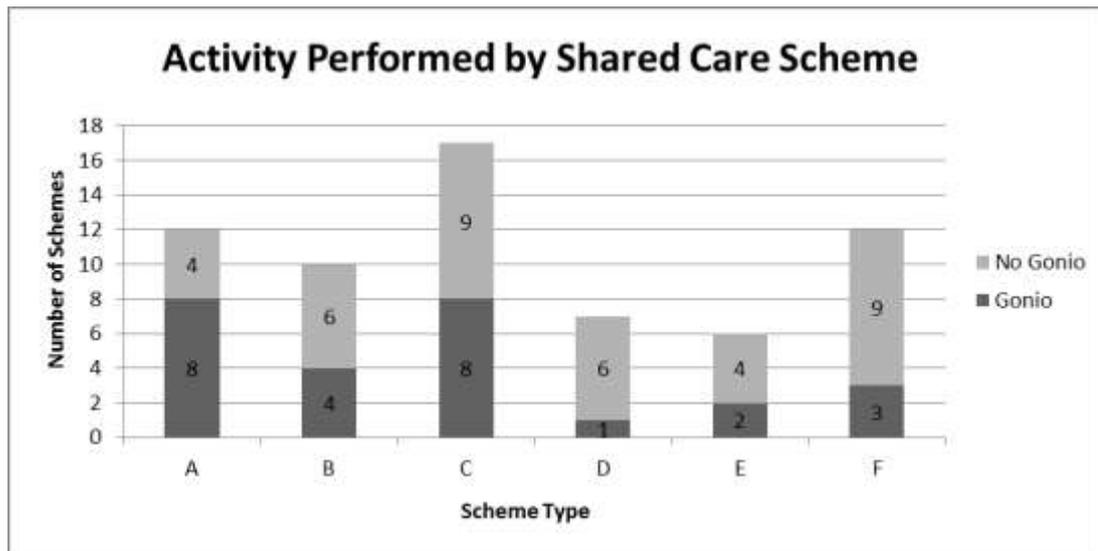


Figure 3-6 Number of schemes where gonioscopy is performed. A=Hospital based optometrists (n=12), B= Hospital based optometrists and other healthcare professionals (n=10), C=Hospital based nurses (n=16), D= Hospital based nurses and orthoptists (n=7), E= Hospital based orthoptists (n=6), F=Community optometrists (n=12)

3.3.7 Gonioscopy as the gold standard

As reported in Section 2.2.1, the use of gonioscopy as the reference standard has been criticised by several authors. It is subjective in nature, requiring considerable skill and experience (Lavanya *et al.*, 2008) with poor inter-observer reproducibility (Gazzard and Nolan, 2009). Some authors have also questioned the validity of gonioscopy to predict angle closure. Nolan *et al.*, (2007), argue that the known effect of angle distortion caused by the surface contact of the gonioscopy lens as well as the effects of light exposure on the angle configuration may affect the accuracy of gonioscopy. They state that there are likely to be cases of angle closure missed by gonioscopy. The literature search showed that there is no evidence looking at the longitudinal follow up of patients who have open angles on gonioscopy but who could go on to develop angle closure in the future. This is a surprising omission: it therefore appears that the key performance of the “gold standard” has not been assessed. As discussed in Section 3.3.3, Sakata *et al.*, (2010) found a considerable number of subjects classified with occludable angles by two different AS-OCT devices but were classified open with gonioscopy. It may be the case that these subjects go on to develop PACG at a later stage. AS-OCT may

therefore be able to detect this risk at an earlier stage than gonioscopy although further research will be required to investigate this.

Despite these drawbacks, gonioscopy offers a real time direct view of the ACA structures and allows the clinician to fully assess the ACA in all four quadrants of the eye.

3.3.8 NICE Impact on Clinical Practice

The publication of the NICE guideline had a considerable impact on optometry practice. It has been described as having far reaching consequences for the clinical practice of optometrists across the UK (Steele and Spry, 2009). The initial negative response was partly due to the need for optometrists to refer more patients. Edgar *et al.*, (2010) reported a thirty-seven per cent increase in referrals in the three months after its introduction. Ratnarajan *et al.*, (2013) highlighted the difficulties this placed on hospital eye clinics.



Figure 3-7 Article reporting on NICE guideline (Optician Online, 2009)

Shah and Murdoch (2011), investigating the impact the introduction of the NICE guideline has had on glaucoma case detection, found that in an outer London NHS

hospital eye clinic there was no change in the absolute numbers of glaucoma cases detected despite the increase in number of referrals. The authors question the cost effectiveness of the NICE guidance when they found no improved case detection. However their analysis is based on data collected over two months, six months after the introduction of the guideline and prior to the issue of the additional referral criteria recommendations by the College of Optometrists and Royal College of Ophthalmologists (College of Optometrists and Royal College of Ophthalmologists, 2010) It may be prudent to repeat this analysis over a longer time period to fully assess the impact of the NICE guidance on glaucoma case detection.

Other health professionals appeared to have a more positive approach towards the NICE guideline. Freeman (2009) in Nursing Times, stated that the guideline provides a framework allowing nurses to work more in partnership with other healthcare professionals, enhancing the care for this group of patients. Sparrow (2013) (the former Chair of the NICE Glaucoma Guideline Development Group) argues that the guideline has resulted in an increased awareness of glaucoma and he feels this will hopefully lead to better and more balanced eye care for glaucoma patients across the UK.

The NICE guidance has however faced criticism due to its “one size fits all” approach to healthcare. Ackland *et al.*, (2014) argue that the use of a guideline protocol for treating glaucoma is potentially restrictive. They feel that clinicians should be able to exercise their own judgement and this is more likely to benefit the individual patient.

3.4 Summary of Findings of the Literature Review

There is a variety of methods to assess the ACA. This literature review investigated the evidence comparing gonioscopy (the gold standard) to other methods. Newer devices such as the AS-OCT and SPAC in theory allow optometrists to carry out

quantitative measurements of the anterior angle but none seem to perform as accurately as gonioscopy.

The main findings of the literature review are as follows:

- There is a paucity of evidence comparing ACA results between clinicians and between different professions
- There is a lack of evidence comparing gonioscopy between clinicians in non-Asian populations. Research comparing ACA assessment methods in a European population is much needed
- There is a lack of published data on optometrist gonioscopy results
- There appears to be limited evidence on the comparison of gonioscopy findings between observers in the UK

Two papers (Foster *et al.*, 2000; Thomas *et al.*, 1996) measured inter-observer repeatability for gonioscopy however the sample sizes in both of these studies were small. One paper (Sakata *et al.*, 2010) measured intra-observer repeatability for gonioscopy. Further research is needed comparing gonioscopy results between optometrists and other healthcare professionals and new evidence is required investigating the repeatability of ACA assessment methods within a European setting.

Three papers evaluate how OCT devices operating with a short wavelength laser (830 nm) can be used to image the anterior segment. These studies highlight the fact that this wavelength does not penetrate the sclera and the resulting scatter of light which affects the image quality. Kalev-Landoy *et al.*, (2007) highlight that posterior segment OCTs are widely used in clinical practice in the UK and can provide sufficient detail in most cases to assist with the everyday clinical assessment of glaucoma patients.

Prior to the NICE guideline publication, there was considerable variation in the practice of gonioscopy in glaucoma shared care schemes operating in England. Only

three out of twelve community optometrist groups appeared to carry out gonioscopy (Vernon and Adair, 2010). Van Herick results by optometrists do appear to show good agreement with gonioscopy results by a consultant ophthalmologist (Bourne *et al.*, 2010).

Further research is therefore needed to investigate the impact the NICE guideline has had on optometrist clinical practice and how optometrist gonioscopy results compare to other HCPs.

3.5 Objectives of the Research

The research described in this thesis comprises three studies:

1. The aim of the first study is to investigate the impact of the NICE guideline on clinical practice of optometrists in the UK, in particular in relation to anterior chamber angle assessment.
2. The aim of the second study is to assess the ability of optometrists and other healthcare professionals (HCPs) at carrying out gonioscopy. How do gonioscopy results for HCPs compare to a consultant ophthalmologist? Are HCPs able to carry out gonioscopy accurately and safely?
3. The aim of the third study is to investigate the repeatability of gonioscopy as well as other methods of anterior chamber angle assessment. How does gonioscopy compare to other methods of ACA assessment and how repeatable are optometrists at carrying out these tests in a community setting?

The next three chapters will describe the research carried out. Chapter Four outlines a questionnaire investigating the change in clinical practice of optometrists since the publication of the NICE guideline. Chapter Five investigates how gonioscopy results by optometrists and other healthcare professionals (HCPs) compare to results by a consultant ophthalmologist. Chapter Six will investigate how gonioscopy, van Herick and AS-OCT results compare in a community optometry setting.

4 THE IMPACT OF THE NICE GUIDELINE ON THE CLINICAL PRACTICE OF UK OPTOMETRISTS

4.1 Introduction

The NICE guideline on the diagnosis and management of chronic open angle glaucoma and ocular hypertension remarked that gonioscopy is not routinely carried out in UK community optometric practice. The literature review in Chapter Three highlighted the fact that the guideline will have a number of consequences for the clinical practice of optometrists across the UK. There is a lack of evidence on gonioscopy findings by optometrists as well as limited evidence from European populations on anterior chamber angle assessment methods. This chapter will investigate what clinical impact the guideline has had on the clinical practice of UK community optometrists. An anonymous, online questionnaire was designed, validated and employed to determine any change in optometry practice since the publication of this guideline.

4.2 Background

As discussed in Section 1.5, the NICE committee recommends that all people suspected of having COAG or ocular hypertension are offered a series of tests to confirm diagnosis (NICE, 2009):

- Intra-ocular pressure measurement using Goldmann applanation tonometry
- central corneal thickness (CCT) measurement/pachymetry
- peripheral anterior chamber configuration and depth assessments using gonioscopy
- visual field measurement using standard automated perimetry
- optic nerve assessment, with dilatation, using stereoscopic slit lamp biomicroscopy with fundus examination

See Section 1.3, for a description of these tests. Myint *et al.*, (2011) reported that in 2008, 16% of community optometrists used applanation tonometry, 7% pachymetry and 12% gonioscopy. Ninety-five per cent of the respondents reported they had access to automated visual field testing and 73% carried out optic nerve

assessment using slit lamp bio-microscopy. This showed that community optometrists, in 2008, were in the most part, able to offer the required methods for visual field testing and optic disc assessment but not for IOP measurement, corneal thickness and angle assessment. Optometrists who wish to take on new roles within glaucoma referral refinement and shared care schemes may need to adapt and learn these skills in order to be compliant in NICE guidance.

As discussed in Section 3.3.8, there was an increase in referrals from community optometrists following the publication of the NICE guideline (Edgar *et al.*, 2010) and this has had a detrimental effect on hospital eye department waiting times. From the onset the introduction of the guideline clearly has had an effect on optometrist practice. Has its introduction led to any change in optometrist clinical practice?

4.3 Aims

The aim of this study is to investigate any change in the clinical practice of optometrists since the publication of the NICE guideline. This is important as it will provide new evidence on how optometrists have responded to the guideline and will highlight any areas where optometrists may need access to further training.

As discussed above, community optometrists in 2008 did not routinely carry out applanation tonometry, pachymetry or gonioscopy. In addition, after the initial increase in referrals from optometrists in 2009, the Royal College of Ophthalmologists and the College of Optometrists advised optometrists to repeat IOP prior to referring a patient.

The research questions for this study are:

- Has there been a change in the method of IOP measurement (contact versus non-contact tonometry)?
- Has there been a change in the use of pachymetry in clinical practice?
- Has there been a change in the practice of gonioscopy by optometrists since the guideline has been published?

- Do optometrists repeat their IOP measurements prior to referral?

This study takes the form of an online anonymous questionnaire.

4.4 Study Design and Methods

A survey is a method of collecting information from a sample of the population of interest, usually by personal interviews, postal or other self-completion questionnaire methods (Bowling, 2009). An online questionnaire was used in this quantitative, cross-sectional, cohort survey. This was seen as an economical method of obtaining the required information in a relatively short space of time.

The Questionnaire

The questionnaire was anonymous and is divided into two parts. The first part (questions one to eight) relate to general information about the optometrist: length of time qualified, location, type of practice. The second part (questions nine to seventeen) relates specifically to the NICE guideline. The frequency the tests are carried out was graded into four categories:

- Yes I often used this test (more than once a week)
- Yes I sometimes used this test (approximately once a month)
- Yes I occasionally used this test (approximately once every few months)
- No I did not use this test

There may be a change in the frequency of carrying out a test caused by the recommendations in the NICE guideline so this method of questioning was deemed the most appropriate at determining any change in clinical practice.

Please see Appendix A1, for the email invitation and questionnaire.

Piloting of Questionnaire

The survey was sent to six practising optometrists who were asked to assess the questions for accuracy and completeness. The optometrists were asked if they understood the questions and whether the response choices were understandable and appropriate or if there was any ambiguity. Based on their feedback, minor

amendments were made. The content of the questionnaire was reviewed by the Institute of Optometry Research Ethics Committee. See Appendix A2 for the comments and amendments made.

Ethical approval was granted by LSBU Research Ethics Committee (REC) and the Institute of Optometry in January 2011 (see Appendix A3). Participation in the survey was voluntary and anonymous. It was assumed that entering the survey constituted informed consent.

Optometrists were invited by email to carry out an online questionnaire using an internet provider of online surveys (Survey Monkey; <http://surveymonkey.com>, Oregon, USA). The College of Optometrists has 9520 UK practising members (College of Optometrists, 2012). A random sample of one thousand members was chosen to give an appropriate level of accuracy. Non-practising members, those based overseas and student members were excluded. In addition a short article was placed in the "Optometry Today" journal with a link to the online survey internet page.

The randomly selected College members were invited by email to carry out an online questionnaire on 19 January 2011. A reminder questionnaire was sent out three weeks later to catch non-responders. Optometrists were given six weeks to respond from the initial email. Information was stored on a password protected Excel spreadsheet (version 14.0 Microsoft Redmond, Washington, USA) on a secure password protected computer and backed up onto a password protected external hard disk. Data will be archived for seven years after completion of the study and then destroyed.

4.5 Statistical Analysis

Data were entered into an Excel spreadsheet and transferred to SPSS (version 18, SPSS Inc., Chicago, IL) for analysis. The percentage changes in optometrists carrying out gonioscopy, pachymetry and applanation tonometry since the NICE guideline

publication were calculated. SPSS Cross tabulation tool “Cross-tabs” was used to calculate the values for any increase and decrease in clinical practice. The non-parametric Wilcoxon matched pair test the McNemar Test were used to assess the significance of any change (Bland, 2000).

4.6 Results

From one thousand College members contacted, there were 388 complete responses, giving a response rate of 38.8%.

Table 4-1 and Figure 4-1 show that most respondents qualified between 1980 and 2009 and the university attendance appears to be evenly spread out.

Table 4-1 Questions 1-2

	n	Percentage
<i>Q1. In what year did you qualify as an optometrist?</i>		
Before 1970	14	3.6%
1970 - 1979	46	11.7%
1980 – 1989	99	25.2%
1990 - 1999	100	25.4%
2000 - 2009	114	29.0%
2010-	20	5.1%
<i>Q2. At which university did you study optometry?</i>		
Anglia Ruskin	8	2.0%
Aston	91	23.2%
Bradford	65	16.5%
Cardiff	51	13.0%
City	103	26.2%
Glasgow	16	4.1%
Manchester	42	10.7%
Ulster	4	1.0%
Other	13	3.3%

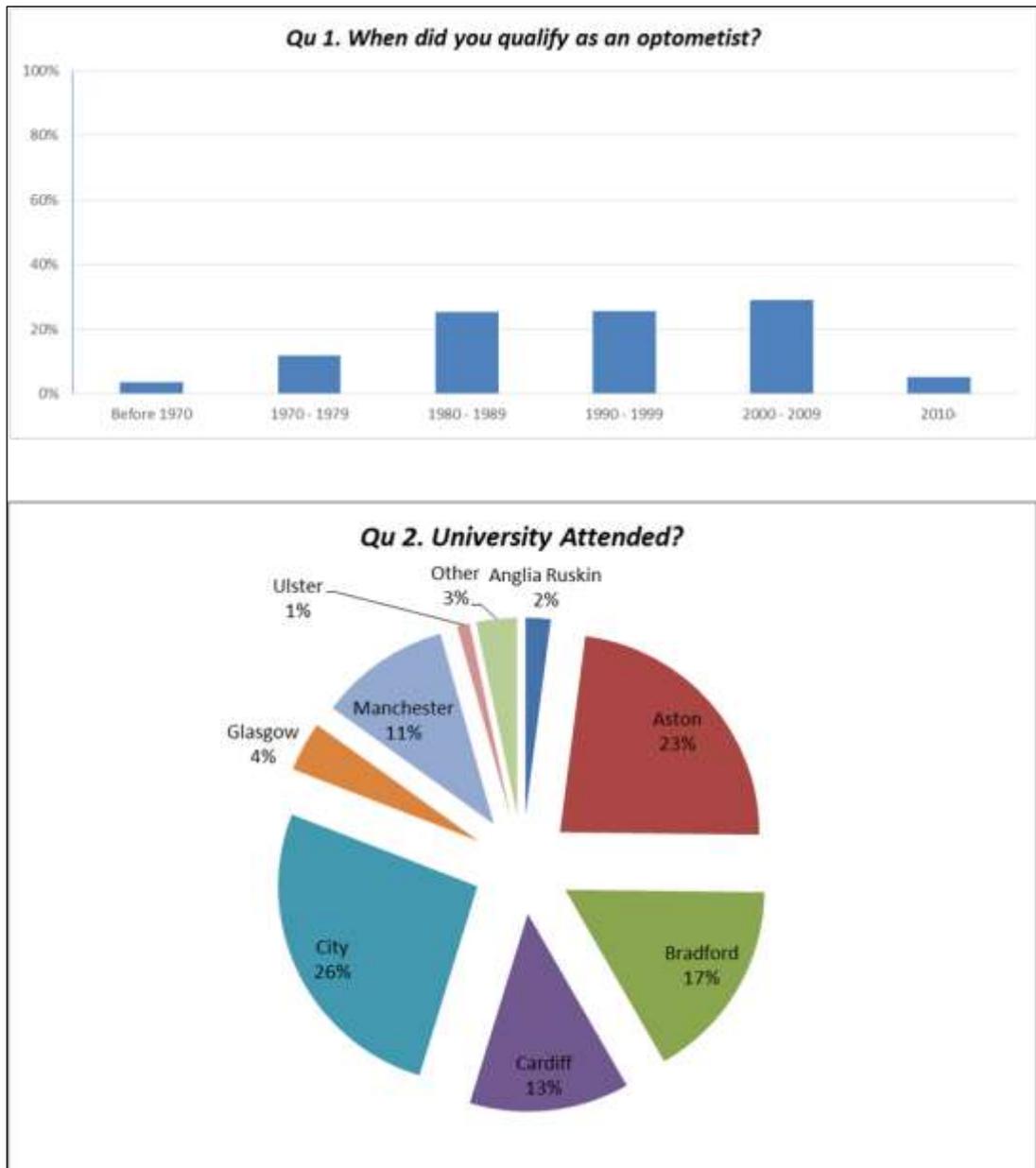


Figure 4-1 Results for Question 1-2

Table 4-2 and Figure 4-2 show that the majority of respondents are based in community practice and are located evenly across the country.

Table 4-2 Results for Questions 3-4

	n	Percentage
<i>Q3. Which type of practice do you consider to be your principal place of work?</i>		
Community - independent	164	42.1%
Community - joint venture/multiple	141	36.2%
Community practice - locum	55	14.1%
Hospital	16	4.1%
Academic/research	3	0.8%
Other	11	2.8%
<i>Q4. Where is the practice in which you spend most of your time?</i>		
England - Eastern	26	6.6%
England - East Midlands	28	7.1%
England - London boroughs	38	9.7%
England - North East	17	4.3%
England - North West	49	12.5%
England - South East	95	24.2%
England - South West	51	13.0%
England - West Midlands	35	8.9%
England - Yorkshire and Humber	29	7.4%
Wales	19	4.8%
Scotland	2	0.5%
Northern Ireland	4	1.0%

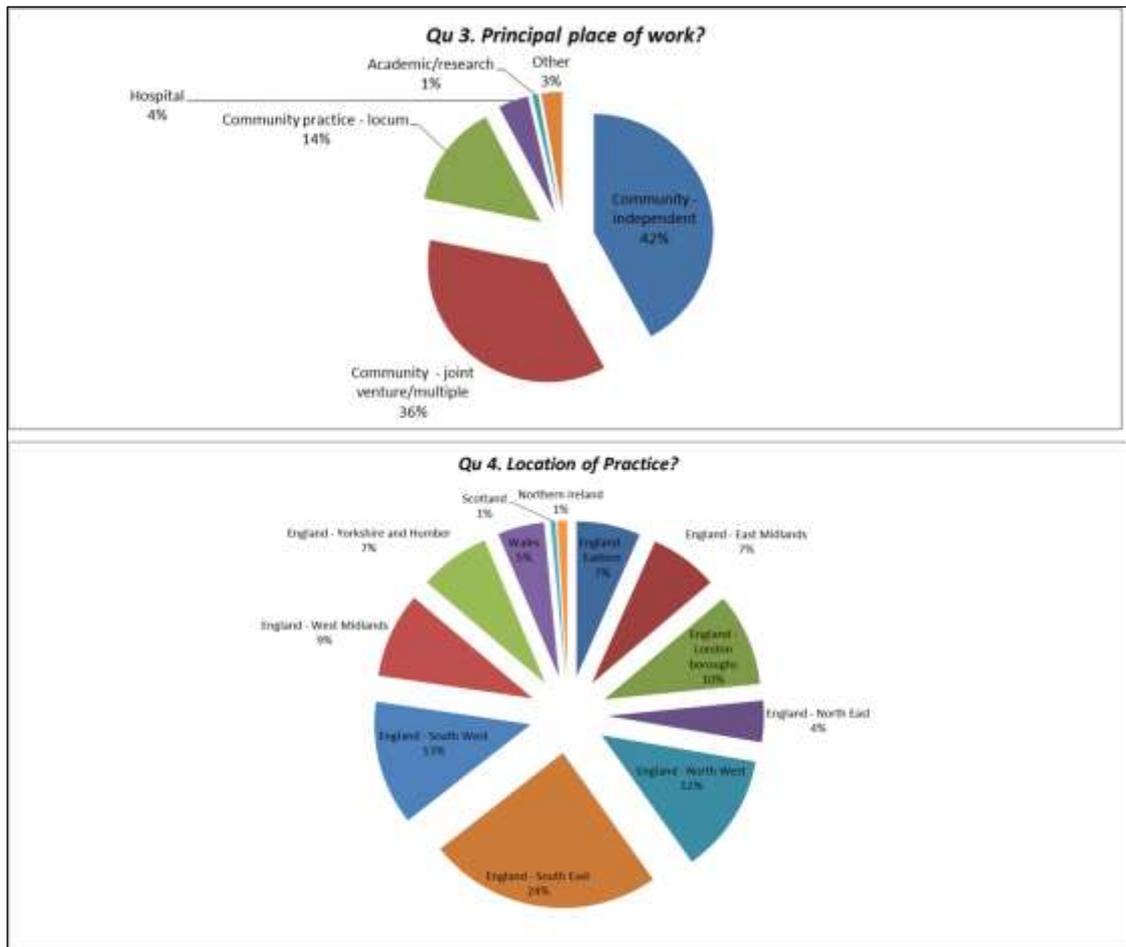


Figure 4-2 Results for Questions 3-4

Table 4-3 shows that 15.6% are involved in a glaucoma shared care scheme and 31.3% in a glaucoma referral refinement scheme.

Table 4-3 Results for Questions 5-7

	n	Percentage
<i>Q5. Do you work in more than one of the areas listed in Question 4?</i>		
Yes	28	7.4%
No	350	92.6%
<i>Q6. On average, how many eye examinations do you carry out in a typical week?</i>		
0 - 20	44	11.3%
21 - 40	90	23.1%
41 - 60	129	33.1%
61 - 80	95	24.4%
81 or more	32	8.2%
<i>Q7. Are you involved in a Glaucoma/OHT Shared Care scheme at present or have you been involved in one within the last two years?</i>		
Yes	61	15.6%
No	330	84.4%
<i>Q8. Are you involved in a Glaucoma Referral Refinement scheme at present or have you been involved in one within the last two years?</i>		
Yes	122	31.3%
No	268	68.7%

The changes in clinical practice for questions 9 to 16 were analysed using SPSS “Cross-Tabs”. Results are shown in Table 4-4. Appendix A4 gives further details on calculation these values. There has been a significant increase ($p < 0.01$) in the regular practice of applanation tonometry, no change in the practice of gonioscopy ($p=0.467$) and a small increase in pachymetry ($p=0.04$). Also there has been a decrease ($p < 0.01$) in respondents who repeat measuring IOPs. Results are shown graphically in Figure 4-3, Figure 4-4, Figure 4-5, and Figure 4-6.

Table 4-4 Significance in the change in clinical practice (see Appendix A4)

Clinical Test	Increase in practice (n)	Decrease in practice (n)	p value [‡]
Applanation Tonometry (n=389)	108	28	< 0.01 [‡]
Gonioscopy (n=386)	15	13	0.467 [‡]
Change in Pachymetry (n=387)	19	7	0.036 [‡]
Repeating IOPs (n=389)	21	70	< 0.01 ^{**}
			[‡] Wilcoxon Signed Ranks Test ^{**} McNemar Test

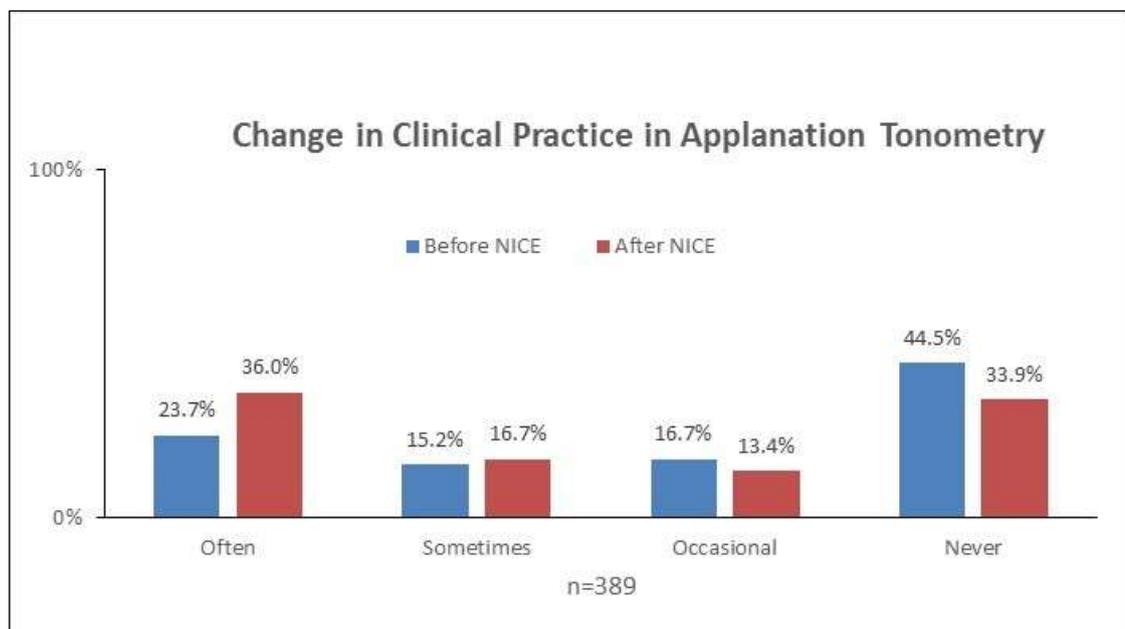


Figure 4-3 Change in Applanation Tonometry

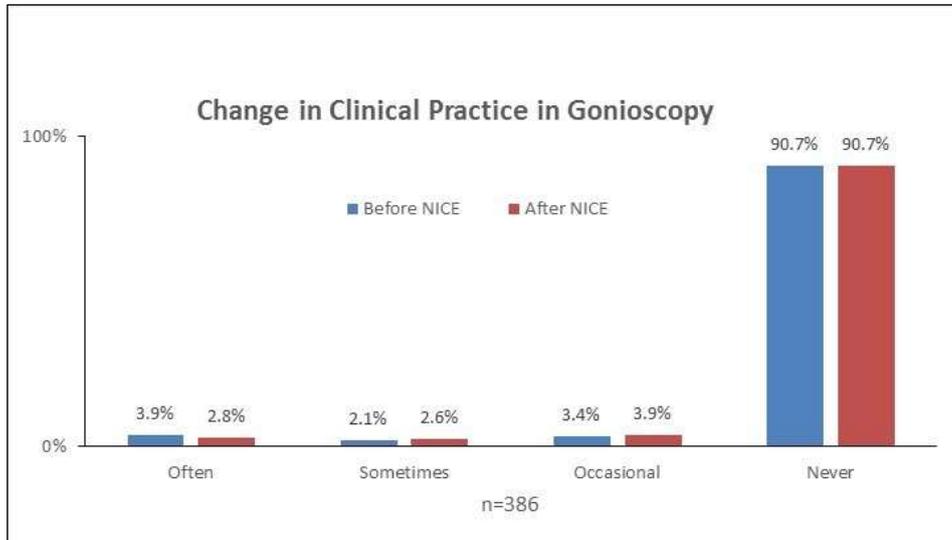


Figure 4-4 Change in Gonioscopy

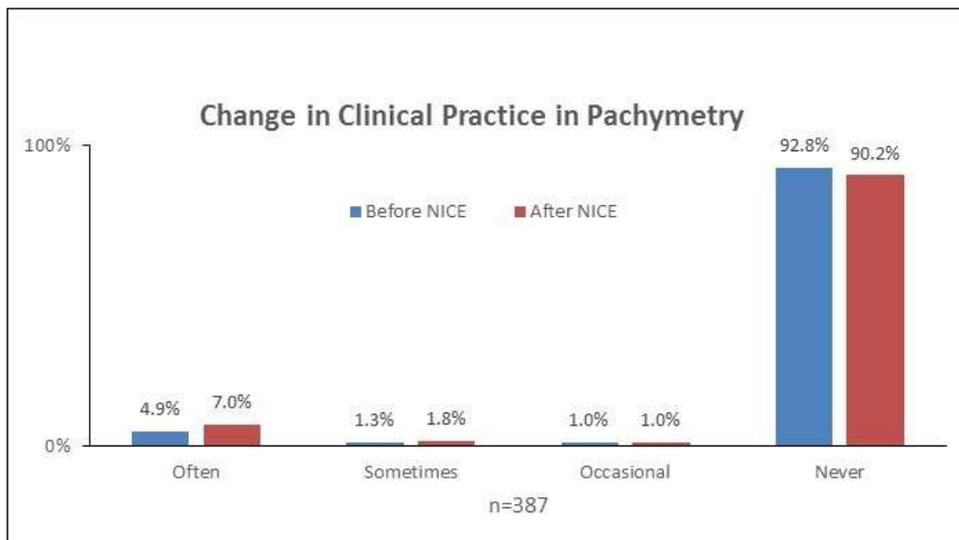


Figure 4-5 Change in Pachymetry

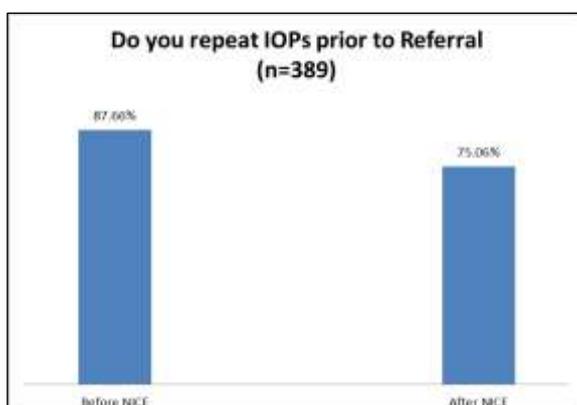


Figure 4-6 Change in Repeating IOPs

Comments by respondents

There were 158 responses to the final open question asking for comments about the effect the NICE guideline has had on practice. Content analysis was carried out on the responses by the author, in order to analyse and understand the text. The responses were coded as positive, negative or neutral (Bowling, 2009). These codes were independently verified by a second researcher.

Ninety-five responders (60.1%) were coded as negative, 63 respondents (39.9%) mentioned the increase in the numbers of referrals.

“More patients referred who were previously monitored. Have to manage increased patient anxiety.”

“Increase in referrals and more clinic time management.”

“More work for no money”

Twenty-two responders (13.9%) were positive about the effect of the NICE guideline:

“It has improved practice and skills - I did not use Goldmann only Perkins prior to guidelines I would like to increase skills i.e. gonioscopy.”

“I just find that it is helpful to have definite referral guidelines.”

“It will improve Optometric Practice for High Street businesses”

Forty-one comments (25.9%) were coded neutral:

“Almost no impact at all”

“It hasn't changed whether I choose to refer- or not regarding query glaucoma”.

This highlights the fact that not all respondents felt strongly about the introduction of the guideline.

4.7 Discussion

This study offers new evidence on the change in clinical practice amongst optometrists since the introduction of the NICE guideline on glaucoma. The guideline recommends a series of tests to be carried out when diagnosing patients with Chronic Open Angle Glaucoma and ocular hypertension.

The makeup of the respondents closely matches a College of Optometrist survey carried out in 2007 (College of Optometrists, 2008). The number of respondents involved in a glaucoma/OHT shared care scheme (15.6%) appears to match with the College survey (11-12%). In the current study 31.3% were involved in a referral refinement scheme whereas only 19% of respondents in the College survey were involved in a scheme. This may be due to the increase in these schemes since the introduction of the NICE guideline (Ratnarajan *et al.*, 2013).

The results of the questionnaire show there has been an increase of 12.3% in the regular practice of applanation tonometry ($p < 0.01$); there was no change found in the practice of gonioscopy ($p=0.47$) and a small increase (2.1%) in regular practice of pachymetry ($p=0.04$). So changes in practice of pachymetry have been small. In addition there has been a decrease of 12.6% in the number of optometrists who repeat IOP measurements prior to referral ($p < 0.01$).

The increase in the practice of applanation tonometry is likely to be due to the recommendation by the Association of Optometrists to refer patients with IOP > 21 mmHg (Association of Optometrists *et al.*, 2010). If IOPs are over 21 mmHg with a non-contact tonometer, they should ideally be checked using the more accurate applanation tonometry prior to referral. In some areas referral refinement schemes were set up where optometrists could refer to another optometrists who would undertake contact tonometry.

The small increase in practice of pachymetry may be due to the ease of use of this test and its well documented importance in qualifying a patient's acceptable level

of IOP (Gordon *et al.*, 2002). However this small increase is not clinically significant due to the relatively small number of respondents who reported they use the test.

The lack of change in gonioscopy may be due to the fact gonioscopy is not routinely taught on UK optometry undergraduate courses and it is not a requirement for community optometrists when they are assessing patients at risk of glaucoma. It requires considerable skill and training to perform and it therefore may take time for an increase in its practice to be noted. There has however been an increase in courses on gonioscopy at optometry conferences and at local CET events over the last few years; a future investigation of gonioscopy practise may show an increase in its use. Training in gonioscopy and the need to practice it on a regular basis to maintain competency in it will be discussed in Section 7.4.

The small number of optometrists who do currently practice gonioscopy may have implications for future glaucoma referral refinement and shared care schemes where gonioscopy skills are likely to be required.

The 12.6% decrease in the number of practitioners who repeat IOPs prior to referral ($p < 0.01$) is an unexpected finding. After the publication of the NICE guideline, the Association of Optometrist advice was to refer all patients with IOPs over 21 mmHg and this may explain the reduction in the number of respondents who do not repeat IOPs. Further recommendation was issued in December 2009 (College of Optometrists and Royal College of Ophthalmologists, 2010) which advised on repeating IOP measurement prior to referring. The consequence this advice may not have taken effect at the time of the questionnaire. Another reason for the decrease in repeating IOPs may be due to the increase in practice of applanation tonometry. This is the gold standard method and therefore optometrists may feel there is less need to repeat findings with this test. Another factor might be the increase in the number of glaucoma referral refinement schemes allowing optometrists to refer to another community optometrist for applanation tonometry without needing to repeat the IOP readings.

The effect of NICE guideline on optometrist practice was coded as positive, negative or neutral (Bowling, 2009). Sixty per cent of the comments were coded as negative, see Figure 4-7. Many optometrists expressed a concern about the increase in anxiety on patients as well as the need to refer more patients. There was however a considerable interest expressed by respondents in learning new skills such as gonioscopy and again this is promising for future glaucoma shared care provision.

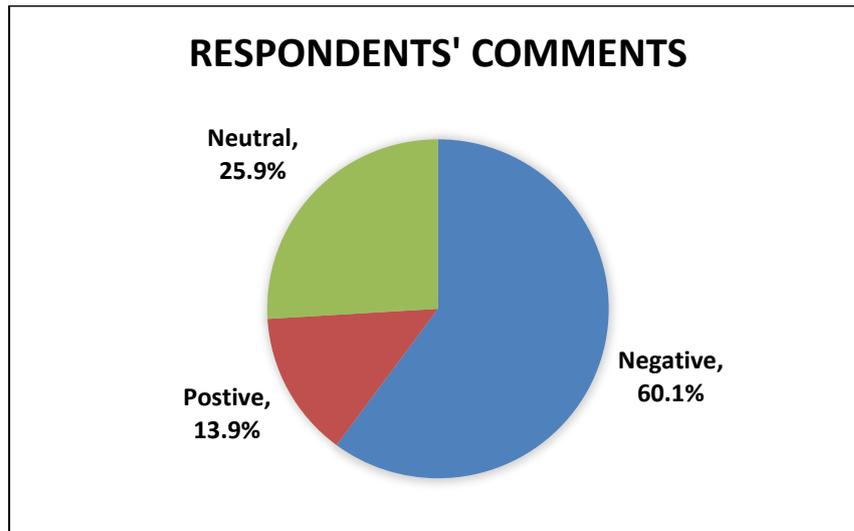


Figure 4-7 Coding the responses of respondents

The negative responses would appear to agree with comments by other optometrists who have expressed concern about the increase in anxiety on patients as well as the need to refer more patients since the publication of the guideline:

“NICE’s reaction to the AOP’s advice on NICE guidelines do little to reduce the mud in the water surrounding the referral of glaucoma potentials in practice. The latest NICE missive still sets up a situation where thousands of additional patients will be passed on to the hospital service.”

The Big Optometry Blog: <http://www.opticianonline.net/blogs/big-optometry-blog/2009/06/latest-nice-statement-on-glaucom>, (Accessed 02 April 2014).

However, on a more positive note, the publication of the guideline has generated interest in learning new skills such as gonioscopy. This is promising for future

glaucoma referral refinement and glaucoma shared care schemes where these skills might be required.

4.7.1 Comparison to other evidence

This study offers new evidence investigating changes in clinical practice since the NICE guideline was introduced.

Prior to the guideline publication, the College of Optometrists survey in 2007 reported that 54% of respondents carried out applanation tonometry, and 6% reported the use of a gonioscopy lens (College of Optometrists, 2008). Another survey, carried out in 2008 (Myint *et al.*, 2011) found that 16% of respondents used applanation/contact tonometry and 12% of the respondents reported they had access to a gonioscopy lens.

Prior to the NICE guideline publication, the total proportion of the respondents who practised applanation tonometry (occasionally, sometimes and regularly) was 55.5% and 23.5% reported they used it on a regular basis. This would appear to correlate well with the College survey (54%) but not so with Myint's study (16%). The lower value for the survey by Myint *et al.*, might be due, in part, to their exclusion of hospital based optometrists. Hospital optometrists are more likely to use applanation tonometry and therefore excluding them is likely to have an effect on the results.

The total proportion of the respondents who practised gonioscopy (occasionally, sometimes and regularly) was 9.3% before NICE. Myint *et al.* reported that 12% of the respondents had access to a gonioscopy lens and the College found 6% used a gonioscopy lens. The current study results therefore fall between these two studies. This may be due in part to the fact that the current study and the College study investigated how often gonioscopy was used as opposed to whether there was a gonioscopy lens available to use. This is a more relevant question, due to the need to practice gonioscopy on a regular basis to become more competent and confident

in the procedure. It is encouraging to know that a considerable number of community based optometrists have access to a gonioscopy lens (12%), and this might encourage more practitioners to start carrying out gonioscopy over time.

One of the strengths of this study is the higher response rate (38.8%) compared to other surveys. The 2007 College of Optometrists survey sent to all College Members had a response rate of 30% (College of Optometrists, 2008). The survey by Myint et al in 2008 sent to all Association of Optometrist members had a response rate of 27.5% (Myint *et al.*, 2011). The short nature of the questionnaire and the fact that the subject was topical at the time it was conducted are likely to have contributed to this good response rate.

4.7.2 Limitations

There are some limitations of this study. Only 10% of the College of Optometrists members were randomly contacted and so from a relatively small sample it is difficult to draw general conclusions for the UK optometry community. Despite this, the demographic of the respondents in the current study appear to match a survey sent to all College Members in 2007. Membership of the College of Optometrists is voluntary although ninety-five per cent of all UK optometrists are College Members or Fellows (Hadwin *et al.*, 2013).

There may be some self-selection bias and the change in behaviour of the respondents may not fully match the behaviour of all optometrists. There may also be some margin of error in the results due to the retrospective aspect of the survey, with the reliance on optometrists “remembering” their previous clinical practice. This may have affected the accuracy of their answers. If a questionnaire was also carried out before the introduction of the guideline, this might have produced a more truthful representation of clinical practice. However such a study would have taken longer to carry out and an advantage of the retrospective nature of the current study is the fact it was carried out and analysed within a more manageable time frame.

Another limitation of the study was not including the practice of rebound tonometry as well as applanation tonometry. Rebound tonometry has been shown to compare well to Goldmann applanation tonometry (Fernandes *et al.*, 2005) and if the questionnaire was used again it might be prudent to investigate whether there has been an increase in the use of rebound tonometry since the NICE guideline was introduced. Although it would now be more difficult for respondents to remember what tests they used prior to the NICE guidance. This along with other future work will be discussed in Section 7.6.

4.8 Summary

This survey has shown that the introduction of the NICE guideline on glaucoma has caused significant change in some aspects of the clinical practice of optometrists. There has been a statistically significant increase in the number of respondents who carry out applanation tonometry, a small increase in the practice of pachymetry (unlikely to have an impact clinically due to the small numbers who use it) and no change in gonioscopy practice. The response rate for this questionnaire is higher than some other recent optometrist surveys.

At present, there would appear to be only a small number of optometrists who regularly carry out gonioscopy. As optometrists take on more roles in diagnosing and managing patients with glaucoma in hospital and community settings, their ability to show competency in gonioscopy is likely to become more important. Those optometrists who do show competency are likely to be well placed to play an important role in future glaucoma referral refinement and shared care provision. Further research is required looking at the ability of optometrists to learn new skills such as gonioscopy.

In addition, community optometrists are increasingly using new technology such as OCT devices within their practice. The ability of these devices to screen patients at risk of PACG is likely to be of interest to optometrists as well as local stakeholders responsible for local ophthalmic care provision.

In the next chapter the gonioscopy findings for hospital based optometrists as well as for other healthcare professionals will be compared to those by a consultant ophthalmologist.

5 GONIOSCOPY COMPETENCE

5.1 Introduction

The previous chapter showed that only a small number of optometrists (3%) currently carry out gonioscopy regularly in the UK. The questionnaire did show, however, that there is interest amongst optometrists in learning gonioscopy and the present author has observed a noticeable increase in gonioscopy workshops offered at UK Optometry conferences in recent years.

The literature review in Chapter Three highlighted the lack of evidence comparing gonioscopy between clinicians. This chapter will investigate how gonioscopy findings for optometrists along with other healthcare professionals (HCPs) compare to those by a consultant ophthalmologist within a hospital setting. Optometrists who show competency in gonioscopy are well placed to offer valuable skills in the future of glaucoma care provision.

5.1.1 Background

As discussed in Section 1.5.1, the NICE guideline on chronic open angle glaucoma and ocular hypertension recommends that people suspected of having glaucoma are offered a series of tests, including an assessment of the peripheral anterior chamber using gonioscopy, to confirm diagnosis (NICE, 2009). The guideline recognises that gonioscopy is not routinely carried out by optometrists and suggests methods to help with costs involved in purchasing a gonioscopy lens:

“Gonioscopy is not extensively used in current practice and many optometrist practices in the community are not equipped to perform this test. Community optometrists could choose between purchasing a gonioscopy contact lens themselves and participating in a Hospital Eye Service (HES) scheme where this equipment would be provided.” (NICE, 2009, Appendices p. 272)

5.2 Aim and research questions

The aim of this study is to investigate whether gonioscopy results by optometrists, as well as other HCPs, are accurate in comparison with those by a consultant.

The research questions are:

- What are the sensitivity and specificity values for gonioscopy by optometrists and other HCPs compared to a consultant?
- How do these results compare to gonioscopy findings between two consultants?

Gonioscopy requires the practitioner to make subjective judgements so it is unlikely that there will be 100% repeatability between practitioners. In addition to comparing results between HCPs, a small number of cases comparing gonioscopy results between consultants will be assessed. This will provide a reference for the present work. The criteria for agreement between practitioners are discussed in Section 5.5.

5.3 Ethics

This study investigates whether a clinical service reaches a predetermined standard and is therefore best described as a clinical audit. Clinical audit is defined as a *“quality improvement process that seeks to improve patient care and outcomes through systematic review of care against explicit criteria and the implementation of change”* (NICE, 2002, p.1).

This study was registered as a Clinical Audit at the NHS Trust Research and Development Department in January 2011. University Research Ethics approval was granted by LSBU Research Ethics Committee (REC) in March 2012 (see Appendix B1). Information sheets were given to the HCPs and consultants (see Appendix B2 and B3) and written consent was obtained. No patient information was collected other than age, gender, ethnicity. Information was stored on a password protected Excel file on a secure password protected computer and backed up onto a

password protected external hard disk. Data have been archived and will be kept for seven years after completion of the study and will then be destroyed.

5.4 Methods

5.4.1 Study setting

This study was carried out in the glaucoma clinic at an ophthalmology department at a London NHS Foundation Trust. Here, optometrists, orthoptists and nurses, (termed healthcare professionals, HCPs, in this thesis) work alongside ophthalmologists in a multi-disciplinary setting. As part of their initial training in glaucoma, the HCPs undergo competency training in Goldmann Applanation Tonometry and assessing the optic nerve head. These tests are part of the core competencies outlined for optometrists working in the UK (General Optical Council, 2011). The HCPs' findings for tonometry and optic nerve assessment are compared to the consultant ophthalmologist for accuracy and consistency prior to commencing work in the clinic. Initial training is also given on gonioscopy. Gonioscopy is not currently a core competency for optometrists or other HCPs. A data sheet was devised by the team to compare the HCP gonioscopy findings to those of a consultant, see Appendix B4. This sheet was developed from discussions between team members on how to improve gonioscopy training in the Trust.

Patients referred to the glaucoma clinic are seen initially by an HCP who carries out a number of tests including measuring the IOP and gonioscopy. The HCP records the gonioscopy results on a data sheet along with anonymous demographic details (age, gender, and race). The consultant then examines the patient and also carries out gonioscopy and their findings are recorded in the main hospital patient records. The consultant is not aware of the HCP results until afterwards. The HCP then records the consultant's gonioscopy results in the data sheet for comparison. Any difference between the findings is discussed and further training is offered to the HCP if necessary.

5.4.2 Sample Size Calculation

The following equation from Bland and Altman (1986) was used to calculate the sample size:

$$\text{Standard Error (95\% C.I.)} = 1.96 \sqrt{\frac{3s^2}{n}}$$
$$\text{Coefficient of Repeatability} = 1.96s$$

s = standard deviation of the differences between measurements by the 2 methods

n = sample size

Eperjesi and Holden (2011) found a coefficient of repeatability CR=1.60 when comparing anterior chamber depth grades for three different methods of ACA assessment. In the current study the comparison between two clinicians carrying out gonioscopy is likely to have a similar SD. Using the formula above, a sample size of 124 was calculated to give 95% limits of agreement.

5.4.3 Gonioscopy Technique

Standard clinical gonioscopy procedures were employed (Friedman and He, 2008). The test was performed under low illumination (circa 20-25 lux, measured with a Luxmeter iPhone App, Application Manufactory, Germany) with a one mirror hand held MagnaView gonioscopy lens (Ocular Instruments Inc., Bellevue, WA). Oxybuprocaine Hydrochloride 0.4% drops (Chauvin Pharmaceuticals Ltd, Surrey, UK) were instilled to anaesthetise the cornea and a coupling agent (Viscotears Gel, polyacrylic acid 0.2%, Novartis AG Switzerland) was applied to the lens. The assessment was carried out at high magnification (x16), a 1mm beam was reduced to a narrow slit, a vertical beam was offset horizontally to assess the superior and inferior angles and offset vertically for the nasal and temporal angles. Light was prevented from falling on the pupil. The patient was instructed to look straight ahead (the primary position) and slight tilting of the lens to gain a view was permitted, as recommended by Salmon (2009). One quadrant of the ACA can be

viewed at a time using the one mirror gonioscopy lens. The lens was rotated by 90° to view each quadrant and the angle was graded for each quadrant Schaffer's convention (Salmon, 2009). See Section 2.2.1 for further details.

As outlined in Section 2.2.1, following gonioscopy an eye can be classified as either "open" (no potential risk of PACG at that time) or "occludable" (at risk of PACG). For the purpose of this study an eye was classified as occludable if posterior trabecular meshwork was visible for less than 270 degrees (Grade 0-1) and open if posterior trabecular meshwork was visible in all four quadrants (Grade 2-4) (Nolan *et al.*, 2007). These grading criteria was chosen as it offered the most conservative approach to screening, based on discussions with the consultants in the Trust.

Consultant – Consultant Findings

In addition to gonioscopy findings between the HCP and a consultant, a small number of "Consultant versus Consultant" results were also collected. These results were collected retrospectively from hospital notes, provided that gonioscopy had been repeated within a two month time period. In this instance the second clinician would not have been masked to the previous results. The implications of this are considered in the discussion (see Section 5.7.2).

5.5 Data Analysis

Due to the recognised correlation in using results for subject's right and left eye (Ray and O'Day, 1985), one eye from each subject was selected randomly for the analysis, provided both eyes were eligible for the study. Statistical analysis was carried out using SPSS (version 18, SPSS Inc., Chicago, IL).

See Section 2.3.1, for definitions of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). In this study, sensitivity is defined as the proportion of those found "occludable" by the consultant that were also found to be occludable by the HCP. Specificity is the proportion of those "open" by the consultant that were also found to be open by the HCP. Positive predictive value

(PPV) is the proportion of subjects who are graded “occludable” by the HCP and who also are graded “occludable” by the consultant. Negative predictive value (NPV) is the proportion of subjects who are graded open by the HCP and are also graded “open” by consultant.

True positives are defined as subjects diagnosed with an occludable angle by the consultant, false negatives are subjects diagnosed with open angles by the HCP but found to be occludable by the consultant. True negatives are subjects diagnosed with an open angle by the consultant, false positives are subjects diagnosed with an occludable angle by the HCP but found to have an open angle by the consultant.

Ninety five per cent confidence intervals for sensitivity and specificity were calculated using the Clopper-Pearson binomial probability confidence interval exact method (Clopper and Pearson, 1939) via the online statistical calculator (Soper, 2014). A binomial distribution has only two possible outcomes. This method is based on cumulative probabilities of the binomial distribution. It has been described as a robust method to calculate confidence intervals and can be used safely in a variety of different situations (Newcombe and Altman, 2000). For further details on this method see Appendix B5.

From the literature there appears to be no clinical precedents in place for evaluating competency in gonioscopy. For the purpose of this study it was agreed that 85% for sensitivity and specificity would be an acceptable level when comparing the HCP gonioscopy findings to a consultant’s.

5.5.1 Weighted kappa method

See Section 2.3.2, for details on the use of the weighted kappa “ κ_w ” statistic. As shown in the literature review weighted kappa have been used by other researchers to measure inter observer gonioscopy repeatability between two clinicians (Foster *et al.*, 2000; Thomas *et al.*, 1996).

The specific values of weight chosen by other researchers are not disclosed so in this study, it was felt prudent to place the least weight on a false negative result, that is when an HCP grades an angle as open and the consultant grades it as occludable (at risk of PACG). This situation could potentially lead to a missed case of PACG and a delay in a patient receiving the correct treatment.

The details of the weighted kappa formula along with the values of the weights chosen are shown in Section 2.3.2. Greater importance was placed on difference in findings between the HCP and consultant than for the same findings. A worked example along with details on the weights chosen is shown in Appendix B6.

In order to reduce any learning bias, the first five gonioscopy results were not included in the analysis. HCPs who had collected less than ten gonioscopy comparisons were also excluded from the analysis.

5.6 Results

5.6.1 HCP Compared to Consultant

HCPs datasheets were collected and analysed from March 2012 until June 2013. Results were obtained for four HCPs and two consultants. The HCPs consisted of three optometrists and one nurse practitioner see Table 5-1.

Table 5-1 Details of work experience for each clinician

HCP	No. of years working in glaucoma clinic
HCP1 – Optometrist	3
HCP2– Optometrist	2
HCP3–Nurse Practitioner	8
HCP4– Optometrist	2
Consultant	No. of years working as a glaucoma consultant
C1	10
C2	5

The results for one HCP (HCP4) were excluded as they had only completed one datasheet. Table 5-2 outlines the demographic details obtained. Datasheets that did not contain complete demographic details such as ethnicity and gender were still included in the analysis.

Table 5-2 Patient Details

n=126		p value
<u>Number (%) "Occludable"</u>		
By HCP	32 (25.4%)	0.11 ¹
By Consultant	26 (20.6%)	
Mean Age (SD)	60.5(12.5)	0.18 ²
Not recorded	15	
<u>Gender</u>		0.92 ³
Female	55	
Male	51	
Not recorded	20	
<u>Race</u>		0.90 ⁴
Caucasian	35	
African racial origin	12	
Asian (racial origin India)	3	
Other	4	
Not recorded	72	
<u>Random Eye Allocation</u>		0.65 ³
Left	60	
Right	66	
SD= Standard Deviation ¹ Related Samples McNemar Test ² One Sample Kolmogorov-Smirnov Test ³ One Sample Binomial Test ⁴ One Sample Chi-Square Test		

There was no significance found in the results for gender or age. The ethnicity of the patients in this audit appeared to match the ethnic makeup of the patients seen in the glaucoma clinic at the Trust ($\chi^2 = 5.99$, $p=0.90$).

Gonioscopy results were analysed for 126 eyes. Table 5-3 shows a breakdown of the results for each HCP and consultant. Overall the HCPs and consultants agreed on an open angle classification for 92 eyes and agreed on an occludable angle

classification for 24 eyes, see Figure 5-1. Overall agreement for all HCPs was good: $\kappa_w = 0.62$. Agreement values for each HCP ranged from 0.35-0.74.

Table 5-3 Results for each HCP and Consultant

	n	Sensitivity % (95% C.I)	Specificity % (95% C.I)	κ_w	PPV %	NPV %
HCP1/C1	35	100 (63-100)	96 (81-100)	0.74	89	100
HCP1/C2	35	78 (40-97)	84 (65-96)	0.49	64	92
HCP2/C1	16	100 (48-100)	91 (59-100)	0.75	83	100
HCP2/C2	10	100 (2-100)	78 (40-97)	0.35	33	100
HCP3/C1	20	100 (16-100)	100 (81-100)	0.62	100	100
HCP3/C2	10	100 (2-100)	100 (66-100)	0.62	100	100
Total Results	126	92 (75-99)	92 (85-96)	0.62	75	98

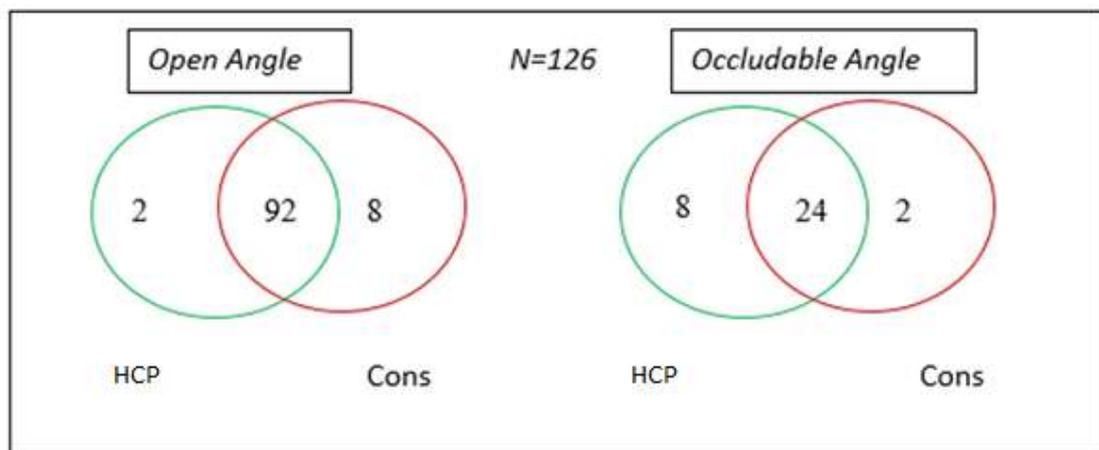


Figure 5-1 Gonioscopy outcomes for all HCPs and Consultants

5.6.2 Consultant compared to Consultant

One reason for repeating gonioscopy by a second consultant may be due to a second opinion being sought on a patient. Due to the variable nature of gonioscopy, a second set of results might be required prior to making a decision on treatment options. The gonioscopy results by two separate consultants were obtained for 10 subjects. Demographic details for the subjects are shown in Table 5-4. The comparison results are shown in Figure 5-2 and Table 5-5.

Table 5-4 Details for Gonioscopy findings between Consultants

n=10	10	P value
Mean Age of patients(SD) Unknown	63.5(11.6) 2	0.870 ¹
Gender of patients Female Male Unknown	6 2 2	0.289 ²
Race of patients Caucasian African racial origin Unknown	4 2 4	0.743 ³
Random Eye Allocation Left Right	2 8	0.109 ²
SD= Standard Deviation ¹ One Sample Kolmogorov-Smirnov Test ² One Sample Binomial Test ³ One Sample Chi-Square Test		

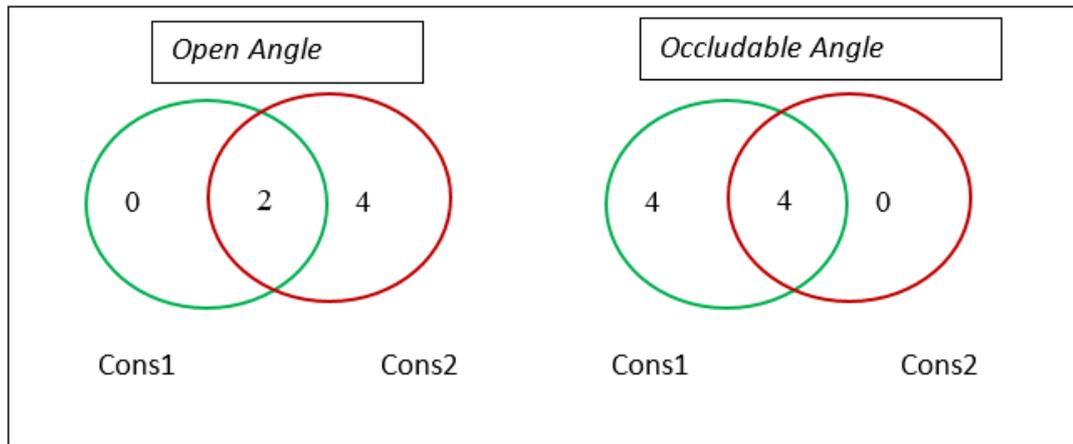


Figure 5-2 Gonioscopy findings between two consultants

Table 5-5 Gonioscopy Results between two consultants

"Gold Standard"	n	Sensitivity	Specificity	κ_w	PPV	NPV
Consultant 2	10	100.0%	33.3%	0.30	50%	100%

5.7 Discussion

This study outlines an audit comparing gonioscopy results by optometrists and other HCPs with those by a consultant within a hospital setting. Sensitivity, or the ability of the HCP to detect an "occludable" angle, ranged from 78% to 100%. Specificity, or the ability of the HCP to detect an open angle also ranged from 78% to 100%. Positive predictive values, or the likelihood that a patient classified occludable by an HCP is occludable by the consultant, ranged from 33% to 100%. Negative predictive values or the likelihood that a patient classified open by an HCP is open by the consultant, ranged from 92% to 100%. Weighted kappa results for each HCP ranged from $\kappa_w = 0.35$ to 0.75. The overall weighted kappa value for all HCPs and consultants was good $\kappa_w = 0.62$.

In five out of six cases the 85% target for sensitivity was reached and in four out of the six cases the 85% target for specificity was reached. These values would suggest that HCPs are able to carry out gonioscopy safely within a hospital setting. The lower positive predictive values would suggest that HCPs might err on the side of

caution and classify more eyes as occludable in order to not miss a potential case of PACG.

The number of years working in a glaucoma clinic may be a factor in gonioscopy competence. The HCP with the least experience (HCP2) had the poorest agreement value ($\kappa_w = 0.35$). In this case there were two false positive results out of a sample size of ten and it may be the case that this HCP is over cautious when carrying out gonioscopy. More experienced HCPs would therefore appear to be more competent in classifying an eye as open or occludable.

For both HCP1 and HCP2 the weighted kappa values are somewhat better for one consultant C1 (0.74, 0.75) than for C2 (0.49, 0.35). This would suggest there may be variation in results between “gold standard” experts.

The small sub study comparing gonioscopy results between two consultants highlighted the subjective nature of gonioscopy. The sensitivity was excellent (100%) however the specificity was poor (33%). Weighted kappa agreement between the consultants was fair ($\kappa_w = 0.30$). The second consultant was not masked to the previous gonioscopy findings and one might therefore expect better agreement. However this subset of patients is not likely to be representative of typical patients seen in the clinic so direct comparison should be avoided. These patients might have unusual ACA features which require a second opinion, gonioscopy may be difficult to carry out or interpret.

Although these factors may reduce the ability to compare the results of HCP-consultant agreement with consultant-consultant agreement, this study clearly shows the subjective nature of gonioscopy, particularly in more complex cases. The use of kappa to measure agreement is however sensitive to the sample size and the small sample size in some of these cases in this study may be a factor in explaining the poor values for weighted kappa obtained.

5.7.1 Comparison to other evidence

These weighted kappa statistic values found in this study appear to be lower than results found by other researchers. Thomas et al (1996) measured inter-observer agreement in gonioscopy between two ophthalmologists in Vellore, India (n=96): $\kappa_w = 0.81$. Foster et al, (2000) looked at inter-observer agreement in gonioscopy results between two ophthalmologists in 55 eyes of 28 subjects in Mongolia: $\kappa_w = 0.80$.

Direct comparison between the results should however be made with caution. The weights used in the current study were chosen in order to place the most emphasis on when an HCP classifies an eye as open and the consultant classifies it as occludable, due to the potential risk of missing a case of PACG. No details are given on the values of the weights used in the other studies. The un-weighted kappa values from the current study for each HCP were 0.92, 0.58, 0.86, 0.41 and 1.00. These values would appear in some cases to match more closely the results by other researchers. It may be the case that the weights used in the current study are more rigorous than those used by the other researchers and this may explain the lower values obtained.

The size of the patient sample per HCP was also less in the current study (ranging from 10 to 35) than in other studies. As noted above, a small sample size is likely to affect the precision of the kappa values obtained. In addition the majority of patients in the current study were Caucasian (64.8%) whereas in the other studies they were Asian. The prevalence of PACG is higher and the anterior segment dimensions are known to be different in Asian eyes (Wang *et al.*, 2013). The ophthalmologists involved in these studies are also likely to be more experienced in gonioscopy as a result of encountering more patients with PACG. Agreement between them is likely to be higher than that between the HCPs with limited experience in gonioscopy and a more experienced consultant ophthalmologist.

Other studies have evaluated optometrists' performance in various other aspects of glaucoma diagnosis and management (Banes *et al.*, 2006; Marks *et al.*, 2012). These

authors used the kappa as well as the weighted kappa statistic to measure agreement on management decisions such as the visual field status and optic disc appearance between optometrists and a consultant ophthalmologist (see Table 5-6). Both studies reported that lack of agreement was caused in some instances by optometrists being over cautious when making decisions. The fact that in the current study HCPs classified a total of 32 cases occludable compared to 26 by the consultant would also suggest that HCPs acted cautiously in their decision making. These findings on comparing gonioscopy outcomes would therefore concur with studies investigating other aspects of glaucoma management decision making.

Table 5-6 Agreement in management decisions between optometrists and a consultant

Management Decision	Banes <i>et al.</i> , (2006)	Marks <i>et al.</i> , (2012)
Visual field status	$\kappa = 0.33$	$\kappa = 0.42-0.50$
Optic Disc	n/a	$\kappa = 0.17-0.31$
Clinical Management	$\kappa = 0.67$	$\kappa = 0.73-0.81$
Next clinic appointment	$\kappa_w = 0.35$	n/a

5.7.2 Limitations

This study assumes that the consultant gonioscopy findings are the gold standard, when measuring accuracy of HCP gonioscopy findings. However, there appears to be some variation in findings between the two consultants and the HCPs, with one consultant appearing to show better agreement with the HCPs' gonioscopy results than the other consultant (see Table 5-3), this may limit its function as the gold standard method when assessing the ACA.

Due to the busy nature of the clinic, some of the demographic details are missing in this study. However from the details obtained from these patients, they do appear to match the demographic makeup of patients seen in the glaucoma clinic at the Trust.

The consultant may not always have been masked to the HCP findings. Due to clinic setting, the data sheet with the HCP gonioscopy results might have been occasionally seen by the consultant, therefore potentially biasing the results. In the consultant-consultant findings the second consultant was not masked to the first results and again this may cause some degree of bias in the results.

In a College of Optometrists survey in 2007, only 3% of optometrists listed their principle work as hospital based. Optometrists working in a glaucoma clinic are not necessarily representative of optometrists in the UK. Hospital optometrists working alongside ophthalmologists are able to seek the opinion of a colleague so their ability at maintaining skills in gonioscopy may differ from community based optometrists.

There was a range in experience in gonioscopy by the HCPs in this study, so one should avoid direct comparison between the HCPs. There is also a difference in the number of gonioscopy results collected for each HCP. In addition two of the HCPs were optometrists and one was a nurse practitioner, so there may be a difference in clinical decision making between these professions.

The level of illumination in each of the clinic bays used by clinicians may also differ and this may affect the gonioscopy findings when for example a patient was seen in one bay by the HCP and in another bay by the consultant.

The size of the patient sample per HCP ranged from 10 to 35. The small sample size in some of these cases clearly places bias on the results. Collecting more data for each HCP is likely to give more accuracy to the results.

Comparison between the results for HCP-consultant and consultant-consultant should also be treated with caution due to the fact that the patients for whom consultant-consultant data were available are likely to represent more difficult cases, for example when one consultant is seeking the opinion of a colleague.

5.8 Summary

This study described new evidence comparing gonioscopy findings between clinicians within a UK hospital setting. HCPs working in a hospital setting appear to have good competency in detecting patients at risk of PACG with gonioscopy when compared to a consultant ophthalmologist. Agreement, using the weighted kappa statistic, ranged from fair to good. These values appear similar to values found by other researchers comparing decision making by optometrists and consultants in other aspects of glaucoma management. Agreement between two consultants in a smaller sample was poor, highlighting the subjective nature of gonioscopy.

Outside of Asia, there has been no published evidence comparing gonioscopy results between clinicians, and no data comparing gonioscopy results between non ophthalmologists, who are likely to be less experienced in gonioscopy. Further work is therefore needed comparing the gonioscopy findings between ophthalmologists and between optometrists and other HCPs.

Optometrists who work in the community who wish to become adept at gonioscopy would benefit from using this model of gonioscopy competency training. Community optometrists could attend a hospital clinic on a number of occasions and have their gonioscopy results compared to a consultant to ensure they practice it safely. However in order to maintain their skill levels at gonioscopy they may need regular “top-up” training sessions within a hospital clinic setting at a future date.

This chapter also highlights the variation of gonioscopy findings between different clinicians, particularly in complex cases. Is gonioscopy the best method to assess the anterior chamber angle? How repeatable are optometrists at gonioscopy and how does gonioscopy compare to other methods of anterior chamber angle assessment such as van Herick and anterior segment optical coherence tomography (AS-OCT). Chapter Six will investigate the repeatability of gonioscopy and how gonioscopy compares to van Herick and AS-OCT in a community optometry setting.

6 REPEATABILITY AND COMPARISON OF CLINICAL TESTS FOR ANTERIOR CHAMBER ANGLE ASSESSMENT

6.1 Introduction

This chapter will investigate the agreement between gonioscopy and two other methods of anterior chamber angle assessment and examine the repeatability of these tests in a community optometry setting.

6.1.1 Background

The various methods of ACA assessment were reviewed in Chapter Two, see Table 2-3. As noted by other researchers, gonioscopy is a clinically demanding skill and subjective in nature (Salmon, 2009). Accuracy in carrying out the test can be affected by patient cooperation, examiner's skill and frequency of practice as well as variation in illumination levels (Lavanya *et al.*, 2008).

The literature reviewed in Chapter Three highlighted the lack of evidence comparing gonioscopy with other methods of anterior chamber angle assessment in non-Asian populations as well as comparing ACA assessment methods between clinicians.

A survey on the nature of glaucoma shared care schemes in England, carried out in 2006 (Vernon and Adair, 2010), found that gonioscopy was performed in eight out of the twelve hospital based optometrist schemes but only three out of twelve community optometry schemes reported carrying out gonioscopy. In two other surveys, only a small number of community optometrists (6-12%) reported having access to a gonioscopy lens (College of Optometrists, 2008; Myint *et al.*, 2011). Since the publication of the NICE guideline, it is likely that glaucoma shared care schemes will increasingly offer gonioscopy, so it is important to assess the ability of optometrists to carry out this task.

The questionnaire sent to optometrists investigating the impact of the NICE guideline on clinical practice, outlined in Chapter Three, showed that only 3% of

optometrists routinely carry out gonioscopy and there has been no change, as yet, in gonioscopy practice since the introduction of the NICE guideline. On a positive note, the questionnaire also highlighted the fact that many optometrists are keen to learn new skills including gonioscopy.

Chapter Four focussed on the ability of optometrists, along with other healthcare professionals (HCPs) at performing gonioscopy compared to a consultant ophthalmologist within a hospital setting. HCPs appear to be able to perform gonioscopy at clinically acceptable levels of sensitivity and specificity. Agreement between HCPs and consultant ophthalmologists were found to be reasonably good. The study also showed there can be variation in gonioscopy findings between consultant ophthalmologists.

Other methods of ACA assessment include the van Herick method (see Section 2.2.2) and Anterior Segment Optical Coherence Tomography (AS-OCT), (see Section 2.2.3). The van Herick method is a quick and easy test and is routinely carried out by optometrists in practice (Debasia *et al.*, 2013). It gives an estimation of the depth of the peripheral anterior chamber depth, although it does not allow direct visualisation of the drainage angle. It is a subjective test and can be affected by illumination. In addition it may be subject to error due to anatomical variations between individuals (Gispets *et al.*, 2014). Some researchers have shown that it can perform well when compared to gonioscopy (Foster *et al.*, 2000), although others found less convincing agreement with gonioscopy (Thomas *et al.*, 1996). NICE recommends the use of the van Herick method when gonioscopy is not possible (NICE, 2009).

Optical Coherence Tomography (OCT) uses the principle of low-coherence interferometry to produce high resolution, cross sectional images of the eye. As described in Section 2.2.3, original OCT devices use an 820 to 870-nm super luminescent diode (SLD). Dedicated anterior segment OCTs, operating at a longer wavelength (1310 nm) provide clearer anterior images and better penetration of the anterior segment structures. AS-OCT is believed to offer a more objective

method of assessing the ACA compared to van Herick method and gonioscopy. It can be performed by ancillary staff and has been mooted as a potential rapid diagnostic screening tool for the detection of PACG in Asia (Nolan *et al.*, 2007).

In the UK, in 2008, only two percent of community optometrists reported having access to an OCT machine (Myint *et al.*, 2011). There has, however, been an increase in the acquisition of OCT equipment in the last five years. Although there are no official figures available, discussions with industry representatives indicate that over 600 posterior segment OCT instruments have been sold to community optometrists in recent years.

The anterior segment function in these devices is likely to prove popular amongst optometrists who have already purchased OCT equipment and are interested in assessing the anterior chamber angle but may not be experienced in gonioscopy. With the number of OCT instruments in community practices likely to increase further in the near future, if this method of assessing the ACA is shown to be comparable with gonioscopy, then this could allow a major advance in the detection of PACG by optometrists.

6.1.2 Aims of Study

The aims of this study are to investigate:

- the repeatability of gonioscopy, van Herick method and AS-OCT for anterior chamber angle assessment by an optometrist in a community setting
- the agreement between gonioscopy, van Herick method and AS-OCT in a community optometry setting

If optometrists can show good repeatability and accuracy in anterior chamber angle assessment they will be well placed to meet the NICE criteria in the provision of care for glaucoma and ocular hypertension patients.

6.1.3 Ethics

NHS ethical approval was obtained by the Camberwell and St Giles Research Ethics Committee in October 2011. NHS Research Governance approval was obtained from NHS Southwark, South East London. University Ethical approval was obtained from the London South Bank University REC, see Appendices C1-3. Potential subjects were given an information sheet to read through (see Appendix C4) and were then contacted by telephone to discuss the study. Written informed consent was obtained from all subjects. Information was stored on a password protected Excel file on a secure password protected computer and backed up onto a password protected external hard disk. Data will be archived for seven years after completion of the study and then destroyed.

6.2 Methods and Study Design

6.2.1 Study setting

Subjects aged ≥ 40 years were recruited from optometry clinics at the Institute of Optometry, London and from an independent community practice (Cole Martin Tregaskis Optometrists) in Essex. Inclusion criteria were patients who have had an optometric eye examination within the last year, including patients diagnosed with glaucoma (both open angle and angle closure) or thought by their optometrist to be at risk of glaucoma (e.g., ocular hypertension or family history of glaucoma). Exclusion criteria were patients with corneal disorders including arcus senilis, (an age related condition, which causes opacification of the peripheral cornea making van Herick grading more difficult), recent eye infection or eye inflammation (within the last 6 months), any previous refractive surgery, peripheral iridotomy or intra-ocular surgery. These conditions could all influence the assessment of the ACA.

6.2.2 Sample Size Calculation

A sample size of eighty-five subjects was calculated using Bland and Altman's formula for inter-method agreement (Bland and Altman, 1986). The number of

repeated measures in this study is 2, and 15% confidence interval was chosen to give an acceptable level of precision. The details of this calculation are outlined below:

$$95\% CI = \frac{1.96 \times sd}{\sqrt{2n(m-1)}}$$

$$0.15sd = \frac{1.96 \times sd}{\sqrt{2n(m-1)}}$$

$$0.15 = \frac{1.96}{\sqrt{2n(m-1)}}$$

sd = standard deviation
m = number of measurements
n = number of subjects

$$m=2$$

$$2n(2-1) = (1.96/0.15)^2$$

$$\mathbf{n=85.36}$$

6.2.3 Study Procedure

Subjects were invited to attend for a series of tests on two occasions approximately one month apart. This was considered an acceptable time period within which any chronic change in the ACA would be unlikely. All tests were carried out by one researcher, the present author (PC) at both visits. The tests comprised:

- Short clinical discussion (including questions related to systemic and ocular health, medications and family history)
- Visual acuity
- Examination of the anterior eye using a slit lamp microscope, including assessment of cornea, conjunctiva, anterior chamber, iris
- Anterior angle assessment using the van Herick method
- Goldmann Applanation Tonometry
- Gonioscopy Angle Assessment

- Anterior angle imaging using anterior segment optical coherence tomography (AS-OCT)

The tests were carried out in this order at both visits.

6.2.4 Van Herick Method

As described in Section 2.2.2, the van Herick method allows a quick assessment of the nasal and temporal angles. The standard clinical procedure was carried out. A narrow vertical beam was directed at the temporal limbus, offset by 60°. The beam was positioned at the most peripheral point of the cornea (beside the limbus) to allow a clear view of peripheral iris and anterior chamber (Van Herick *et al.*, 1969). The peripheral angle was estimated as a percentage of the thickness of the adjacent cornea using a standard grading scheme: 0%, 5%, 15%, 25%, 40%, 75%, ≥100%, (Foster *et al.*, 2000). This was repeated also for the nasal angle.

Van Herick method and gonioscopy were performed in a darkened room (approximately 20 lux, measured with Luxmeter (2012), Application Manufactory (Version 1.1), <http://itunes.apple.com>).

An eye was defined as “occludable” if the grading was <25% grading in either the nasal or temporal angle.

6.2.5 Gonioscopy Technique

Standard clinical gonioscopy procedures were employed as previously outlined in Chapter Four, Section 5.4.3. This test was performed with a one mirror hand held MagnaView gonioscopy lens (Ocular Instruments Inc., Bellevue, WA) by a single trained examiner (PC) using the same slit lamp used for the van Herick method. The assessment was carried out at high magnification (x16).

As recommended by Nolan *et al.*, (2007) an eye was classified occludable with gonioscopy if posterior pigmented trabecular meshwork was not seen in at least

one quadrant (90°), in other words, one quadrant or more graded Grade 1 or Grade 0, see Section 2.2.1.

6.2.6 Anterior Segment Optical Coherence Tomography Imaging

For all subjects, the images were taken by a single examiner (PC) with a spectral domain Topcon OCT-2000 (Topcon Europe Medical B.V, Netherlands) operating at wavelength 840 nm and using the Anterior Segment mode. As recommended by the manufacturer a 3mm line scan size was selected and the scan count was set at 32. The scan zone was centred on the limbus and the participant asked to look at the fixation target. Two scans were taken for the nasal and temporal quadrant for each eye. For each quadrant, one scan was selected for analysis based on quality of the image and visibility of the structures including visibility of the scleral spur. The superior and inferior quadrants were not captured due to the need to manipulate the lids when acquiring these images, potentially causing distortion of the angle (Sakata *et al.*, 2008a). AS-OCT was performed in a completely dark room (approximately 5-10 lux, measured with Luxmeter (2012), Application Manufactory (Version 1.1), <http://itunes.apple.com>).

An OCT operating at 840 nm is not able to penetrate the scleral tissue, causing the light to scatter and deterioration of the image quality (Radhakrishnan *et al.*, 2005). A standalone AS-OCT operating at a longer wavelength (1300 nm) gives better visualisation of the angle structures, however posterior segment OCTs are more widely available and have been shown to offer an acceptable method of assessing the anterior segment (Kalev-Landoy *et al.*, 2007).

6.2.7 Anterior Segment Optical Coherent Tomography Grading

The evaluation of the anterior chamber angle using AS-OCT depends on determining the location of the scleral spur see Figure 2-5. As described in Section 2.2.3, the scleral spur is an anatomical landmark at the junction between the inner wall of the trabecular meshwork and the sclera (Sakata *et al.*, 2008b). Nolan et al

(2007), using a standalone anterior segment OCT (operating at 1300 nm) classified an angle as occludable if any contact is visible between the peripheral iris and any part of the angle wall anterior to the scleral spur..

For this study, an eye was classified as “occludable” with AS-OCT if any iris contact was visible anterior to the position of the scleral spur for either the nasal or temporal image or both.

The eye was graded as open if no iris contact was visible anterior to the scleral spur in either the nasal or temporal image. Nolan *et al.*, (2007) recognise the difficulty in accurate identification of scleral spur. In cases where the scleral spur position was difficult to assess, a “best estimate” of its position was used. If the image quality was deemed too poor, the angle was graded as “unsure”.

Once the position of the scleral spur has been determined (when visible) or estimated (when not visible), the Topcon “Angle Measurement” software tool allows the user to measure the size of the angle. With a captured image, two lines are drawn; one along the inner corneal endothelium towards the scleral spur and one from the scleral spur to the front surface of the iris. The software calculates this angle in degrees. Figure 6-1 shows two images assessed by the software. In the left hand image, the scleral spur is easy to locate and the angle measurement tool easy to carry out. In the right hand image the scleral spur is more difficult to locate and this makes calculating the angle more challenging.



Figure 6-1 AS-OCT image capture and angle assessment. Left image - open angle. Right image occludable angle. SS= scleral spur, S = sclera, C = cornea, I = iris

6.2.8 AS-OCT Images Masking Procedure

All images were transferred onto one database and assigned a unique code. Due to the recognised bias of only one examiner (PC) carrying out all three tests, the data were re-coded by a second researcher (BE) who randomised and anonymised the images. A third researcher (LM), an optometrist, who was masked as to the van Herick grading and gonioscopy results and was not involved in the data collection or recoding, graded the OCT images. He was masked as to the identity of the subjects, the clinic at which they were tested, and whether the images were from the first or second visit. Although researcher PC carried out the OCT data acquisition, this process does not require any subjective judgement, just the capturing of images. Subjective judgement is required for the analysis of these images and this is why this process was carried out by a masked third party.

Gonioscopy results at each visit were used as the reference standard against which van Herick method and AS-OCT were compared. Subjects who were found to have undiagnosed narrow angles with one or more of the three methods were referred appropriately for an ophthalmologist opinion in line with normal optometric practice.

Due to the recognised correlation in using results for subject's right and left eye (Ray and O'Day, 1985), one eye from each subject was selected randomly for the analysis, provided both eyes were eligible for the study. For a given subject, the

same eye's data were analysed for the second visit as the first, but following the masking outlined above.

6.3 Data Analysis

Statistical analysis was carried out using SPSS (version 18, SPSS Inc., Chicago, IL). The kappa statistic (κ) was used to measure intra-observer repeatability of each test, see 2.3.2. Weighted kappa was not used in this instance as the use of weights would imply the first or second visit was the gold standard. Sensitivity and specificity of the van Herick method and AS-OCT at classifying an angle as open or occludable, were calculated. Ninety five percent confidence intervals were calculated using the Clopper-Pearson binomial probability confidence interval exact method (Clopper and Pearson, 1934), using an online statistical calculator (Soper, 2014).

6.4 Results

Eighty four subjects were recruited and eighty three subjects attended for both visits. Three subjects were unable to tolerate gonioscopy and their results were not included in the analysis. From the remaining subjects ($n = 80$) 53 were female (66.2%), with the majority of the subjects Caucasian (87.5%); demographic features are outlined in Table 6-1.

In four cases AS-OCT images were un-gradable due to difficulty in locating the scleral spur, two subjects at visit 1 and a two different subjects at visit 2. The van Herick and gonioscopy results for these subjects were still included in the repeatability analysis. The number of occludable eyes found by each test and the repeatability values for each test are shown in Table 6-2.

Table 6-1 Demographic Features

Measure	Results
Age Mean (SD) Range	58.94 (10.03) years 40-80 years
Gender	53 Female 27 Male
Race Caucasian African racial origin Asian (racial origin; all India)	70 6 4
Random Eye Allocation	47 Left; 33 Right

Table 6-2 Number of subjects graded occludable by each test and repeatability

Test	No. Occludable		Repeatability κ
	Visit 1	Visit 2	
Gonioscopy n=80	12 (15%)	13 (16%)	0.29
Van Herick n=80	17 (21%)	12 (15%)	0.54
AS-OCT n=76	12 (15%)	10 (13%)	0.47

6.4.1 Repeatability of Gonioscopy

From results for 80 eyes, 12 subjects were found to have occludable angles on visit 1 (15%); 13 subjects on visit 2 (16.2%). Five subjects were found to have occludable angles at both visits. Agreement between the two visits was measured by kappa was fair ($\kappa=0.29$), see Figure 6-2.

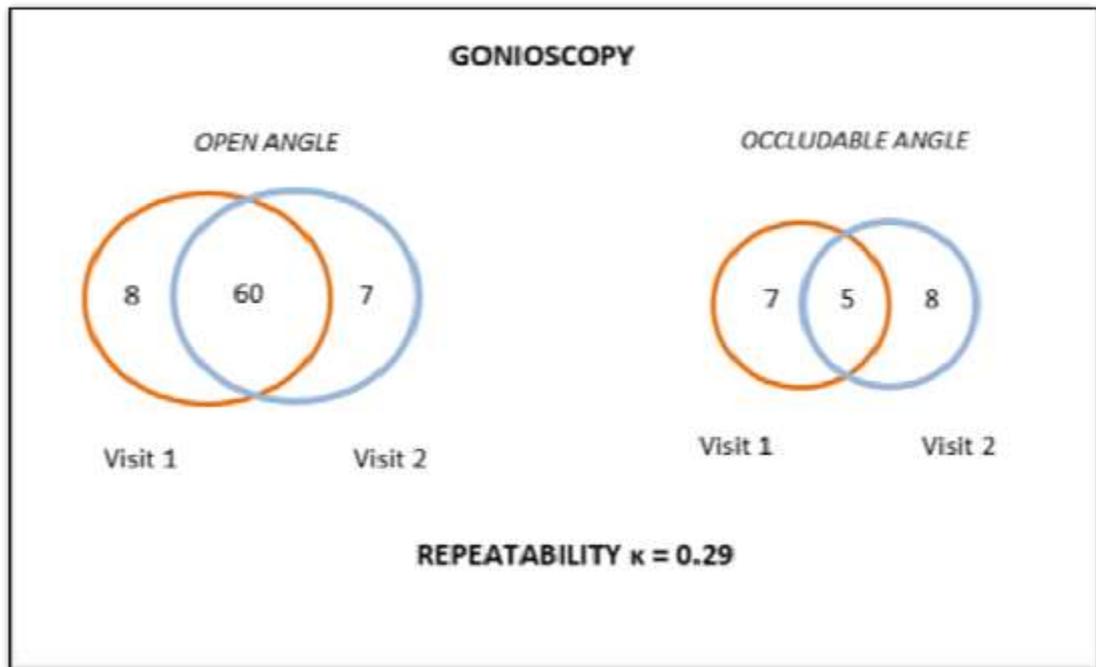


Figure 6-2 Gonioscopy Repeatability (n = 80)

6.4.2 Repeatability of van Herick

From the data for 80 eyes, 17 subjects were found to have occludable angles at visit 1 (21.2%) and 12 subjects at visit 2 (15%). Nine subjects were found to have narrow angles at both visits. Agreement between the two visits, measured by kappa was moderate ($\kappa = 0.54$), see Figure 6-3.

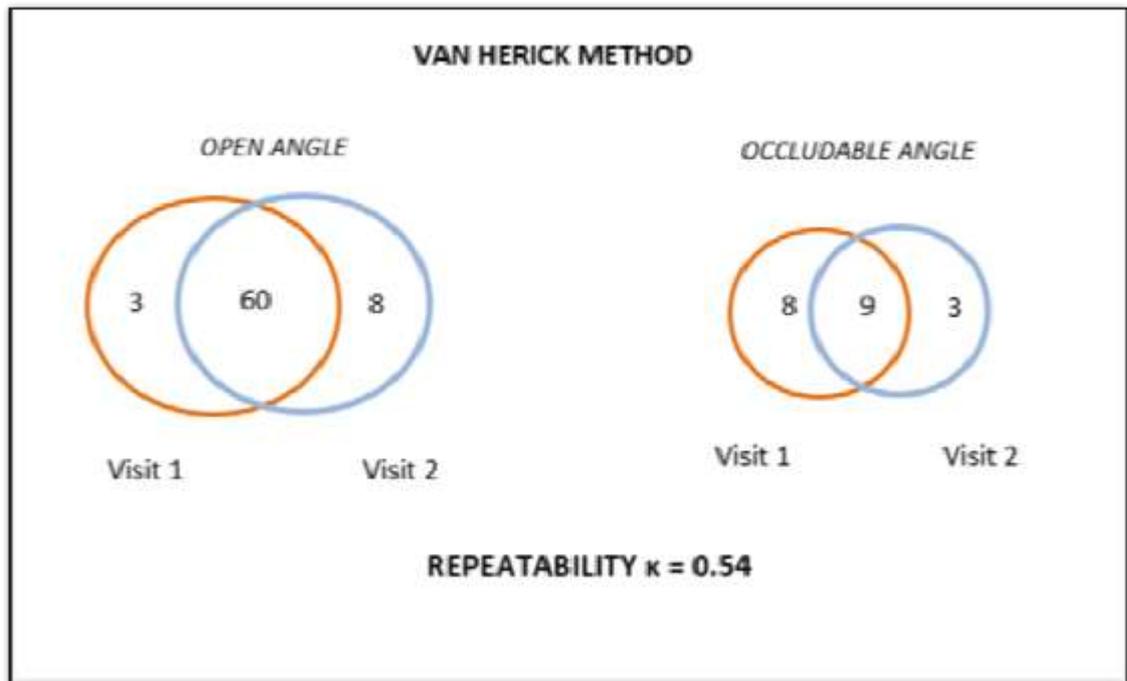


Figure 6-3 Van Herick Repeatability (n = 80)

6.4.3 Repeatability of AS-OCT

Images for four eyes were un-gradable with AS-OCT due to poor image quality, two in visit 1 and two different subjects in visit 2. From the subset of 76 out of 80 eyes, 12 subjects were found to have occludable angles at visit 1 (15.2%) and 10 subjects at visit 2 (12.6%). Six subjects were found to have occludable angles on both visits. Agreement between the two visits measured by kappa for 76 eyes was moderate ($\kappa = 0.47$), see Figure 6-4.

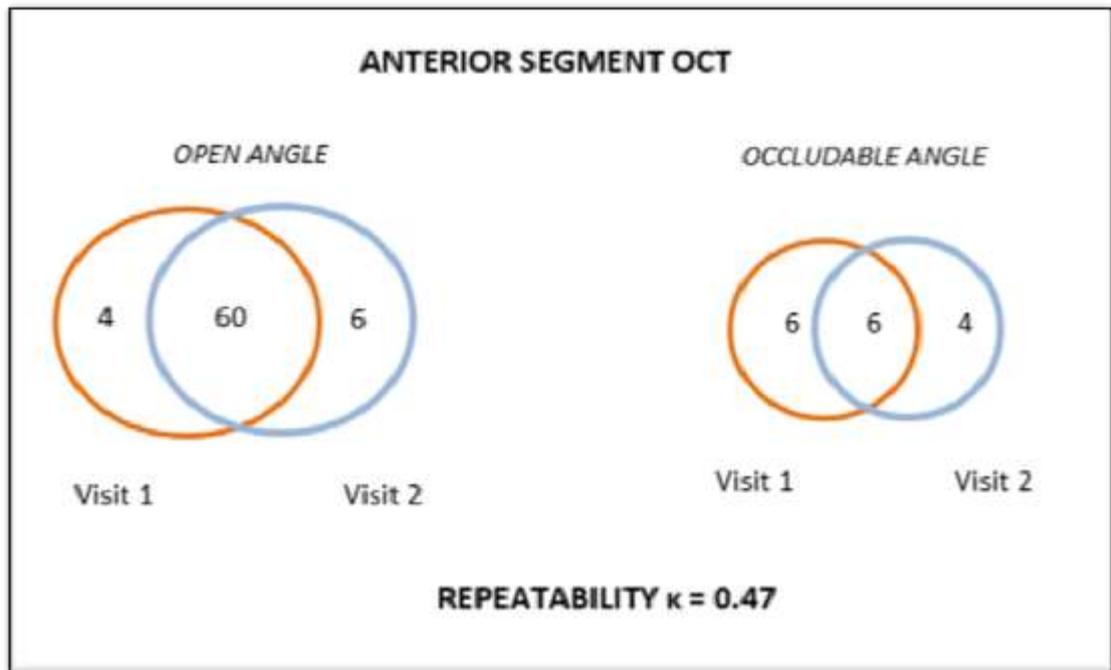


Figure 6-4 AS-OCT Repeatability (n = 76)

6.4.4 Agreement between van Herick, Gonioscopy and AS-OCT

Visit 1

From visit one, 78 out of 80 eyes had complete results for all three tests. Images for two eyes were un-gradable with AS-OCT and therefore their results were not included in this analysis. One of these subjects was classified as occludable by gonioscopy. For the subset of 78 eyes, eleven of the subjects were found to have occludable angles with gonioscopy, 17 with van Herick and 14 with AS-OCT. Four subjects were found to have narrow angles with all three methods; see Figure 6-5.

Visit 2

From visit two, images for two eyes were un-gradable with AS-OCT and therefore their results were not included in this analysis. One of these subjects was classified as occludable by gonioscopy. For the subset of 78 eyes, 12 subjects were found to have occludable angles with gonioscopy, 12 with van Herick and 10 with AS-OCT. Three subjects were found to have occludable angles with all three methods; see Figure 6-6.

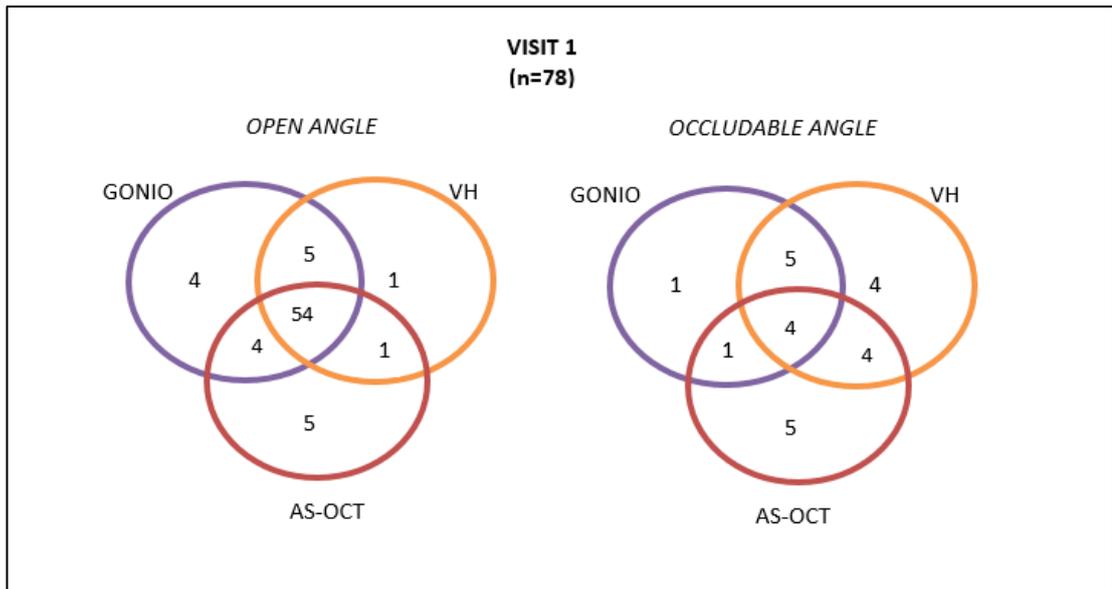


Figure 6-5 Number of eyes graded open or occludable for gonioscopy, van Herick method (VH) and AS-OCT at Visit 1. Two subjects were excluded as their images were un-gradable with AS-OCT.

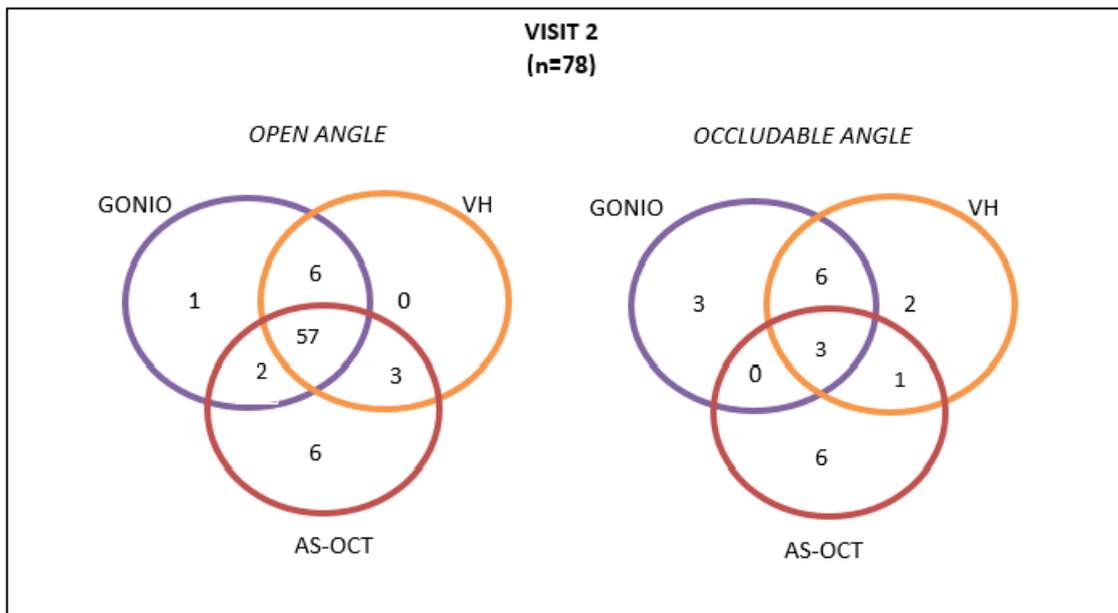


Figure 6-6 Number of eyes graded open or occludable for gonioscopy, van Herick method (VH) and AS-OCT at Visit 2. Two subjects were excluded as their images were un-gradable with AS-OCT.

6.4.5 Sensitivity and Specificity

Table 6-3 and Figure 6-7 show the values for sensitivity and specificity for the van Herick method and AS-OCT compared to gonioscopy for each visit. The sensitivity and specificity values for van Herick method were good for both visits, the AS-OCT had poor sensitivity and good specificity.

Table 6-3 Sensitivity and specificity of the Van Herick method and AS-OCT at each visit for 78 subjects (CI=confidence Interval)

	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)
Van Herick Visit 1 n=78	82 (48 - 98)	88 (74 - 96)
Van Herick Visit 2 n=78	75 (43 - 94)	95 (87 - 99)
AS-OCT Visit 1 n=78	45 (17 - 77)	87 (76 - 94)
AS-OCT Visit 2 n=78	25 (5 - 57)	89 (79 - 96)

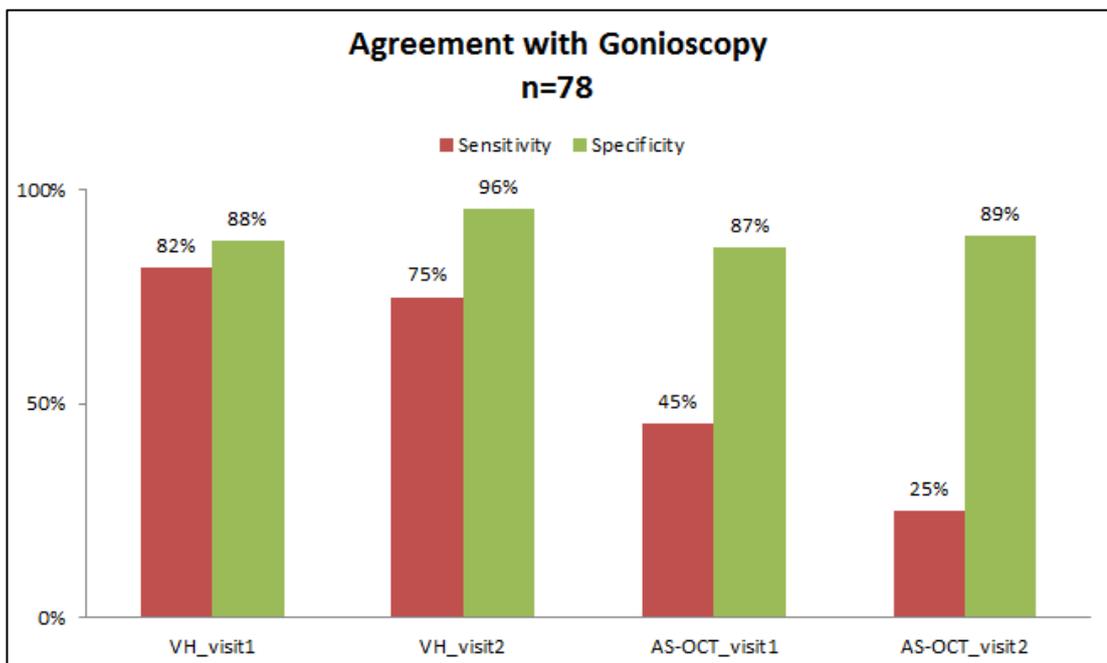


Figure 6-7 Sensitivity and Specificity for van Herick method (VH) and AS-OCT for visit 1 and 2

6.4.6 Choice of Criteria for Occludable Diagnosis

Van Herick Method Criteria

The criterion for an occludable angle chosen for the van Herick method was if the nasal or temporal limbal chamber depth was measured as <25%. In order to assess if this was the most accurate cut-off for sensitivity and specificity compared to gonioscopy, the analyses were repeated using a range of different cut-off van Herick values that could be used (<5% to <100%) and the sensitivity and specificity results for each level were recalculated see Table 6-4.

Figure 6-8 plots the sensitivity values against “1-specificity” values. This receiver operating characteristic ROC curve is shown a measure of the test quality (Gilchrist, 1992). The optimum point on an ROC curve is that which lies as close to the top left corner as possible (Bland, 2000). It would therefore seem that the cut-off point chosen (i.e. VH<25%) gives the best levels of sensitivity and specificity compared to the gonioscopy results.

Table 6-4 Van Herick (VH) Occludable Definition

	VH Criteria	Sensitivity	Specificity
Visit 1	< 5%	0%	100%
	< 15%	27%	97%
	< 25%	82%	88%
	< 40%	91%	78%
	< 75%	91%	63%
	< 100%	100.0%	52%
Visit 2	< 5%	8%	100%
	< 15%	50%	98%
	< 25%	75%	95%
	< 40%	83%	85%
	< 75%	92%	62%
	< 100%	92%	53%

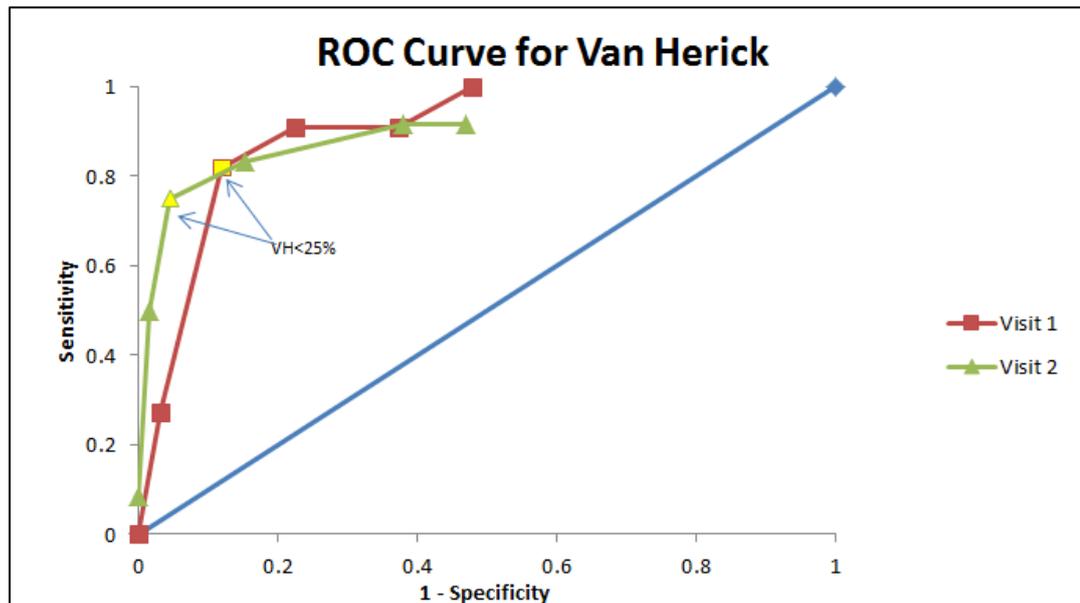


Figure 6-8 Van Herick (VH) cut off levels (< 5%, < 15%, <25%, <40%, <75%, <100%). The blue line represents a plot with a predictive value equal to that of chance.

AS-OCT Criteria

In addition to grading the angle as occludable only from estimating the position of the scleral spur, the size of the angle measured using the “Angle Measurement” software could be used and an angle cut-off amount could be used as a criterion for defining the angle as occludable with AS-OCT. For example an image could be graded as occludable if the angle measured < 15°, instead of just judging the position of scleral spur. The angle measurement method was also used and results for different cut-off angle sizes (<10°, <15°, <20°, <30°) were calculated. The sensitivity and specificity results were compared to just the scleral spur position method. The sensitivity and specificity values are shown in Table 6-5 and a graph plotting sensitivity against “1-specificity” was produced, see Figure 6-9 for the receiver operating characteristic (ROC) curve.

Table 6-5 AS-OCT Occludable Criteria AS-OCT Angle Measurement Criteria (<10, <15, <20, <30) compared to using scleral spur method.

	AS-OCT Criteria	Sensitivity	Specificity
Visit 1	Angle < 10°	17%	91%
	Angle < 15°	67%	75%
	Angle < 20°	92%	48%
	Angle < 30°	100%	6%
	<i>Scleral spur method</i>	45%	87%
Visit 2	Angle < 10°	23%	94.%
	Angle < 15°	67%	75.%
	Angle < 20°	85%	49.%
	Angle < 30°	92%	3.%
	<i>Scleral spur method</i>	25%	89%

From the ROC curve (Figure 6-9) it would therefore seem that the best cut-off angle measurement point would be to choose the criteria “Angle<15°”. Using the scleral spur position alone appears gives lower sensitivity but a better specificity value than using the criteria “angle size < 15°”.

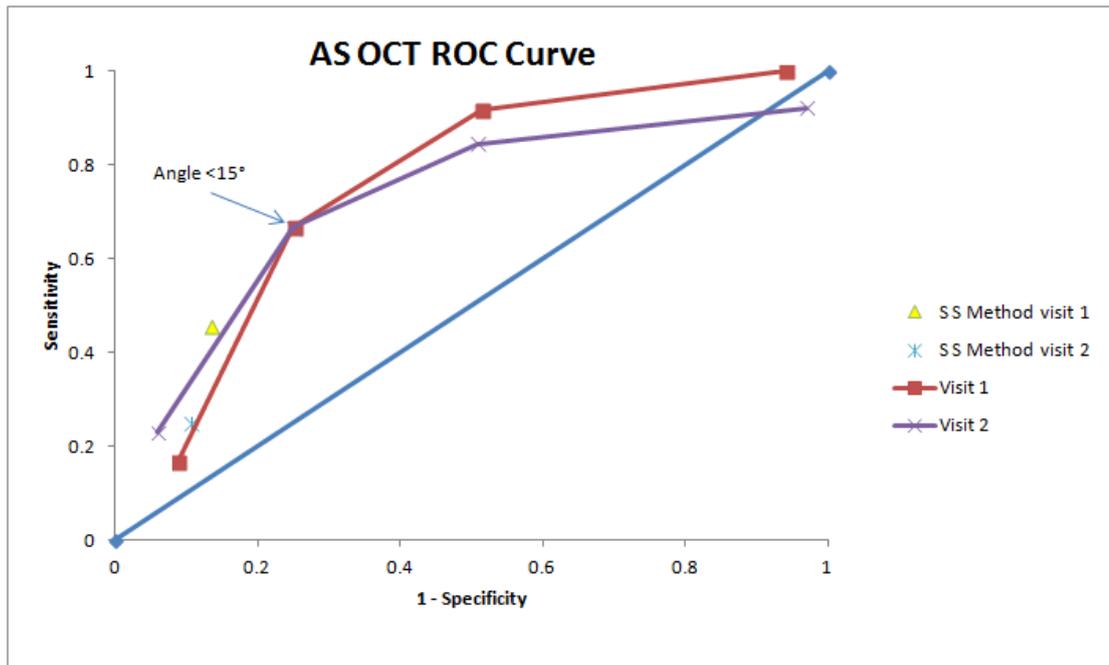


Figure 6-9 AS-OCT cut off levels (<math><10^\circ</math>, <math><15^\circ</math>, <math><20^\circ</math>, <math><30^\circ</math>) compared to using position of scleral spur (SS) method. The blue line represents a plot with a predictive value equal to that of chance.

If the two criteria were combined together there does not appear to be any improvement in sensitivity and specificity values compared to using the criteria "Angle<math><15^\circ</math>" alone (see Table 6-6).

Table 6-6 Combining AS-OCT Criteria

	AS-OCT Criteria	Sensitivity	Specificity
Visit 1	Angle <math><15^\circ</math> or scleral spur method	67%	72%
	Scleral spur method alone	45%	87%
Visit 2	Angle <math><15^\circ</math> or scleral spur method	69%	73%
	Scleral spur method alone	25%	89%

From the values it would seem more accurate to classify the angle as open or occludable using the angle measurement tool with Angle <math><15^\circ</math> as the cut off criterion, rather than the position of the scleral spur. However, the scleral spur

position is used by other authors so it would still seem appropriate to use this method also.

Combining van Herick and AS-OCT results

Combining the results for AS-OCT scleral spur method (SS) results with van Herick method provides valuable information on whether there is a benefit from carrying out both the tests instead of just one. The scleral spur method was used rather than the angle measurement tool in order to make the results more comparable to other published evidence where the same criterion is used.

Sensitivity and specificity values for when van Herick and/or AS-OCT results are combined are shown in Table 6-7. The use of the “and/or” Boolean operator means that subjects were judged to have an occludable angle if they failed the criterion for van Herick or failed the criterion for AS-OCT or failed the criteria for both.

Table 6-7 Combining results for van Herick and AS-OCT (SS=scleral spur)

	Measure	Sensitivity	Specificity
Visit 1	Van Herick <25% or AS-OCT SS Method	84%	81%
	Van Herick <25% and AS-OCT SS Method	36%	81%
	AS-OCT SS Method alone	45%	87%
	Van Herick <25% alone	82%	88%
Visit 2	Van Herick <25% or AS-OCT SS Method	69%	87%
	Van Herick <25% and AS-OCT SS Method	33%	86%
	AS-OCT SS Method alone	25%	89%
	Van Herick <25% alone	75%	95%

Combining both methods in this way appears to slightly improve sensitivity at visit 1 (compared to only using the van Herick method alone) but slightly reduce the sensitivity at visit 2. Combining both methods clearly improves the sensitivity at both visits compared to using AS-OCT alone. For van Herick, there appears to be

less of a gain in sensitivity and therefore there would seem to be only a small benefit in carrying out AS-OCT imaging if a clinician finds a narrow angle with van Herick method.

In summary when comparing the results for van Herick and AS-OCT to gonioscopy (the gold standard) for each visit, van Herick shows good sensitivity (75% to 82%) and very good specificity (88% to 95%), whereas AS-OCT using the scleral spur method shows poor sensitivity (25% to 45%) but good specificity (87% to 89%).

6.5 Discussion

6.5.1 Overview

This study focussed on the intra-observer repeatability of gonioscopy, van Herick method and AS-OCT methods when assessing the ACA and measured the sensitivity and specificity of the van Herick method and AS-OCT at detecting an occludable ACA within a community optometry setting.

The intra-observer repeatability for assessing the ACA was better for both the van Herick method and AS-OCT than for gonioscopy (kappa for van Herick and AS-OCT were 0.54 and 0.47 respectively, whereas gonioscopy was 0.29). The greater subjective nature of gonioscopy may be a factor in explaining the lower kappa agreement. All four quadrants are assessed in gonioscopy compared to only the nasal and temporal quadrants for van Herick and AS-OCT and the fact that there are more structures to observe and consider in gonioscopy may also contribute to its lower repeatability.

Compared to gonioscopy, the van Herick method showed good sensitivity (visit 1: 82%, visit 2: 75%) and good specificity (visit 1: 88%, visit 2: 95%); AS-OCT shows poor sensitivity (visit 1: 45%, visit 2: 25%) but good specificity (visit 1: 87%, visit 2: 89%). Van Herick and AS-OCT would therefore appear to be good at detecting patients with open angles, with the van Herick method more sensitive than AS-OCT at identifying occludable angles. Based on these results, if a practitioner were only to use an AS-OCT similar to the device used in this study, and no other ACA assessment method, this could result in a significant number of patients with an occludable angle being incorrectly identified as being open and not at risk of angle closure. This could have implications for the use of this type of OCT device being used as a screening device for detecting angle closure.

The advantage of the AS-OCT imaging is that it can be delegated to ancillary technical staff. In Asian populations where the prevalence of primary angle closure is higher, AS-OCT imaging using a standalone AS-OCT device operating at 1300 nm,

has been seen as a potentially important method for screening large populations (Nolan *et al.*, 2007). The prevalence of PACG is lower in Europe and from the results for a posterior segment OCT, operating at 840nm, there would seem to be little value in carrying out AS-OCT as an alternative to the van Herick method when screening for PACG. Patients in optometry practice who display occludable angles with the van Herick method, should be further assessed with gonioscopy rather than have additional anterior segment imaging using a posterior segment OCT device.

The use of gonioscopy as the reference standard is however limited by the fact it has fair repeatability itself. The result of such repeatability would be that the apparent performance of the other techniques would appear to fluctuate greatly between visits when compared to gonioscopy at different visits.

The van Herick method led to the classification of a greater number of subjects as having occludable angles ($n = 17$) than gonioscopy ($n = 12$) at the first visit and one less than gonioscopy ($n = 12$) at the second visit. As the van Herick method does not provide visualisation of the ACA structures, it might reasonably be expected to produce more occludable angles than gonioscopy. An eye was classified as occludable, with the van Herick method, if the grading was $<25\%$, a criterion that is commonly employed in clinical practice. If the criterion were changed to, say, $<40\%$ (i.e. including those at 25%), the sensitivity of the test increases (visit 1: 91% , visit: 2 83%), but the specificity reduces (visit 1: 78% , visit 2 85%). Although the scales of measurement are very different in these techniques, it would appear that the criteria for classifying angles as occludable with the van Herick method are more liberal (or that the criteria with gonioscopy are more conservative). The relationship between the clinical criteria for classifying angles as occludable or open, with different methods of assessment would therefore appear to require further investigation.

One reason for the lack of agreement between AS-OCT and the two other methods could be the lower illumination level when carrying out this test. AS-OCT was

performed in a darkened room (5-10 lux), whereas gonioscopy and van Herick method were performed at the slit lamp microscope in a dimly lit room (20 lux). Despite efforts to prevent light falling on the pupil, some stray light will inevitably expose the pupil to light, artificially opening the ACA, when carrying out gonioscopy and van Herick method (Lavanya *et al.*, 2008). A difference in pupil size between these tests may help explain why certain cases, five at visit one and six at visit two, classified as occludable with AS-OCT were classified as open with van Herick method and gonioscopy. Further investigation into the effect of pupil size on the results is discussed in Section 7.7.

AS-OCT analysis was based on the information from one scan only along a single horizontal axis, whereas the van Herick method and gonioscopy allow a wide angle view for each quadrant. Small changes in the location of the scan with each AS-OCT image could change the visibility of the angle structures and therefore the subsequent grading of the angle. Using information from additional scans might help verify the true nature of the angle. These factors may partly explain why the sensitivity values for AS-OCT were significantly lower than those for the van Herick method.

For AS-OCT, the location of the scleral spur is used to determine if an angle is open or occludable. Previously studies have found that the location of the scleral spur may not be possible in up to 30% of cases (Sakata *et al.*, 2008b). In this study two cases at visit one and two cases at visit 2 were found to have un-gradable AS-OCT images at each visit due to difficulty in locating the scleral spur. Two of these cases were classified as occludable with gonioscopy, but all four were reported open with the van Herick method. One might speculate that it is more difficult to view the scleral spur in those eyes with an occludable angle with this type of AS-OCT. Reviewing the images for those cases where the angle was reported to be occludable by gonioscopy but open with AS-OCT, it is possible that the margin of error around the estimated position of the scleral spur may have been greater than for the subjects with open angles. This may also partly explain the poor sensitivity of AS-OCT.

In this study, a spectral domain OCT, with an 840 nm laser (Topcon 3D OCT-2000) was used, whereas a standalone anterior segment OCT, with a 1300 nm laser, allows deeper penetration of the anterior segment structures and therefore better visualisation of the scleral spur. This could offer better agreement with gonioscopy, however standalone devices are not commonly used in community optometry practice at the present time in the UK.

6.5.2 Comparison to other evidence

Intra-observer repeatability for gonioscopy in this study appears lower than that found in previous studies. In a study based at a glaucoma clinic in Singapore, the intra-observer repeatability of gonioscopy, performed on 20 eyes, was found to be very good ($\kappa = 0.80 - 1.00$), when comparing ACA status for each quadrant of the eye (Sakata *et al.*, 2010) whereas in the current study, the repeatability of gonioscopy was fair ($\kappa = 0.29$). Direct comparison between the results however should be made with caution. In the current study the eye was graded as occludable or open depending on the status of all four quadrants of the eye. In the Singapore study each quadrant was individually compared. The use of all four quadrants in the current study is likely to increase the variability and this would explain the lower value for repeatability.

In addition Sakata *et al.* had a smaller sample size than the current study ($n=20$ compared to $n=80$) and the subjects were mostly Chinese (87%) compared to Caucasian (87.5%). The prevalence of PACG is higher in a glaucoma clinic in Asia compared to an optometry clinic in the UK and the anterior segment dimensions are known to differ in Asian eyes compared to European eyes (Wang *et al.*, 2013). In addition the ophthalmologist involved in Sakata *et al.* study is likely to be more experienced at gonioscopy and also more likely to encounter patients with PACG than an UK optometrist.

The values for the sensitivity and specificity of the van Herick method largely agree with those in other published literature. Foster *et al.*, (2000) found sensitivity and specificity values for van Herick (also using gonioscopy as the reference standard) to be 84% and 86% respectively in 1717 subjects in Mongolia, whereas the sensitivity and specificity values in the current study for van Herick method were 82% (visit 1), 75% (visit 2) and 88% (visit 1), 95% (visit 2) respectively. Park *et al.*, (2011) found good agreement for van Herick in 93 eyes in Korea (sensitivity=92% and specificity=90% for the temporal quadrant).

The values for sensitivity and specificity of AS-OCT differ somewhat from those in other published literature. Nolan *et al.*, (2007), using the Zeiss prototype AS-OCT, (1300 nm laser), found excellent sensitivity (98%) but poor specificity (55%), with gonioscopy as the reference standard. In the current study, sensitivity was poor (46%, 25%) but specificity was good (87%, 89%) for visits 1 and 2, respectively. A standalone AS-OCT, with a long wavelength laser, allows deeper penetration imaging and improved visualisation of the scleral spur, compared with a conventional OCT with at a shorter wavelength laser. It is possible that the lower sensitivity of AS-OCT in the current study, could be partly explained by the difficulty in visualising the scleral spur with a device employing a laser of such a short wavelength.

6.5.3 Limitations

This study is limited by the relatively young age of the subjects (mean age 58.9 years) and the fact that most subjects were Caucasian (87.5%, $p < 0.01$). Glaucoma is more prevalent in an older population and the prevalence of PACG is higher in Asian populations. Having more subjects with occludable angles would increase the power of this study. Complete results were obtained for seventy-eight subjects, slightly lower than the desired sample size. Unfortunately time constraints did not permit the recruitment of further subjects.

Another limitation is the fact all three tests were carried out by one examiner, in the same order at both visits. This could introduce an “order effect” where the order of the tests could influence the outcome. It is possible that results from the van Herick method may influence the judgement during gonioscopy. However, this sequence is true to normal clinical practice where the clinician will carry out gonioscopy after assessing the angle with van Herick, and often a clinician may only carry out gonioscopy if the van Herick results look narrow. In order to reduce any order effect bias in the study, another approach might have been to carry out the three ACA assessment tests in a random order or alternatively to reverse the order at the second visit (so-called ABBA design). However carrying out van Herick method after gonioscopy is not ideal as any viscotears gel remaining on the cornea after gonioscopy may impede the view required to assess the angle. Also pressing the gonioscopy lens on the eye potentially could temporarily distort the cornea and a break might be needed before carrying out the van Herick method.

For the OCT testing although the images were all taken by one practitioner this procedure is virtually fully automated and so this is unlikely to have influenced the results. For this test, it is the process of estimating the angle from the image which involves subjective judgement and the subjective nature of this was investigated in the research by using a masked second grader.

Another potential limitation is that although the visits were one month apart, there was a chance that the examiner could remember some of the results from the first visit. However, in view of the large number of angle assessments that the examiner made during this period alongside his clinical work in the hospital eye service, the examiner was not consciously aware of recollecting any results. A second researcher, masked to the gonioscopy and van Herick findings, was recruited to analyse the acquired AS-OCT images and thereby reduce any potential for bias in the findings.

The AS-OCT images captured provide information on the angle from a single axis scan only along the temporal and nasal quadrant, whereas van Herick and

gonioscopy allow a wide angle view along each quadrant being examined. This affects the direct comparability of the methods used. However it is valuable to compare these methods as this represents normal clinical practice by community optometrists.

Most published research outlined in Chapter Two on AS-OCT describes OCT devices designed specifically for Anterior Segment. These operate at a longer wavelength (1300 nm compared to 840 nm for the Topcon OCT) allowing deeper penetration imaging and better visualisation of the angle. Results with a dedicated AS-OCT device are likely to give greater accuracy for anterior chamber analysis in comparison to the results. However, the Topcon OCT instruments are commonly used in ophthalmology clinics and increasingly in optometry practice in the UK (Kalev-Landoy *et al.*, 2007) so the results obtained in this study are relevant for these settings.

This study is limited by the possibility that results from the van Herick method may influence the judgement during gonioscopy. However, this sequence is true to normal clinical practice where the clinician will carry out gonioscopy after assessing the angle with van Herick, and often a clinician may only carry out gonioscopy if the van Herick results suggest a narrow ACA. Image acquisition with the AS-OCT is mostly automated, and is therefore unlikely to have influenced the results of the other tests. For this method, it is the process of estimating the angle from the image which involves subjective judgement, and this was controlled for, in the research, by using a second grader, masked to the previous results.

The AS-OCT images captured provide information on the anterior chamber from a single axis scan only along the temporal and nasal quadrant, whereas van Herick and gonioscopy allow a wide angle view at each quadrant. On first consideration, this may be assumed to affect the direct comparability of the methods used, but here clinical classifications aided by these techniques were compared, rather than the raw measurements, in order to evaluate their utility in clinical decision making.

Most published research on comparing AS-OCT to gonioscopy is based on OCT devices designed specifically for investigating structures in the anterior segment. These devices use longer wavelength lasers (1300 nm, compared with 840 nm in the Topcon OCT), allowing deeper penetration imaging and improved visualisation of the scleral spur and ACA. These devices would therefore most likely enable more accurate ACA classifications than those found in the current study. However, posterior segment OCT devices, such as the one used in this study, are commonly used in ophthalmology clinics (Kalev-Landoy *et al.*, 2007) and increasing in optometry practices in the UK, so the choice of instrument here enables a more realistic comparison of currently used clinical techniques.

6.6 Summary

This chapter provides new evidence looking at the repeatability of gonioscopy and other methods of angle assessment by an optometrist in a European population. Gonioscopy is known to be subjective in nature and this presents difficulties when assessing its repeatability and reproducibility.

The intra-observer repeatability for assessing the ACA appears to be better for both the van Herick method and AS-OCT than for gonioscopy. When compared to gonioscopy, the van Herick method appears to show good agreement whereas the AS-OCT method is only fair. The use of this type of OCT device on its own would therefore not seem acceptable when assessing patients at risk of PACG. This may have implications for its use as a method of assessing the ACA in glaucoma shared care clinics and in “virtual clinics” where tests could be carried out by ancillary staff and the results reviewed at a later time by a clinician. The findings in this study would agree with the NICE guideline recommendation that the van Herick method, as opposed to other method of ACA assessment such as AS-OCT should be offered as an alternative to gonioscopy when clinical circumstances rule out gonioscopy.

Further work is needed comparing gonioscopy and van Herick results by different examiners. In the next chapter the results from the three individual studies will be

summarised. Further topics for research in anterior chamber angle assessment will be highlighted. The future role of optometrists in glaucoma shared care will be discussed and recommendations for the running of these schemes will be proposed.

7 GENERAL DISCUSSION

7.1 Introduction

In this thesis new evidence has been presented on tests involved in the diagnosis and monitoring of glaucoma care in the UK. Changes in optometrists' clinical practice after the publication of the NICE guideline on diagnosis and management of chronic open angle glaucoma and ocular hypertension have been investigated. Gonioscopy undertaken by optometrists and other healthcare professionals (HCPs) has been shown to compare favourably with consultant ophthalmologist results. Gonioscopy has been compared to the van Herick method and AS-OCT in a community optometry setting.

In this thesis, the recommendations by NICE on ACA assessment has been shown to have implications for optometrists along with other HCPs working in glaucoma clinics and in glaucoma shared care schemes. Optometrists who show proficiency at gonioscopy are well placed to expand their role in glaucoma shared care within hospital and community settings.

Gonioscopy is a difficult skill to learn but over time it may need to be carried out more frequently by optometrists involved in glaucoma management. In this thesis it was therefore relevant to determine if simpler, perhaps more objective methods of assessing the ACA would provide a suitable alternative to gonioscopy for community optometrists.

This chapter will summarise the findings of this thesis. The limitations of this research will be reviewed. Recommendations for future work will be posited and the impact of the findings for optometrists as well as for patients will be discussed.

7.2 Thesis Findings

7.2.1 Literature review

The literature review in Chapter Two highlighted the lack of evidence comparing gonioscopy to other methods of ACA assessment within a European setting. A considerable number of papers have been published investigating the use of standalone AS-OCTs at identifying patients at risk of PACG in Asia. However due to differences in anterior segment dimensions, there may be different mechanisms responsible for PACG in Asian and non-Asian eyes (Wang *et al.*, 2013). These studies may therefore be of limited relevance when making decisions on European populations (NICE, 2009).

In addition there was a lack of compelling evidence, in the literature, for replacing gonioscopy with another more objective method of ACA assessment. This is of relevance to UK optometrists who may not be proficient at gonioscopy and who are interested in becoming involved in glaucoma shared care or in improving their ability to detect and differentially diagnose glaucoma. The literature review reveals that the van Herick method would appear to perform better than AS-OCT when considering an alternative to gonioscopy. The low specificity values found in two AS-OCT studies (Nolan *et al.*, 2007; Park *et al.*, 2011) might have some implications for considering its use in an optometry setting due to resulting high proportion of false positives and subsequent unnecessary worry placed on the patient.

7.2.2 Survey

This study investigated the change in clinical behaviour after publication of the NICE guideline. The survey showed a significant increase in the regular practice of applanation tonometry ($p < 0.01$), a small increase in the practice of pachymetry ($p = 0.04$) although clinically this was not significant, and no significant change in the regular practice of gonioscopy ($p = 0.047$). The increase in applanation tonometry is likely due to the recommendation that if IOPs are over 21 mmHg using non-contact tonometry, they should be repeated ideally using contact tonometry prior to

referring patients (College of Optometrists and Royal College of Ophthalmologists, 2010). The practice of gonioscopy and pachymetry were found to be small and this may be explained by the fact that they are not currently core competency requirements for optometrists in the UK. The increase in gonioscopy workshops offered at optometry conferences in recent years may have a positive effect on the numbers who practice gonioscopy in years to come.

7.2.3 Gonioscopy Competence

The sensitivity and specificity of gonioscopy findings for optometrists and other healthcare professionals (HCPs) compared to consultant ophthalmologists were found to be good. Weighted kappa results measuring agreement for each HCP and consultant were mostly good although the results would suggest that agreement would appear to be better with one consultant than the other, highlighting the subjective nature of this method of ACA assessment. Looking at the results overall agreement between the HCPs and consultants was found to be good ($\kappa_w = 0.62$). These results show that optometrists along with one other HCP (a nurse practitioner) are able to perform gonioscopy accurately and competently in a hospital setting. Gonioscopy results between two consultants were also collected retrospectively on ten patients and agreement was found to be lower in this group, this however may be due to the more difficult nature of assessing the ACA in this group of patients.

Optometrists and other HCPs, who receive adequate training, perform gonioscopy safely and reliably in a hospital setting. Optometrists who work in the community who wish to become adept at gonioscopy would benefit from adapting this type of model of gonioscopy competency training. Data sheets collected by the optometrists provide feedback that helps improve competency in gonioscopy and they are a useful tool in teaching and training sessions. Due to the lack of published evidence comparing gonioscopy findings between different clinicians and between different professions, further work is needed comparing the gonioscopy findings

between ophthalmologists and between different HCPs. This will be discussed further in Section 7.7.

7.2.4 Comparison and repeatability of anterior chamber angle assessment tests

The third study investigated the agreement of van Herick and AS-OCT with gonioscopy for eighty subjects recruited from community optometry practice. The prevalence of eyes at risk of PACG in this cohort is less than that found in a glaucoma clinic, although the prevalence of PACG in a European population is higher than previously thought (Day *et al.*, 2012).

The intra-observer repeatability for assessing the ACA was better for both the van Herick method and AS-OCT than for gonioscopy. The poorer result for gonioscopy may be influenced by the fact that it is a more subjective than van Herick and AS-OCT. Gonioscopy findings may vary depending on the angle the lens makes with the eye, the co-operation of the patient and the effect of any light falling on the pupil. In addition gonioscopy assesses all four quadrants of the eye whereas for van Herick and AS-OCT, only nasal and temporal quadrants were investigated in this study. All these factors are likely to deleteriously influence repeatability. These factors will be discussed further in Section 7.3.

The van Herick method showed good sensitivity and good specificity when compared to gonioscopy; AS-OCT shows poor sensitivity but good specificity. From these results the van Herick and AS-OCT would therefore appear to be good in the identification patients with open angles, with the van Herick method more sensitive than AS-OCT at identifying occludable angles.

Sensitivity and Specificity compared to other studies

In Chapter Three, the range in sensitivity and specificity values were displayed for nine previous ACA studies (see Figure 3-4 and Figure 3-5). The results from the

current study (J and K) have now been added to these results, see Figure 7-1 and Figure 7-2.

Figure 7-1 shows how the van Herick sensitivity and specificities values from the current study (J1 and J2) compare with the previous studies. The cut off criteria for the van Herick method varies between each of the studies. The current study uses the same criteria as Foster *et al.*, (2000), Bourne *et al.*, (2010) and Park *et al.*, (2012): cut off level <25%. Thomas *et al.*, (1996) and Baskaran *et al.*, (2006) use a more lenient cut of at $\leq 25\%$. The sensitivity and specificity values appear to be broadly comparable with these previous studies, the closest match appears to be with Study H1 (Bourne *et al.*, 2010). This is a community based optometry study comparing van Herick values by eight optometrists to gonioscopy results by a glaucoma consultant. The results would therefore appear to correlate well with a study where the optometrists' van Herick findings were compared to gonioscopy findings by a consultant ophthalmologist.

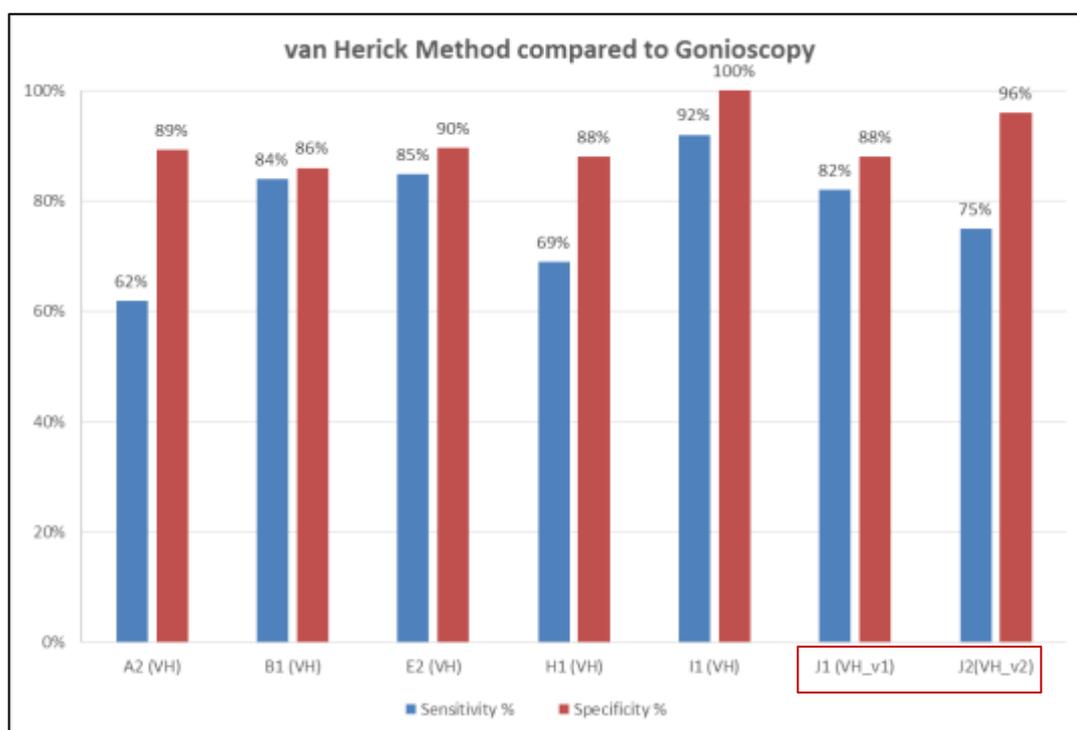


Figure 7-1 Van Herick Sensitivity and Specificity values for current study (J1 and J2) compared to other studies.

CODE A: Thomas *et al.*, (1996) FL=Flashlight (1/3 shadow), VH=Van Herick $\leq 25\%$ B: Foster *et al.*, (2000) VH ≤ 15 E: Baskaran *et al.*, (2006) VH $\leq 25\%$; H: Bourne *et al.*, (2010) VH $\leq 15\%$, I: Park *et al.*, (2012) VH $\leq 15\%$ J: Current Study VH $\leq 15\%$ J1 - visit 1, J2 - visit 2.

Figure 7-2 shows how the AS-OCT sensitivity and specificities for the current study (K1 and K2) compare to other published data. The current study would appear to match C1 (Radhakrishnan *et al.*, 2005) with poor sensitivity and good specificity values. The other studies (F, G and I) show the inverse, with good sensitivity and poor specificity.

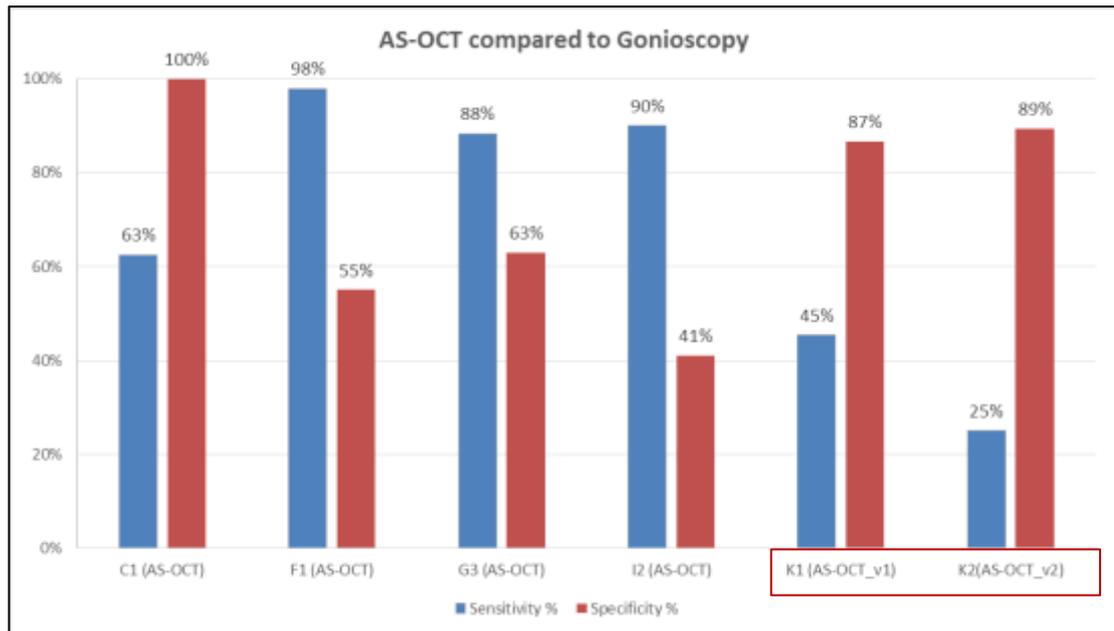


Figure 7-2 AS-OCT Sensitivity and Specificity values for current study (K1 and K2) compared to other studies.

CODE C: Radhakrishnan *et al.*, (2005) F: Nolan *et al.*, (2007). G: Lavanya *et al.*, (2008). I: Park *et al.*, (2012) J: Current Study VH \leq 15% J1-visit 1, J2 visit 2. K: Current study AS-OCT K1 - visit 1 K2 - visit 2.

The details for each of these AS-OCT studies are shown in Table 7-1 . It is of interest to note that Study C (58.3% Caucasian, 12.5% African American and 16.7% Asian) and the current study (Study K, 87.5 Caucasian) took place outside of Asia. The mechanism of angle closure is known to be different between Asian and non-Asian eyes (Wang *et al.*, 2013). From the sensitivity and specificity values above, one could speculate that AS-OCT is more sensitive at detecting an occludable angle in Asian than in non-Asian eyes and is better at detecting an open angle in non-Asian than in Asian eyes. These could be due to a difference in the position of the scleral spur position between the two groups. One could postulate that the scleral spur is easier to locate in Asian eyes that are occludable than non-Asian eyes. This finding would mean that using an AS-OCT to screen for PACG is of less benefit outside of Asia.

Table 7-1 Details of AS-OCT studies

Study	n	Location	Type of OCT /wavelength	Proportion of Occludable Eyes by gonioscopy (%)
C	24	Cleveland, Ohio	Prototype OCT/1300 nm (Carl Zeiss Meditec Inc., Dublin,, CA, USA)	29%
F	200	Singapore glaucoma clinic	Prototype OCT/1300 nm (Carl Zeiss Meditec Inc., Dublin, CA, USA)	49.5%
G	2052	Singapore polyclinic	Visante /1300 nm (Carl Zeiss Meditec Inc., Dublin, CA, USA)	20.5%
I	148	Asan glaucoma clinic, Korea	Visante v2.0 /1310nm (Carl Zeiss Meditec Inc., Dublin, CA, USA)	62.8%
K	80	Optometry practice, UK	Topcon OCT 2000/850 nm (Topcon Europe Medical B.V, Netherlands)	15% (visit 1) 16.2% (visit 2)

All the studies with the exception of Study K used a dedicated standalone AS-OCT. In addition there is considerable variation in prevalence of occludable and in sample size between the studies. Direct comparison between the groups should be therefore made with caution.

7.3 Gonioscopy - the gold standard?

As discussed in Chapter Three, several authors have questioned the validity of gonioscopy as the reference standard to predict angle closure. In the study outlined in Chapter Six, intra-observer repeatability was found to be better for the van Herick method and AS-OCT than for gonioscopy.

Various factors may explain the variability in results for gonioscopy. One potential measurement error could be due to light from the slit lamp beam unintentionally falling on the pupil, causing it to constrict and opening the ACA (Friedman and He,

2008). If this happens at one visit and not at the other, the eye may be classified as open at that visit but occludable at the other visit.

Inadvertent pressure on the cornea due to direct contact with the eye may lead to distortion of the ACA, thereby affecting the visibility of the angle structures (Nolan *et al.*, 2007). Results may also be affected by a variation in the angle at which the lens is placed onto the cornea, or a difference in the background illumination levels at different visits.

In addition, during gonioscopy, the clinician has to make a decision relatively quickly in order to minimise the discomfort to the patient, whereas the van Herick method and AS-OCT are much less invasive, and arguably, more time can be taken to grade the ACA using these methods, thereby potentially increasing repeatability. The fact that there are more structures to observe and consider in gonioscopy, compared with van Herick, may also contribute to its lower repeatability.

Nolan *et al.*, (2007), argue that due to the effects of angle distortion and light exposure on the pupil, there are likely to be cases of angle closure missed by gonioscopy. At present there is a lack of published evidence looking at the long term follow up of subjects who are occludable with AS-OCT and van Herick method but are still open with gonioscopy. One study comparing two different AS-OCT devices with gonioscopy (Sakata *et al.*, 2010) found a considerable number of subjects were classified occludable with both AS-OCTs but were open with gonioscopy (see Section 3.3.3).

From the literature review there appears to be a lack of evidence investigating the proportion of patients who are determined to have non-occludable angles by gonioscopy and go on to develop PAC/PACG. It would be valuable to know the proportion of those found to have occludable angles following gonioscopy but decline treatment who then go on to develop acute angle closure. This would give important information on whether gonioscopy is indeed the most suitable method when assessing patients at risk of PACG. It would be unethical to encourage

patients to decline treatment and since the usual treatment (laser peripheral iridotomy) has a low risk of complication it seems unlikely that a meaningful size of sample of patients who decline treatment could be obtained. However, these questions raise the issue that is it important to investigate more comprehensively the sensitivity of the gold standard method of ACA assessment.

In spite of these criticisms, gonioscopy is relatively inexpensive and is a rapid method of assessing the ACA in clinical practice, when carried out by an experienced clinician. It allows direct visualisation of the anterior segment structures and it has a comprehensive and validated grading scheme.

Could another method be used instead of gonioscopy as the “gold standard”? The van Herick method in the current study was found to have better repeatability than gonioscopy. Sensitivity and specificity values for van Herick method have been found to be good when compared to gonioscopy in the current study as well as in evidence from other researchers (Foster *et al.*, 2000; Park *et al.*, 2012). However, the van Herick method does not allow direct visualisation of the ACA and provides no information on the nature of the angle structures (Debasia, 2014). Gonioscopy allows the clinician to directly view the ACA and this influences treatment options for patients at risk of PACG.

7.4 Training and Further Qualifications

As discussed above, the intra observer repeatability for gonioscopy in the current study was found to be fair. It is possible the repeatability could be even poorer for more novice users. Further clinical training in gonioscopy may therefore improve its utility in optometric practice as well as in investigations of the value of alternative forms of ACA assessment.

The NICE guideline (NICE, 2009) stated that healthcare professionals involved in the diagnosis, monitoring and treatment of glaucoma should have relevant experience and a specialist qualification in glaucoma. The ability to perform a gonioscopic

examination of the ACA, identify anatomical structures, accurately grade the angle width and interpret the significance of clinical findings has been stipulated as part of a competency framework for optometrists with special interest in glaucoma (Myint *et al.*, 2010).

Higher qualifications such as the College of Optometrists' diploma in glaucoma and various MSc modules in glaucoma are available to optometrists. Additional qualifications by optometrists have been shown to be associated with better performance in clinical techniques (Hadwin *et al.*, 2013). Training in optic disc assessment has been shown to improve glaucoma detection by community optometrists (Patel *et al.*, 2006; Theodossiades *et al.*, 2004). Recent published research investigating the clinical behaviour of Australia and New Zealand optometrists has shown that those with additional therapeutic qualifications have greater confidence in performing gonioscopy than those without such qualifications (Jamous *et al.*, 2014). Offering training in gonioscopy along with encouraging enrolment in higher qualification courses is therefore likely to increase optometrist confidence in carrying out gonioscopy.

Recommendations for Glaucoma Shared Care Schemes

A variety of schemes now exist with optometrists, nurses and orthoptists working alongside ophthalmologists in hospital settings or independently in community settings (Vernon and Adair, 2010). In order to comply with the NICE guideline, glaucoma shared care schemes will need to adapt to allow for assessment by gonioscopy when clinically required. The NICE committee recognise the fact that community optometrists do not routinely carry out gonioscopy and that the take up of this technique might raise some cost implications for the optometrist practice:

Optometrists and other HCPs who undergo training within a hospital setting have been shown in this study to be able to perform gonioscopy accurately and competently. It would therefore seem advisable for optometrists involved in glaucoma share care schemes to follow a similar method of training in a hospital setting prior to carrying out gonioscopy independently in a community setting. A

certain level of competency in gonioscopy would then allow the optometrist to manage glaucoma and ocular hypertension patients independently. When a patient is found to be “occludable” by the optometrist with gonioscopy they could be referred to an ophthalmologist for further investigation.

One such model for gonioscopy competency training for optometrists involved in a shared care clinic might involve the optometrist sitting in with an ophthalmologist for four to five clinic sessions in a glaucoma “new patient” clinic. The optometrist could carry out gonioscopy on a series of patients prior to it being carried out by the ophthalmologist and record both sets of results on a data sheet, similar to that used in Chapter Five (see Appendix B4). The results could then be graded as open or occludable for each clinician. Agreement between the optometrists and ophthalmologist could be measured and sensitivity and specificity of $\geq 80\%$ would seem acceptable. Gonioscopy is a difficult skill to master and requires regular practice to maintain competency (Friedman and He, 2008). Optometrists who do not continue to carry out gonioscopy on a regular basis (for example less than once a month) could arrange to have regular re-training sessions to ensure on going competency. This does however rely on the assumption that gonioscopy by a consultant ophthalmologist is the gold standard method for angle assessment.

7.5 Limitations

The results from respondents in the survey may not fully match the behaviour of all optometrists due to self-selection bias. There may also be some margin for error in the results due to the reliance on optometrists “remembering” their previous clinical practice (before NICE guidelines) and this may affect the accuracy of their answers.

The results for comparing HCP gonioscopy findings to those by a consultant may be influenced by the fact that some of the HCPs were more experienced at gonioscopy than others. Comparison between the results for HCP and consultant and consultant to consultant should also be treated with caution due to the fact that

the second group is likely to consist of more difficult cases where one consultant is seeking the opinion of a colleague.

The results for the final study are limited by the fact that all three tests are carried out by one examiner on both visits. This might mean there is a systematic bias in the findings. It is also possible that results from the van Herick method may influence the judgement during gonioscopy.

The use of gonioscopy as the reference standard in this study is also limited by the fact it has fair repeatability itself. The result of such fair repeatability would mean that the apparent performance of the other techniques would appear to fluctuate between visits.

As outlined in Section 7.2.4, results with a dedicated AS-OCT device are likely to give greater accuracy for anterior chamber analysis due to better visualisation of the anterior segment structures. However, the results for the current study are more relevant to optometrists in practice who are more likely to have a general use OCT rather than a standalone AS-OCT. Indeed, the present author knows of no community optometrists in the UK to date who have invested the considerable sum necessary for a dedicated AS-OCT. It seems unlikely that purchases of this type will become popular in view of the very limited use of this equipment in contrast with posterior segment OCT instruments, which are routinely used to image many posterior segment conditions.

7.6 Peer review of Findings

The findings from this thesis were presented at three UK optometry conferences and one international conference. See Appendix C5 for copies of the poster presentations.

7.7 Future work

The questionnaire described in Chapter Three was carried out in early 2011, two years after the NICE guideline was introduced. Due to the noticeable increase in gonioscopy workshops in recent years, it was be useful to repeat the survey and see whether there has been any further change in clinical practice particularly with regard to gonioscopy. In addition, the original survey did not enquire about the use of rebound tonometry and it would be of interest to see if there has been an increase in its practice in recent years. Recent findings from Australia and New Zealand have shown a relationship between optometrists who have additional qualifications and those confident in gonioscopy (Jamous *et al.*, 2014). It would be also useful to investigate if there is a similar relationship in the UK.

This thesis has highlighted the lack of evidence comparing gonioscopy to other methods of anterior chamber angle assessment outside of Asia. A recently published paper has compared van Herick method results between community optometrists, hospital based optometrists and ophthalmologists (Jindal *et al.*, 2015). These findings highlight the current interest in ACA assessment amongst the optometry community. Further work is needed comparing gonioscopy and van Herick results by different examiners, comparing optometrist gonioscopy and van Herick findings to junior ophthalmologists as well as how ophthalmologists' gonioscopy findings compare to other ophthalmologists. Inter-observer repeatability values could be calculated and compared to the results from the current study.

It would be useful to look at how changing the definition of an occludable angle by gonioscopy would affect the results for the second and third studies. In both studies, the criterion used by Nolan *et al.*, (2007) was selected, where an eye was graded occludable if trabecular meshwork was visible for less than 270°. Foster *et al.*, (2000) use a narrower criterion, and stated that an angle is occludable if the posterior trabecular meshwork is visible for less than 90°. Using this more stringent definition of an occludable eye with gonioscopy will most likely lead to a smaller

number of occludable angles found by gonioscopy and a decrease in sensitivity of the test due to an increase in false positives.

The level of illumination is known to have an effect on the angle (Nolan *et al.*, 2007). Stray light falling on the pupil during gonioscopy is known to open the angle and can lead to a misdiagnosis of the angle as open. The author discussed the problems with gonioscopy with a fellow researcher, Dr Baskaran Mani, whilst attending the Association for Research in Vision and Ophthalmology conference. Dr Mani mentioned the fact that AS-OCT operates at lower illumination and is likely to give a more accurate evaluation of the true state of the ACA. Future work could look at measurement of the pupil size when carrying out the van Herick method, AS-OCT and gonioscopy and whether there is any significant difference in the findings relating to illumination levels with each of these techniques.

The use of an OCT device operating at 840 nm does not provide as good a view of the anterior segment structures as a standalone anterior segment OCT operating at 1300 nm, and this may explain why the AS-OCT results in this study perform poorly compared to the van Herick method. Future work could assess how different AS-OCT instruments compare to each other within a clinical setting and how they both compare to gonioscopy. In addition it would be valuable to investigate if AS-OCT performs differently for patients from different ethnicities. The sensitivity and specificity of AS-OCT would appear to differ for Asian and non-Asian eyes (see Section 7.2.4) and further work is required to validate this finding.

It would also be useful to carry out longitudinal studies investigating whether eyes that have been graded as occludable with AS-OCT or van Herick but open with gonioscopy will go on to develop angle closure in the future. A follow up study could be carried out on the current cohort to investigate whether AS-OCT and or van Herick method are better predictors of potential angle closure than gonioscopy. Results for van Herick and AS-OCT and van Herick method could also be combined (as discussed in Section 6.4.5) to ascertain whether when they are used together

they are better at predicting angle closure earlier than gonioscopy. Further ethics approval for this would be required before commencing this additional study.

7.8 Impact of Findings

7.8.1 Impact on Optometry profession

The capacity for glaucoma care within a hospital setting is not currently sufficient to meet demand (Steele, 2013). Recent proposals from NHS England have suggested a move away from a hospital-based delivery system towards patient-centred care involving a range of professions, with close co-ordination between them (NHS England, 2013). Glaucoma patients traditionally seen in a hospital setting are likely to be offered follow up care in a community setting in future. If such resources are to be used efficiently, it is important that optometrists who wish to become involved in diagnosing and managing glaucoma patients can show competency in performing the required tests.

Chapter Four results indicate that many optometrists are willing to learn new skills, with a significant increase in the practice of applanation tonometry. A recently published survey of New Zealand optometrists found that 42.6% of respondents intend to purchase a pachymeter in the next one to five years (Heidarian and Mason, 2013). In the UK, a survey carried out in March 2013 (Debasia *et al.*, 2014) found that 17% of optometrists now use a pachymeter. It would seem that the impact of the NICE guidance on glaucoma is still causing changes in clinical practice to occur. A repeat of the survey described in Chapter Four may now elicit further change in clinical practice than when it was originally carried out.

The results from the gonioscopy competence study described in Chapter Five help validate the argument that optometrists and other HCPs working in glaucoma clinics are able to competently perform tests traditionally carried out by ophthalmologists. Professor David Henson (Professor of Ophthalmology & Vision

Sciences in the School of Medicine, Manchester University), stated in a lecture at the College of Optometrists' annual conference in March 2012, that:

“Optometrists are already skilled in detecting glaucoma and ocular hypertension. Transferring suspect and stable glaucoma from ophthalmologists to optometrists is the answer” (Henson, 2012).

The findings from this thesis provide evidence in favour of further involvement by optometrists in glaucoma management.

The results from the final study outlined in Chapter Six, question the value of labelling gonioscopy as the “gold standard” method to assess the ACA. The poor repeatability for gonioscopy found in this study may have an impact on the willingness of optometrists to learn this skill and on their confidence in reporting gonioscopy findings. The superior repeatability of the van Herick method and the fact that it has good agreement with gonioscopy may mean optometrists are likely to continue using this tool to assess the ACA, rather than attempt gonioscopy. In addition the poor sensitivity values found in the current study for AS-OCT may mean it is less likely optometrists would consider using this method to assess the ACA. Gonioscopy does remain the “gold standard” method to assess the ACA as it allows direct visualisation of the ACA. Optometrists should be encouraged to learn this skill and gain confidence in using it.

7.8.2 Impact on Patients

As discussed in Chapter One, patient choice will be at the centre of future NHS provision. Within glaucoma care, patients are made aware of who is responsible for each aspect of their care and they should also be given the opportunity to choose if they wish their care to be shared between the ophthalmologist and optometrist (Steele. 2013).

One aspect of optometrists becoming more involved in glaucoma care may involve the need to re-refer patients back to ophthalmologists when there is a change in their clinical status. In the study outlined in Chapter Six, one subject “PS” was referred to an ophthalmologist as a result of the study findings. He had previously been referred to the hospital eye service in 2007 with “narrow angles”. An ophthalmologist, at that time, graded the ACA as normal and discharged him back to his optometrist. He volunteered to participate in the study and the ACA was classified by gonioscopy, van Herick method and AS-OCT as occludable at both visits (see his results in Appendix C6). He was re-referred and subsequently received treatment for occludable angles.

He kindly contacted the practice to inform them of the outcome of his appointment with the consultant ophthalmologist (Mr R):

“Mr R advised me that I should undergo Peripheral Iridotomy as soon as possible, although tests again showed borderline shallow angles. This surprised me but I very much appreciated your advice that I should follow Mr R’s considerable opinion...Mr R carried out this procedure at the hospital yesterday, 15th Oct and as at today, I have no ill effects from the procedure which Mr R said went well.”

Subject “PS”

This case-study provides some indication of impact of the investigating PACG from a patient’s perspective. A “patient based” perspective is a valuable addition in measuring the outcome of a study and can supplement the information obtained in clinical based health research (Bowling, 2005). This case highlights the fact that the clinical status of the ACA can change over time (NICE, 2009). Patients who previously have been investigated for occludable ACA and are found to be normal, at that time, may need to be re-referred if the nature of the ACA changes.

7.9 Summary of Findings

The literature review on gonioscopy showed there is a paucity of evidence comparing gonioscopy between clinicians and on the accuracy of optometrists at gonioscopy. There are to date no published data comparing optometrists' gonioscopy results to other clinicians. Literature comparing gonioscopy to other methods of ACA assessment shows that in Asian populations, where the prevalence of PACG is higher than in the UK (Day *et al.*, 2012), gonioscopy remains the gold standard compared to methods such as AS-OCT, van Herick method and Scanning Peripheral Anterior Chamber Depth Analyzer (SPAC).

A questionnaire was sent to College of Optometrist Members to investigate the effect of the NICE guideline on clinical behaviour. There was a significant increase in the number of practitioners who report carrying out contact/applanation tonometry, a small increase in the practice of pachymetry, but no significant change in gonioscopy practice. An interesting finding has been the decrease in the number of practitioners who repeat IOPs prior to referral. This study demonstrated that optometrists have changed their clinical behaviour in response to new national guidelines. There is however still only a small percentage of optometrists who carry out gonioscopy in the UK. There may have been an increase in gonioscopy practice since the time of the questionnaire and a repeat questionnaire would be a useful way to determine if this is the case.

Comparison of optometrists and other healthcare professionals' gonioscopy findings to the results obtained by consultant ophthalmologists showed that optometrists and other healthcare professionals are able to perform gonioscopy accurately and safely in a hospital setting. This shows that optometrists are capable of taking on new clinical skills in an evolving National Health Service where an ageing population is placing increasing demands on overstretched hospital eye departments.

Finally, the repeatability and agreement for three methods of ACA assessment was investigated for van Herick method, Anterior Segment Optical Coherence Tomography (AS-OCT) and gonioscopy. Van Herick and AS-OCT methods appear to show better repeatability than gonioscopy. Van Herick method appears to show good agreement with gonioscopy whereas the AS-OCT method showed only fair agreement. A dedicated AS-OCT which allows better visualisation of the angle is likely to perform better. Some researchers have questioned the value of using gonioscopy as the reference standard method for ACA assessment (Nolan *et al.*, 2007, Dr Baskaran Mani, personal communication, 2014).

The current study does however use technology which is increasingly used by community optometrists and therefore has a direct relevance to an optometry audience. Overall, the results indicate that optometrists along with other HCPs can be trained to use gonioscopy in an accurate and reliable way and that van Herick method may provide a suitable alternative when monitoring patients at risk of glaucoma, for examine in glaucoma shared care schemes.

7.10 Conclusions

In this thesis new evidence has been presented comparing ACA assessments. Optometrists, alongside other healthcare professionals, are well placed to take on new roles in future glaucoma shared-care provision. They are able to perform gonioscopy accurately and competently. The van Herick method would appear to be a more useful test than AS-OCT for optometrists assessing patients at risk of PACG. Future work is needed to look at how gonioscopy and van Herick findings compare amongst different professional groups and whether the van Herick method and AS-OCT are better at predicting primary angle closure than gonioscopy.

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APPENDICES

Appendix A1 Email invitation and Questionnaire

3 January-2011

Thank you in advance for taking a few minutes to complete this short questionnaire looking at the impact of the Glaucoma/Ocular Hypertension NICE Guideline on optometric practice in England and Wales. It forms part of a project for my Professional Doctorate at London South Bank University.

This is a completely anonymous questionnaire, your identity will not be revealed in my thesis, or in any publication or presentation. Your consent is implied by completing and submitting this questionnaire electronically. Once submitted, your data cannot be identified or withdrawn due to the anonymous nature of this study.

The closing date for submission is 28 February 2011 but please complete it as soon as you can.

Please contact me if you have any questions regarding this research.

Peter Campbell

Email: glaucomasurvey@yahoo.com

1. What year did you qualify as an Optometrist?

Before 1970

1970-1979

1980-1989

1990-1999

2000-2009

2010-

2. At which university did you study Optometry?

Anglia Ruskin

Aston

Bradford

Cardiff

City

Glasgow

Manchester

Ulster

Other – please specify.....

3. Which type of practice do you consider to be your principal work?

Community practice – independent (less than 3 practices)

Community practice – joint venture/multiple

Community practice – locum

Hospital

Academic/research

Other please specify.....

4 Where is the practice in which you spend most of your time?

England – Eastern
England – East Midlands
England – London Boroughs
England – North East
England – North West
England – South East
England – South West
England – West Midlands
England – Yorkshire and Humber
Wales
Scotland
Northern Ireland

5. Do you work in more than one of the areas outlined in Question 4?

Yes. Please specify....

No

6. How many eye examinations do you carry out in any typical week?

0- 20

21- 40

41- 60

61 – 80

81 or more

7. Are you involved in a Glaucoma/OHT Shared care scheme at present or have you been involved in one within the last two years?

Yes

No

8. Are you involved in a Glaucoma Referral Refinement scheme at present or have you been involved in one within the last two years?

Yes

No

The NICE Guideline on the diagnosis and management of chronic open angle glaucoma and ocular hypertension was published in April 2009.

For questions 9-17 please select the most suitable answer.

9. Prior to the NICE Guideline publication (April 2009) did you carry out Goldmann/Perkins Applanation Tonometry in practice?

Yes I often used this test (more than once a week)

Yes I sometimes used this test (approximately once a month)

Yes I occasionally used this test (approximately once every few months)

No I did not use this test

10. Do you currently carry out Goldmann/Perkins Applanation Tonometry in practice?

Yes I often use this test (more than once week)

Yes I sometimes use this test (approximately once a month)

Yes I occasionally use this test (approximately once every few months)

No I do not use this test

11. Prior to the NICE Guideline publication (April 2009) did you carry out Gonioscopy (not van Herick or other estimation method or anterior segment OCT) in practice?

Yes I often used this test (more than once a week)

Yes I sometimes used this test (approximately once a month)

Yes I occasionally used this test (approximately once every few months)

No I did not use this test

12. Do you currently carry out Gonioscopy (not van Herick or other estimation method or anterior segment OCT) in practice?

Yes I often use this test (more than once a week)

Yes I sometimes use this test (approximately once a month)

Yes I occasionally use this test (approximately once every few months)

No I do not use this test

13. Prior to the NICE Guideline publication (April 2009) did you carry out Pachymetry in practice?

Yes I often used this test (more than once a week)

Yes I sometimes used this test (approximately once a month)

Yes I occasionally used this test (approximately once every few months)

No I did not use this test

14. Do you currently carry out Pachymetry in practice?

Yes I often use this test (more than once a week)

Yes I sometimes use this test (approximately once a month)

Yes I occasionally use this test (approximately once every few months)

No I do not use this test

15. Prior to the NICE Guideline publication (April 2009) did you routinely repeat IOPs for suspect glaucoma/OHT patients prior to referral?

Yes

No

16. At present do you routinely ask suspect glaucoma/OHT patients to return for repeat IOPs prior to referral?

Yes

No

17. Have you any comments about the impact of the NICE Guideline on your practice?

.....
.....
.....
.....
.....
.....

If you currently carry out gonioscopy and are interested in taking part in research please contact me by email on glaucomasurvey@yahoo.com

Thank you for taking the time to complete this anonymous questionnaire.

Appendix A2 Comments on content of questionnaire from Institute of Optometry REC

The impact of the 2009 NICE Glaucoma Guideline on Optometric Practice

Queries	Suggested Responses
<p><u>MW:</u></p> <p>Short timescale for the completion of the responses. It is now mid December and to expect a return by the dates given is expecting too much.</p> <p>Also one of the dates given on the questionnaire is wrong - 31January 2010!!!</p>	<p>Change Timescale due to delay in sending out survey</p> <p>Suggest: send on 3 January 2011 Responses in by 28/2/1011</p> <p>Date amended</p>
<p><u>DE</u></p> <p>Virtue of being a short questionnaire. You should make more of it being short. I reckon it can be done in less than five minutes (depending on the free text submitted) and this should be stressed. That information could go into the email, which I think might need to be included with the submission.</p> <p>The form asks for copies of any letters, posters etc and I think an email would fall into this category. It is worth taking care over the email, for it needs to tempt the reader to take the next step!</p> <p>Did you do a power calculation on how many of your 400 would need to change categories for the difference to be statistically significant? I am not really familiar with how this works with a chi squared type test.</p> <p>DE's comments in application form 7a: Should you give a copy of the email? 7b "starting to complete" might be better instead of completion of questionnaire</p>	<p>Email included in ethics application form. Information in email to include that the questionnaire can be done in less than five minutes</p> <p>Email included in amended research proposal</p> <p>Power Calculation not carried out as figure of 400 suggested by College as a manageable figure. Chi squared test is to be used as a tool to look at relationships between factors such as geographical location and practice of gonioscopy.</p> <p>7a – email added to research proposal 7b and 7e – I feel term "completion of questionnaire" is acceptable</p>

<p>7e “starting to complete” might be better instead of completion of questionnaire</p> <p><u>Research Proposal</u> Study Design: “Dates have slipped a bit!” Methods: Data will be archived for seven years after completion of the study “and then destroyed” Questionnaire: It is entirely up to Peter of course but I don’t think I would publish my phone number!</p>	<p>Dates have been amended Amended</p> <p>Phone number removed.</p>
<p><u>AW</u></p> <p>Number of preliminary questions, and whether all the information gathered is likely to be of importance to the main thrust of the study. There might be a case for reducing the number of items slightly to increase compliance?</p> <p>Are all the questions likely to be of value to the survey?? I can see that most are, particularly those later on, but some of the early questions may be of less relevance, and might serve to put people off??</p>	<p>Number of questions I feel is acceptable. It is necessary to look for trends in practice of gonioscopy depending on geographical location etc</p> <p>See Mr RR comments below.</p>
<p><u>RR</u></p> <p>Question 11 - I suggest partly rephrase: Did you carry out gonioscopy (not Van Herick or other estimation method)</p> <p>This is to ensure that true gonioscopy rather than anterior chamber angle/depth is being measured. Also, do you wish to exclude OCT - there may be the very occasional practice that uses anterior segment OCT.</p> <p>Question 13 - I expect that the reader will assume that ultrasound is used, but, again, it is possible that an OCT could be used.</p> <p>Question 15 - Suggest add: Prior to the NICE Guideline publication (April 2009) did you routinely repeat IOPs for suspect glaucoma/OHT patients AT THE INITIAL APPOINTMENT prior to referral?</p>	<p>We have rephrased this as suggested.</p> <p>We have changed the question to “Did you carry out gonioscopy (not Van Herick or other estimation method or OCT)?</p> <p>Method of pachymetry measurement is not specified by the NICE Guideline so the different methods are acceptable</p> <p>To simplify things and to keep the number of questions at a minimum I have not stated whether the IOPs are repeated on the same day or with a different instrument. The purpose of this question is just to investigate any change in the number of practitioners who repeat their IOP measurements either using the</p>

This is to emphasize that this is just a repeat, probably done immediately after the first batch of readings. This applies more to NCT than Perkins or Goldmann, since one probably would do a couple of readings if the pressures were high, and each reading is an average, and taken at the lowest value during the arterial pulse.

Add 15 a: If you repeat the measurement, and the initial readings were done with a non-contact instrument, do you use Goldmann or Perkins applanation for the repeat readings.

yes
no

With regard to AW's query about needing all the preliminary questions, I wonder if the University is important, or the area in which the respondent practices, except that different schemes apply in different areas. For example, in parts of Hampshire, Optoms can be paid a fee for doing repeat IOP measurements. Although the LOC and PCT considered restricting this to applanation, they decided not to since many practices do not have access to this. In Portsmouth, however, patients referred under the NICE guidelines as opposed to a fields/discs/pressures glaucoma referral are screened by one or two practices with Goldmann, Pachymetry, fundus photos and van Herick.

The immediate area may also be relevant, but this would be too difficult to interpret. A practice in a wealthy area might be able to do gonioscopy and make a reasonable charge for doing so. In relatively poor areas, many patients would opt for NHS referral. I also imagine that many ophthalmologists would want to do the test anyway, and ignore the optometrist's findings (if in a normal practice).

same or a different method since the NICE Guideline was introduced.

This additional question would provide useful information but it not directly relevant to my research.

Appendix A3 LSBU REC Approval Letter for Study 1 Questionnaire



Direct line: 020-7815 8024
E-mail: harrism7@lsbu.ac.uk

Ref: UREC 1046

Mr. P. Campbell,
Flat 2,
52 Grove Road,
London E3 5DU

10 January 2011

Dear Peter,

Research project: *The impact of the 2009 Glaucoma NICE Guideline on optometric practice in England and Wales.*

Thank you for your application for ethical approval. The Committee notes that your application has also been considered by the Institute of Optometry REC and that you have addressed the points made in that review.

I am pleased to inform you that ethical approval has been granted by Chair's action on behalf of the University Research Ethics Committee, and I wish you every success with your research.

Yours sincerely,

A handwritten signature in black ink, appearing to read "Mark Harris", written over a horizontal line.

Mark Harris
Deputy University Secretary
Secretary, LSBU Research Ethics Committee

c.c. Professor Joan Curzio, Acting Chair, LSBU Research Ethics Committee
c.c. Professor Bruce Evans, Secretary, Institute of Optometry REC

Appendix A4 SPSS Cross-Tabulations Results

Code used

- 1 Yes I often use this test (more than once a week)
- 2 Yes I sometimes use this test (approximately once a month)
- 3 Yes I occasionally use this test (approximately once every few months)
- 4 No I do not use this test

Qu.9/Qu.10 Applanation Tonometry

For results shown below:

- Values highlighted in green represent responses with no change in practice
- Values highlighted in pink represent responses with an increase in practice.
- Values highlighted in blue represent responses with a decrease in practice.

Q9-Q10 Crosstabulation						
Count						
		Q9				Total
		1	2	3	4	
Q10	1	81	24	13	22	140
	2	6	24	13	22	65
	3	0	5	33	14	52
	4	5	6	6	115	132
Total		92	59	65	173	389

Increase in Practice = 24 + 13 + 13 + 22 + 22 + 14 = **108**

Decrease in Practice = 6 + 0 + 5 + 5 + 6 + 6 = **28**

Qu.11/Qu.12 Gonioscopy

Q11-Q12 Crosstabulation						
Count						
		Q11				Total
		1	2	3	4	
Q12	1	7	2	1	1	11
	2	1	3	0	6	10
	3	0	0	10	5	15
	4	7	3	2	338	350
Total		15	8	13	350	386

Increase in Practice = $2 + 1 + 1 + 6 + 5 = 15$

Decrease in Practice = $1 + 0 + 7 + 0 + 3 + 2 = 13$

Qu.13/Qu.14 Pachymetry

Q13-Q14 Crosstabulation						
Count						
		Q13				Total
		1	2	3	4	
Q14	1	15	1	1	10	27
	2	0	3	0	4	7
	3	0	0	1	3	4
	4	4	1	2	342	349
Total		19	5	4	359	387

Increase in Practice = $1 + 1 + 0 + 10 + 4 + 3 = 19$

Decrease in Practice = $0 + 0 + 4 + 1 + 0 + 2 = 7$

Appendix B1 LSBU REC Approval Letter for Study 2 Gonioscopy Competency

**London South Bank
University**

Direct line: 020-7815 6024
E-mail: dippenas@lsbu.ac.uk
Ref: UREC 1206

Mr Peter Campbell
Flat 2
52 Grove Road
London E3 5DU

Dear Peter

Audit of Gonioscopy competency within a NHS Trust.

Thank you for submitting this proposal and for your response to the reviewers' comments.

I am pleased to inform you that ethical approval has been given by Chair's action on behalf of the University Research Ethics Committee.

I wish you every success with your research.

Yours sincerely,



Sharon Dippenaar
Secretary, LSBU Research Ethics Committee

cc:

Prof Joan Curzio, Chair, LSBU Research Ethics Committee

Appendix B2 Participant Information Sheet for HCPs

PARTICIPANT INFORMATION SHEET for HCPs

Version 1.2

Title of Study:

Audit of Gonioscopy Competency within a NHS Trust

You are being invited to take part in a clinical audit which forms part of a Professional Doctorate qualification at London South Bank University. Before you decide it is important for you to understand why this audit is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The purpose of this study is to compare the gonioscopy findings of Healthcare Professionals (optometrists, nurse practitioners, orthoptists) with those of a consultant ophthalmologist.

Why have I been chosen?

As an HCP working in the Trust, you have been collecting your gonioscopy findings and those of the consultant as part of your clinical development training.

Do I have to take part?

No it is entirely up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect in any way your ongoing training development within the Trust.

What will happen to me if I take part?

I am asking your permission to copy your gonioscopy findings and those of the consultant onto an Excel Spreadsheet.

What do I have to do?

You are not asked to do anything other than give your consent for your datasheets to be audited.

What are the possible disadvantages and risks of taking part?

The results of the audit will be shared with the Clinical Lead, and if your gonioscopy findings are found to be markedly different compared to the other HCPs then you will be asked by the clinical lead to undergo further training. This will involve two further training sessions observing the consultant carrying out gonioscopy in clinic.

What are the possible benefits of taking part?

The information obtained from taking part in this study may help in the development of the future training of HCPs in gonioscopy.

Will my taking part in this study be kept confidential?

Yes, the research will be confidential and clinicians will be identified only by anonymous participant numbers. As noted above, the results (including clinician's identity) will be shared with the Clinical Lead but they will not be shared with other members of the clinical team.

Gonioscopy datasheets are currently kept in a locked filing cabinet stored in a secure office within the Trust. The relevant data will be transferred onto an Excel Spreadsheet and stored in a password protected file and the password will only be known to the principal researcher and research supervisor.

The information obtained from this study will be retained for 7 years.

Who has reviewed the study?

The London South Bank University (LSBU) Research Ethics Committee

Contact for Further Information

Do not hesitate to contact me or my supervisor with any questions.
Thank you for your time.

Principal Researcher

Peter Campbell
Glaucoma Practitioner
XXXX Hospital
London xxxxx
Tel 07900 216729

Research Supervisor

Prof Bruce Evans
Institute of Optometry
56-62 Newington Causeway
London SE1 6DS
Email: bruce.evans@virgin.net

If you any further concerns, please contact the LSBU Research Ethics Committee.

Chair: Prof Joan Curzio
Director of Practice Development
Faculty of Health and Social Care
London South Bank University
London SE1 0AA Email: curziojl@lsbu.ac.uk

Appendix B3 Participant Information Sheet for Consultant

PARTICIPANT INFORMATION SHEET for Consultant Ophthalmologist
Version 1.2

Title of Study: Audit of Gonioscopy Competency within a NHS Trust

You are being invited to take part in a clinical audit which is part of a Professional Doctorate qualification at London South Bank University. Before you decide it is important for you to understand why the audit is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The purpose of this study is to compare the gonioscopy findings of Healthcare Professionals (optometrists, nurse practitioners, and orthoptists) with those of a consultant ophthalmologist.

Why have I been chosen?

Your gonioscopy findings have been collected along with those of HCPs as part of HCP clinical development training.

Do I have to take part?

No it is entirely up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect in any way your ongoing training development within the Trust.

What will happen to me if I take part?

No action is required to assist in this part of this study.

What do I have to do?

Your gonioscopy findings will be copied along with the HCP's findings. No action is required on your part.

What are the possible disadvantages and risks of taking part?

None

What are the possible benefits of taking part?

The information obtained from taking part in this study may help in the development of the future training of HCPs in gonioscopy

Will my taking part in this study be kept confidential?

Yes, the research will be confidential and clinicians will be identified only by anonymous participant numbers.

Gonioscopy datasheets are currently kept in a locked filing cabinet stored in a secure office within the Trust. The relevant data will be transferred onto an Excel Spreadsheet and stored in a password protected file and the password will only be known to the principal researcher and research supervisor.

The information obtained from this study will be retained for 7 years.

Who has reviewed the study?

The London South Bank University (LSBU) Research Ethics Committee

Contact for Further Information

Do not hesitate to contact me or my supervisor with any questions.
Thank you for your time.

Principal Researcher

Peter Campbell
Glaucoma Practitioner
XXXX Foundation Trust
London xxxx
Tel 07900 216729

Research Supervisor

Prof Bruce Evans
Institute of Optometry
56-62 Newington Causeway
London SE1 6DS
Email: bruce.evans@virgin.net

If you have any further concerns, please contact the LSBU Research Ethics Committee.

Chair: Prof Joan Curzio
Director of Practice Development
Faculty of Health and Social Care
London South Bank University
London SE1 0AA
Email: curziojl@lsbu.ac.uk

Appendix B4 Gonioscopy Competency Data Sheet

APPENDIX C GONIOSCOPY COMPETENCY

Date:

Subject Number:

Age:

Male/Female

TRAINEE NAME:

RIGHT EYE

LEFT EYE

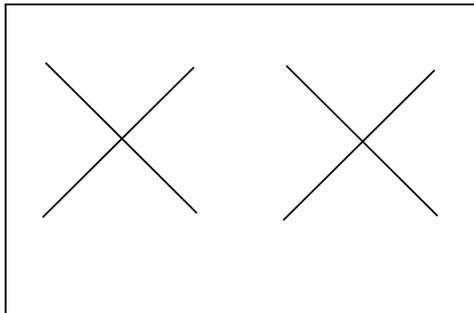
Van Herick

AC

GONIO Findings

Please grade each quadrant from 0 to 4

Y/N	Iris Processes?	Y/N
Y/N	Peripheral Anterior Synechiae?	Y/N
Y/N	Pigment?	Y/N



Agree/Disagree with Consultant?

Comments

CONSULTANT NAME

RIGHT EYE

LEFT EYE

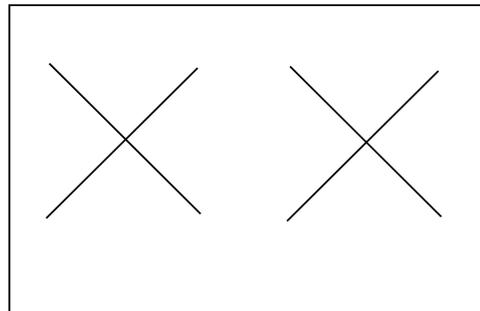
Van Herick

AC

GONIO Findings

Please grade each quadrant from 0 to 4

Y/N	Iris Processes?	Y/N
Y/N	Peripheral Anterior Synechiae?	Y/N
Y/N	Pigment?	Y/N



Appendix B5 Clopper-Pearson binomial probability confidence interval exact method

Binomial probability confidence interval (Clopper-Pearson exact method):

$$\left(1 + \frac{n - x + 1}{xF(1 - \alpha/2; 2x, 2(n - x + 1))}\right)^{-1} < p < \left(1 + \frac{n - x}{(x + 1)F(\alpha/2; 2(x + 1), 2(n - x))}\right)^{-1}$$

x is the number of successes

n is the number of trials

$F(c; d1, d2)$ is the $1 - c$ quantile from an F-distribution with $d1$ and $d2$ degrees of freedom.

Appendix B6 Weighted Kappa Worked Example

Adapted from Fleiss (1981)

Kappa is defined as

$$p_o = \sum_{i=1}^k p_{ii} \qquad p_e = \sum_{i=1}^k p_{i.} \cdot p_{.i}$$

$$\kappa_w = \frac{p_o - p_e}{1 - p_e}$$

i.e. $p_o = \sum_{i=1}^k p_{ii}$ i.e. $p_o = p_{11} + p_{22}$

i.e. $p_e = \sum_{i=1}^k p_{i.} \cdot p_{.i}$ i.e. $p_e = p_{1.} * p_{.1} + p_{2.} * p_{.2}$

$$\kappa = \frac{p_o - p_e}{1 - p_e}$$

Weighted Kappa is defined as:

$$p_{o(w)} = \sum_{i=1}^k \sum_{j=1}^k w_{ij} p_{ij} \qquad = W_{11} * P_{11} + W_{22} * P_{22}$$

$$p_{e(w)} = \sum_{i=1}^k \sum_{j=1}^k w_{ij} p_{i.} \cdot p_{.j} =$$

$$(W_{11} p_{1.}) * p_{.1} + (W_{12} p_{1.}) * p_{.2} + (W_{21} p_{2.}) * p_{.1} + (W_{22} p_{2.}) * p_{.2}$$

$$\kappa_w = \frac{p_{o(w)} - p_{e(w)}}{1 - p_{e(w)}}$$

Weights: $W_{ij} i=1, \dots, k; j=1, \dots, k;$ $0 \leq W_{ij} \leq 1$

Worked Example

This example looks at agreement in gonioscopy findings for one healthcare professional (HCP1) and one consultant C1.

Results were graded as “occludable” (occ) or “open” independently by each HCP and consultant. SPSS was then used to cross tabulate the findings and p values were calculated by dividing each result by the total number of subjects (in this case 35).

HCP/C1 Results

Cross Tabulation

	CONS1(occ=1)	CONS1(open=2)	total
HCP1(occ=1)	8	1	9
HCP1(open=2)	0	26	26
	8	27	35

P _{ii} values	CONS(occ)	CONS(open)	Total
HCP(occ)	p ₁₁	p ₁₂	p _{1.}
HCP(open)	p ₂₁	p ₂₂	p _{2.}
Total	p _{.1}	p _{.2}	1.00

p_values	CONS1(occ=1)	CONS1(open=2)	Total
HCP1(occ=1)	0.2286	0.0286	0.2571
HCP1(open=2)	0.0000	0.7429	0.7429
Total	0.2286	0.7714	1.0000

Kappa

$$p_o = 0.2286 + 0.7429 = 0.9714$$

$$p_e = 0.2571 * 0.2286 + 0.7429 * 0.7714 = 0.6318$$

$$\kappa = \frac{0.9714 - 0.6318}{1 - 0.6318} = 0.9224$$

W values	CONS(occ=1)	CONS(open=2)
HCP(occ=1)	W ₁₁	W ₁₂
HCP(open=2)	W ₂₁	W ₂₂

Choice of Weights

The worse outcome is a false negative finding (HCP=open, Consultant=occludable) and this was given the least weight (W=0). The greatest weight (W=1.0) was given to a true positive finding “HCP=occludable, Consultant=occludable”. The W values for the other two findings (0.3, 0.9) were chosen so that more importance was placed on a difference in findings than when the findings were the same.

W values	Consultant = occludable	Consultant=open
HCP=occludable	1.0	0.3
HCP=open	0.0	0.9

p_values	CONS1(occ=1)	CONS1(open=2)	Total
HCP1(occ=1)	0.2286	0.0286	0.2571
HCP1(open=2)	0.0000	0.7429	0.7429
Total	0.2286	0.7714	1.0000

Weighted Kappa

$$p_{o(w)} = (1.0 * 0.2286) + (0.3 * 0.0286) + (0.0 * 0.000) + (0.90 * 0.7429) = 0.9057$$

$$p_{e(w)} = (1.0 * 0.2571 * 0.2286) + (0.3 * 0.2571 * 0.7714) + (0.0 * 0.7429 * 0.2286) + (0.9 * 0.7429 * 0.7714) = 0.634041$$

$$\kappa_w = \frac{0.9057 - 0.63404}{1 - 0.63404} = 0.7424$$

Appendix C1 NHS NRES Approval Letters

NHS
National Research Ethics Service
NRES Committee London - Camberwell St Giles
(Formerly known as The Joint South London and Maudsley and Institute of Psychiatry
Research Ethics Committee)
Administrative address: Victoria House
Capital Park
Fulbourn
Cambridge
CB21 5XB

Telephone: 01223 597509
Facsimile: 01223 597645

03 October 2011

Mr Peter Campbell
Glaucoma Practitioner
St Thomas' Hospital
Ophthalmology Department
Westminster Bridge Road
London
SE1 7EH

Dear Mr Campbell

Full title of study: The repeatability of optometrists at gonioscopy and other ocular anterior chamber angle assessment methods on adults within a community optometric setting.

REC reference number: 11/LO/0834

Thank you for your e-mail of 03 October 2011. I can confirm the REC has received the documents listed below as evidence of compliance with the approval conditions detailed in our letter dated 09 September 2011. Please note these documents are for information only and have not been reviewed by the committee.

Documents received

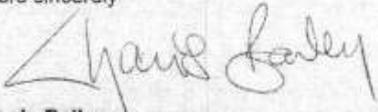
The documents received were as follows:

Document	Version	Date
Protocol	2.1	01 October 2011

You should ensure that the sponsor has a copy of the final documentation for the study. It is the sponsor's responsibility to ensure that the documentation is made available to R&D offices at all participating sites.

11/LO/0834 **Please quote this number on all correspondence**

Yours sincerely



Charis Bailey
Committee Co-ordinator

This Research Ethics Committee is an advisory committee to the East of England Strategic Health Authority
The National Research Ethics Service (NRES) represents the NRES Directorate within
the National Patient Safety Agency and Research Ethics Committees in England



National Research Ethics Service

NRES Committee London - Camberwell St Giles

(Formerly known as The Joint South London and Maudsley and Institute of Psychiatry
Research Ethics Committee)

Administrative address: Victoria House
Capital Park
Fulbourn
Cambridge
CB21 5XB

Telephone: 01223 597509
Facsimile: 01223 597645

09 September 2011

Mr Peter Campbell
Glaucoma Practitioner
St Thomas' Hospital
Ophthalmology Department
Westminster Bridge Road
London
SE1 7EH

Dear Mr Campbell

Study title: The repeatability of optometrists at gonioscopy and other ocular
anterior chamber angle assessment methods on adults within a
community optometric setting.

REC reference: 11/LO/0834

Thank you for your e-mail of 18 August 2011, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair, in consultation with Dr Morven Leese (statistician).

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Ethical review of research sites

NHS sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to

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the National Patient Safety Agency and Research Ethics Committees in England

the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at <http://www.rdforum.nhs.uk>

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Other conditions specified by the REC

Protocol

There are a number of typos/grammatical errors on P3:

1. Determine the repeatability an optometrists at gonioscopy and other angle assessment methods.

Needs to be changed to:

Determine the repeatability of an optometrist at gonioscopy and other angle assessment methods.

2. Research Questions needs to be changed to Research Question

3. What is the repeatability an optometrists at gonioscopy and other anterior angle assessment methods?

Needs to be changed to:

What is the repeatability of an optometrist at gonioscopy and other anterior angle assessment methods?

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

You should notify the REC in writing once all conditions have been met (except for site approvals from host organisations) and provide copies of any revised documentation with updated version numbers. Confirmation should also be provided to host organisations together with relevant documentation.

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Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Covering Letter: from Peter Campbell		19 May 2011
Evidence of insurance or indemnity: Zurich Municipal		01 July 2010
GP/Consultant Information Sheets: Letter to optometrists	1.1	19 May 2011
Investigator CV: Peter Campbell		20 May 2011
Letter from Sponsor: from London South Bank University		28 January 2011
Other: CV for academic supervisor: Prof Bruce Evans		
Participant Consent Form	2.0	04 August 2011
Participant Information Sheet	2.1	04 August 2011
Protocol	2.0	04 August 2011
REC application: 73033/216041/1/758		25 May 2011
Response to Request for Further Information: e-mail from Peter Campbell		18 August 2011

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document "*After ethical review – guidance for researchers*" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

Feedback

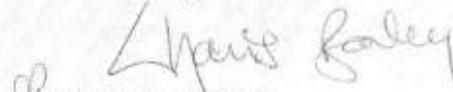
You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

Further information is available at National Research Ethics Service website > After Review

This Research Ethics Committee is an advisory committee to East of England Strategic Health Authority
The National Research Ethics Service (NRES) represents the NRES Directorate within the National Patient Safety Agency and Research Ethics Committees in England

With the Committee's best wishes for the success of this project

Yours sincerely


Mr John Richardson
Chair

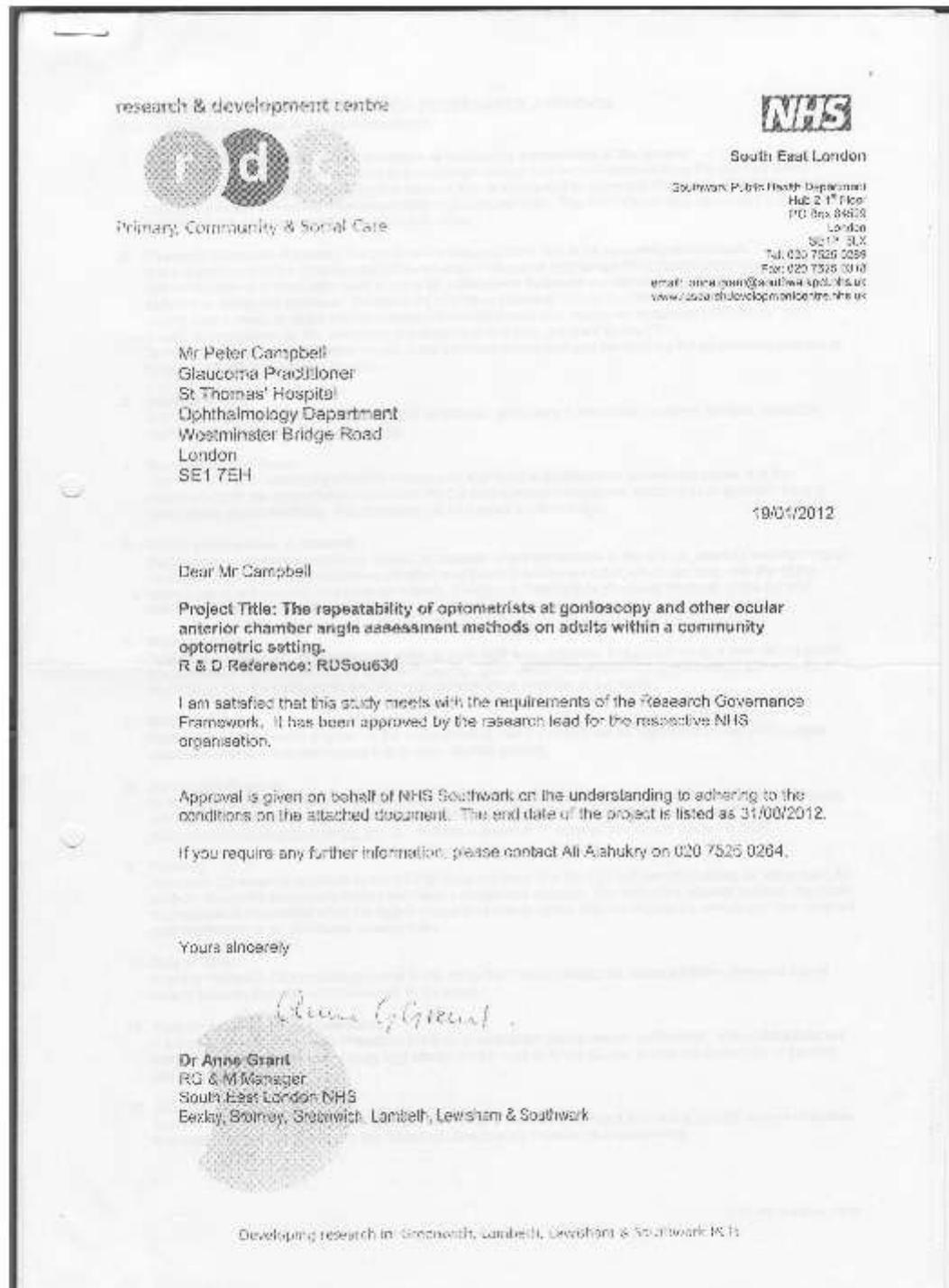
Email: charis.bailey@eoe.nhs.uk

Enc: "After ethical review – guidance for researchers" [SL-AR2]

CC: Nicola Crichton
Institute of Primary Care and Public Health, Faculty of Health and Social Care
London South Bank University
103, Borough road
London
SE1 0AA

Dr Anne Grant
Research Support Unit Southwark PCT
Public Health Dept
2nd Floor, Woodmill
Neckinger
London
SE16 3QN

Appendix C2 NHS Research and Development Approval Letter



Appendix C3 LSBU REC Approval Letter

**London South Bank
University**

Direct line: 020-7815 6024
E-mail: dippenas@lsbu.ac.uk
Ref: UREC 1203

Peter Campbell
Professional Doctorate Student
Student Number 2802116

Dear Peter,

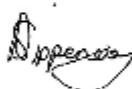
The repeatability of anterior chamber angle assessment tests

Thank you for submitting the documents from the review and acceptance of your study from the NHS REC Ethics Committee approval for your Study 3.

I am pleased to inform you this ethical approval has been upheld by Chair's action on behalf of the University Research Ethics Committee.

I wish you every success with your research.

Yours sincerely,



Sharon Dippenaar
Secretary, LSBU Research Ethics Committee

cc:

Prof Joan Curzio, Chair, LSBU Research Ethics Committee

Appendix C4 Participant Information Sheet for Study 3

RESEARCH PARTICIPANT INFORMATION SHEET

Version 2.1

Title of Study: The repeatability of anterior angle assessment tests

You are being invited to take part in a research study which is part of a Professional Doctorate qualification at London South Bank University. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

One of the tests carried out in glaucoma diagnosis involves looking at the area where the fluid inside the eye (called the aqueous humour) drains away. This area is called *the drainage angle* and it is examined in order to classify the type of glaucoma a person might have. The most accurate way to do this is by using a mirrored contact lens. This procedure is called gonioscopy and is normally carried out by an ophthalmologist (eye doctor) within a hospital setting but can also be carried out by an optometrist (ophthalmic optician).

The other methods of assessing the angle include the van Herick grading system where the structures of the front of the eye are compared in terms of their thickness. This is routinely carried out by optometrists during eye examinations. A third method of examining the drainage angle involves using an imaging device called an AS-OCT (Anterior Segment Optical Coherence Tomography) to capture images of the angle.

The purpose of this study is to compare the findings of optometrists at gonioscopy and other methods of angle assessment on two separate visits, one month apart. This is in order to see how reliable and repeatable optometrists are at these tests.

Why have I been chosen?

You are invited to take part in this study as your optometrist had identified you as someone suitable to have these tests carried out.

Do I have to take part?

No it is entirely up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect in any way your standard of care at this practice.

What will happen to me if I take part?

You will be contacted to arrange two dates for you to come in for the set of tests.

What do I have to do?

The whole visit should last approximately 45 minutes.

After a discussion with you, tests will be carried using the equipment familiar to you from your previous eye examinations.

The front and back of the eyes will be examined, the eye pressure will be measured and the drainage angle will be assessed using the methods outlined above. Each test lasts approximately 4-5 minutes.

What are the side effects of any treatment received when taking part?

Gonioscopy is the standard method of assessing the drainage angle by optometrists and ophthalmologists in an optician practice or in the hospital eye service for over seventy years.

During gonioscopy a mirrored lens comes close to the eye and you may experience slight discomfort on your eye lids during the procedure. This is entirely normal. A gel is placed on the lens during the examination and some of this gel may remain on the eye lashes after the examination. This is easily removed with a tissue at the end of the examination.

What are the possible disadvantages and risks of taking part?

Gonioscopy is a recognized procedure and professional guidelines will be followed at all times. Drops will be used to numb the eye. These last for 20 minutes during which time you should not rub your eyes. There is a very small risk of an eye infection or allergic reaction from gonioscopy and if this occurs it is easily treated with eye drops.

What are the possible benefits of taking part?

The information obtained from taking part in this study may help in the early detection of glaucoma by optometrists in the future and allow more optometrists to become involved in glaucoma service provision.

What if something goes wrong?

Any discomfort you may feel after your examination should resolve after a few minutes. If your eyes become painful, red or sticky afterwards contact the practice to seek advice or contact me directly on the number below. If you are unable to obtain help then contact your local Accident and Emergency Department.

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential in accordance with the Data Protection Act 1998. Any information about you which is shared with others will have your name and address removed so that you cannot be recognized from it.

The information obtained from this study will be retained for 7 years.

Who has reviewed the study?

The Camberwell St Giles Research and Ethics Committee has reviewed this study

Contact for Further Information

Do not hesitate to contact me with any questions

Thank you for your time.

Peter Campbell

Institute of Optometry

56-62 Newington Causeway

London SE1 6DS

Tel 07900 216729

"One or Two, Three or Four...?" Developing Gonioscopy Competency Skills in a NHS Trust

P Campbell^{1,2,3}, R Agarwal^{2,3}, T Redmond⁴, KS Lim¹, BJW Evans^{2,3}



- 1. St Thomas' Hospital, London
- 2. Institute of Optometry, London
- 3. London South Bank University, London
- 4. Dalhousie University, Halifax, Canada

Introduction

Glaucoma is a group of eye conditions characterized by a progressive damage to the optic nerve, if left untreated it leads to impaired vision and blindness¹. In April 2009 the National Institute for Health and Clinical Excellence (NICE) published a guideline on the diagnosis and management of chronic open angle glaucoma and ocular hypertension². One of the recommendations is that all people suspected of having glaucoma undergo gonioscopy at their diagnosis and again when clinically indicated. Optometrists and other allied health professionals (AHPs) who are competent at gonioscopy will prove valuable in the future management of patients with glaucoma and ocular hypertension. Gonioscopy is not, however, routinely carried out in UK optometric practice³.

New patients referred to the glaucoma service at St. Thomas' Hospital often undergo gonioscopy first by an optometrist or other AHP (nurse practitioner, orthoptist) and then by a consultant ophthalmologist. The AHPs have received in house training in gonioscopy. The aim of this study is to compare the gonioscopy findings of AHPs with those of a consultant ophthalmologist (considered the gold standard).

Methods

This study was registered as a Clinical Audit with Guy's and St Thomas' Research and Development Department in January 2011 and ethical approval was obtained from London South Bank University Research Ethics Committee.

Gonioscopy results were analysed for patients who had gonioscopy first carried out by one AHP and repeated by one of the two consultant ophthalmologists. The consultant was masked to the AHP's findings. One eye was chosen at random for the analysis. Gonioscopy is graded using a scale 0-4 for each quadrant of the anterior chamber angle (see Figure 1). For the purpose of analysis, the AHP and Consultant findings were classified into two categories: open or occludable (see Figure 2). There are no clinical precedents in place for evaluating competency in gonioscopy. Using the consultant ophthalmologist as the gold standard, sensitivity and specificity levels were set at 85% for the AHPs.

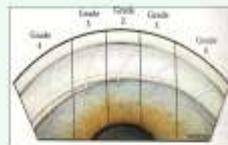


Figure 1. Gonioscopy Slit-lamp grading (from reproduced notes of Zarb, 2001)

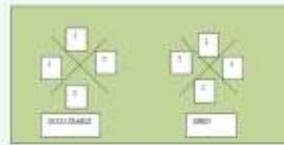


Figure 2. Classification of Occludable and Open-angle Occludable. One quadrant (O) or more (Grade 1-3) is Open. All four quadrants (Grade 4) are Occludable.

Results

Gonioscopy datasheets containing AHP and consultant findings have been used in clinic since 26/10/10. Results have been analysed for 100 patients where gonioscopy was first carried out by one of three AHPs and repeated by one of two consultants. Figure 3 outlines the results for the AHPs and consultant. Agreement, between AHPs and the consultants, using the kappa statistic was calculated as $\kappa=0.710$. Table 1 shows the sensitivity and specificity results for the AHPs.

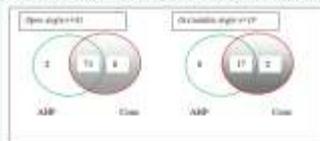


Figure 3. Venn Diagram showing percentage agreement for AHP (Open angle) vs. consultant (Open angle) and for AHP (Occludable) vs. consultant (Occludable).

Table 1	
Sensitivity (proportion of "occludable" correctly identified by the AHP)	17/17 (100%) = 100.0%
Specificity (proportion of "open" correctly identified by the AHP)	73/77 (94.8%) = 94.8%

Discussion

Optometrists and other AHPs who have been received training in gonioscopy show good levels of competency (greater than 85% sensitivity and specificity). There is a lack of evidence in the literature comparing gonioscopy results amongst clinicians. Further work is needed comparing the gonioscopy findings between ophthalmologists and between AHPs. It would also be useful to investigate the agreement between classification of the angle by gonioscopy, van Herick and by novel methods such as anterior segment optical coherence tomography (OCT).

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Acknowledgements

This study forms part of the research towards a Professional Doctorate in Optometry at the Institute of Optometry, London South Bank University. Statistical analysis was performed using SPSS version 16.0 (SPSS Inc, Chicago, IL).

Repeatability and Comparison of Anterior Chamber Angle Assessment Tests

933 - A0285

P Campbell^{1,2,3}, T Redmond^{2,4}, R Agarwal^{2,3}, KS Lim¹, BJW Evans^{2,3}

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- 2 Institute of Optometry, London, UK
- 3 Faculty of Health and Social Care, London South Bank University, London, UK
- 4 Cardiff Centre for Vision Sciences, School of Optometry and Vision Sciences, Cardiff University, Cardiff, UK

INTRODUCTION

Glaucoma is the leading cause of irreversible blindness worldwide. Gonioscopy is the gold standard method in assessing the anterior chamber angle (ACA) and is essential in the differential diagnosis of primary angle closure glaucoma (PACG) and primary open angle glaucoma (POAG). Gonioscopy is a clinically demanding skill and is semi-subjective in nature. The van Herick technique of estimating the limbal chamber depth is widely used as a screening test to identify occludable angles. It has been shown to have good sensitivity and specificity at predicting occludable damage angles compared to gonioscopy¹. Optical Coherence Tomography (OCT) offers an objective method of imaging the anterior chamber angle. It has been shown to have good sensitivity but poor specificity compared to gonioscopy². The majority of scientific investigations into ACA assessment have taken place in East Asia; there has been little published data from European derived populations.

In the UK, the number of cases of POAG is predicted to increase by a third from 2003 to 2021³ and the number of cases of PACG is expected to increase by 19% over the next decade⁴. New evidence is required to evaluate the van Herick technique in comparison with other methods of ACA assessment in a European population.

AIM

The aim of this study is to look at the repeatability of gonioscopy, van Herick and anterior segment (AS) OCT and assess the agreement between these techniques within a community optometry setting.

METHODS

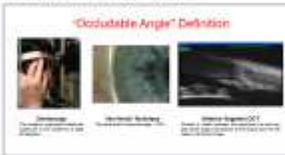
Ethical approval was obtained by the Camberwell and St Giles, London NHS Research Ethics Committee, and by London Southbank University Research Ethics Committee.

Subjects >40 years were recruited from community optometry practice. Exclusion criteria were subjects with corneal disease or any previous ocular laser or intra-ocular surgery. All subjects underwent van Herick, gonioscopy and AS-OCT in a darkened room (20-30 lux) by one examiner (PC) on two occasions, one month apart. For the van Herick test, a narrow vertical beam was directed at the temporal limbus, offset by 60°. The temporal and nasal limbal chamber angle was estimated using a modified grading scheme⁵. Gonioscopy was performed in the primary position with a one mirror hand held MagnaView gonioscopes (Ocular Instruments Inc., Bellevue, WA). Slight tilting of the lens was permitted. All four quadrants were graded using the Sheffer grading scheme.

Anterior Segment images were captured with a spectral domain OCT wavelength 840nm (Topcon 3D OCT-2000, Topcon Europe Medical B.V. Netherlands) set to the Anterior Segment (AS) mode. A 3mm line scan size was selected and the scan count was set at 32. The scan zone was centred on the limbus, two scans of the nasal and temporal quadrant images were captured. These were graded by a second researcher (JM) masked to the gonioscopy and van Herick method results.

DATA ANALYSIS

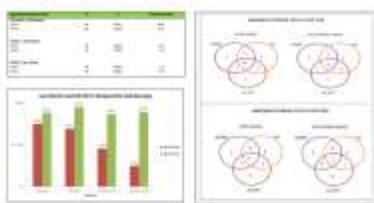
An ACA was classified as open or occludable for each test (see Figure 1). One eye was randomly selected for inclusion in the analysis. Statistical analysis was carried out using SPSS (v18, SPSS Inc., Chicago, IL). The weighted kappa κ_w was used to measure repeatability and agreement, see Appendix 1 for weighting used. The likelihood ratio was also calculated to assess the value of the van Herick technique and AS-OCT at identifying an occludable angle, as classified by gonioscopy.



Results were obtained for 80 eyes of 60 subjects (see Table 1). Two OCT images were deemed ungradable due to poor quality imaging. Repeatability was found to be good for both the van Herick technique and AS-OCT, and fair for gonioscopy (see Table 2). Agreement between gonioscopy and van Herick was good. Agreement between gonioscopy and OCT was fair, as was the agreement between van Herick and OCT (see Table 3). The likelihood ratio values were good for van Herick technique (VH) and poor for the AS-OCT at both sites.

Method	Open	Occludable	Total
Van Herick	15	10	25
Gonioscopy	12	13	25
AS-OCT	10	15	25

Sensitivity and specificity values were good for the van Herick technique. Sensitivity was poor for AS-OCT when compared to gonioscopy (see Figure 2). Comparison of the results for all three tests at each visit is shown in Figure 3.



DISCUSSION

Gonioscopy, despite being a semi-subjective test, is the gold standard method for detecting primary angle closure. Community optometrists in the UK routinely carry out the van Herick test and increasingly have access to OCT technology. In this study, intra-observer repeatability was good for van Herick technique and for AS-OCT, whilst it was fair for gonioscopy. Gonioscopy is subject to greater variability than van Herick technique and AS-OCT. When compared to gonioscopy, the van Herick technique appeared to show better agreement than AS-OCT.

This study is limited by the fact all three tests are carried out by one examiner. A second researcher, masked to the gonioscopy and van Herick findings, analysed the acquired AS-OCT images and thereby reduced any further bias in the findings.

It is also limited by the use of a posterior segment OCT (Topcon 3D-2000) operating at 840nm. A standalone Anterior Segment OCT operating at a longer wavelength (1300nm) gives a better view of the ACA due to less scattering of infrared light. However, posterior Segment OCTs are more widely available in ophthalmology units and are increasingly used in optometric practice. Imaging of the anterior segment with posterior segment machines has been shown to give good visualisation of the ACA⁶.

CONCLUSION

Our findings indicate that the van Herick technique may be preferable to anterior segment OCT (Topcon 3D-2000) when considering alternatives to gonioscopy. OCT instruments that are specifically designed for anterior segment imaging are likely to perform better but are not widely available in clinical practice in the UK at present.

DISCLOSURES

PC: College of Optometrists, UK (F), Topcon (Great Britain Ltd) (F), TR: Heidelberg Engineering GmbH (F)

Thank you to Lewis Marshall (LM) Optometrist at Cole, Martin and Tregalga Optometrists (Dorchester, Dorset, UK) for his help analysing the AS-OCT results.



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