



City Research Online

City, University of London Institutional Repository

Citation: Ratnarajan, G., Newsom, W., Vernon, S. A., Fenerty, C., Henson, D., Spencer, F., Wang, Y., Harper, R. A., McNaught, A., Collins, L., Parker, M., Lawrenson, J., Hudson, R., Khaw, P. T., Wormald, R., Garway-Heath, D. F. and Bourne, R. (2013). The effectiveness of schemes that refine referrals between primary and secondary care - the UK experience with glaucoma referrals: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways Project. *BMJ Open*, 3(7), doi: 10.1136/bmjopen-2013-002715

This is the unspecified version of the paper.

This version of the publication may differ from the final published version.

Permanent repository link: <https://openaccess.city.ac.uk/id/eprint/3762/>

Link to published version: <http://dx.doi.org/10.1136/bmjopen-2013-002715>

Copyright: City Research Online aims to make research outputs of City, University of London available to a wider audience. Copyright and Moral Rights remain with the author(s) and/or copyright holders. URLs from City Research Online may be freely distributed and linked to.

Reuse: Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge. Provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

City Research Online:

<http://openaccess.city.ac.uk/>

publications@city.ac.uk

The effectiveness of schemes that refine referrals between primary and secondary care – the UK experience with glaucoma referrals: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways Project

Gokulan Ratnarajan,^{1,2,3} Wendy Newsom,^{4,5} Stephen A Vernon,⁶ Cecilia Fenerty,⁷ David Henson,⁷ Fiona Spencer,⁷ Yanfang Wang,⁷ Robert Harper,⁷ Andrew McNaught,⁸ Lisa Collins,⁸ Mike Parker,⁹ John Lawrenson,¹⁰ Robyn Hudson,¹ Peng Tee Khaw,⁵ Richard Wormald,⁵ David Garway-Heath,⁵ Rupert Bourne^{1,2,4,5}

To cite: Ratnarajan G, Newsom W, Vernon SA, *et al*. The effectiveness of schemes that refine referrals between primary and secondary care—the UK experience with glaucoma referrals: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways Project. *BMJ Open* 2013;3:e002715. doi:10.1136/bmjopen-2013-002715

► Prepublication history and additional material for this paper is available online. To view these files please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2013-002715>).

Received 11 February 2013
Revised 29 April 2013
Accepted 31 May 2013

This final article is available for use under the terms of the Creative Commons Attribution Non-Commercial 3.0 Licence; see <http://bmjopen.bmj.com>

For numbered affiliations see end of article.

Correspondence to

Dr Gokulan Ratnarajan;
g.ratnarajan@gmail.com

ABSTRACT

Objectives: A comparison of glaucoma referral refinement schemes (GRRS) in the UK during a time period of considerable change in national policy and guidance.

Design: Retrospective multisite review.

Setting: The outcomes of clinical examinations by optometrists with a specialist interest in glaucoma (OSIs) were compared with optometrists with no specialist interest in glaucoma (non-OSIs). Data from Huntingdon and Nottingham assessed non-OSI findings, while Manchester and Gloucestershire reviewed OSI findings.

Participants: 1086 patients. 434 patients were from Huntingdon, 179 from Manchester, 204 from Gloucestershire and 269 from Nottingham.

Results: The first-visit discharge rate (FVDR) for all time periods for OSIs was 14.1% compared with 36.1% from non-OSIs (difference 22%, CI 16.9% to 26.7%; $p<0.001$). The FVDR increased after the April 2009 National Institute for Health and Clinical Excellence (NICE) glaucoma guidelines compared with pre-NICE, which was particularly evident when pre-NICE was compared with the current practice time period (OSIs 6.2–17.2%, difference 11%, CI –24.7% to 4.3%; $p=0.18$, non-OSIs 29.2–43.9%, difference 14.7%, CI –27.8% to –0.30%; $p=0.03$). Elevated intraocular pressure (IOP) was the commonest reason for referral for OSIs and non-OSIs, 28.7% and 36.1%, respectively, of total referrals. The proportion of referrals for elevated IOP increased from 10.9% pre-NICE to 28.0% post-NICE for OSIs, and from 19% to 45.1% for non-OSIs.

Conclusions: In terms of ‘demand management’, OSIs can reduce FVDR of patients reviewed in secondary care; however, in terms of ‘patient safety’ this study also shows that overemphasis on IOP as a criterion for referral is having an adverse effect on both the non-OSIs and indeed the OSIs ability to detect

ARTICLE SUMMARY

Article focus

- Can specialist trained optometrists reduce the first-visit discharge rate of patients identified in primary care as being at risk of glaucoma and therefore reduce the burden on the hospital eye service?
- What is the temporal trend in first-visit discharge rates?
- What is a safe model of glaucoma referral refinement that can be used to establish a national framework?

Key messages

- Specialist trained optometrists can reduce the first-visit discharge rate of patients subsequently reviewed in secondary care compared with direct referrals from non-specialist optometrists (36.1% vs 14.1%, difference 22%, CI 16.9% to 26.7%; $p<0.001$). However, in terms of ‘patient safety’ this study also shows that the overemphasis on intraocular pressure as a criterion for referral is having an adverse effect on both the specialist and non-specialist optometrist’s ability to detect glaucomatous optic nerve features.
- First-visit discharge rates have increased in the time periods post National Institute for Health and Clinical Excellence (NICE) glaucoma guideline publication, and are continuing to increase, particularly for the optometrists with no specialist interest in glaucoma.
- It is the authors’ recommendation that patients with a high chance of being diagnosed with glaucoma based on the examination findings of the non-specialist optometrist should be referred directly to secondary care and those at lower risk could effectively be reviewed by a specialist trained optometrist carrying out a comprehensive eye examination.

ARTICLE SUMMARY

Strengths and limitations of this study

- This is the first multisite review of glaucoma referral refinement schemes in the UK.
- The time series for the study was carefully selected to encompass all the major changes in clinical guidelines and practice since 2009. However, by definition a retrospective observational time series study will not provide data on all time points.
- The false-negative rate, or percentage of patients who were inappropriately discharged by the specialist and non-specialist optometrists, is not known. This will be addressed in an upcoming prospective study using the recommendations of this report.

glaucomatous optic nerve features. It is recommended that referral letters from non-OSIs be stratified for risk, directing high-risk patients straight to secondary care, and low-risk patients to OSIs.

INTRODUCTION

Glaucoma is the world's leading cause of irreversible blindness.¹ This progressive optic neuropathy is characterised by damage to the optic nerve head and nerve fibre layer, with visual field (VF) loss which is usually asymptomatic until the disease becomes advanced. Up to 20% of referrals to ophthalmology clinics in the UK are for suspected glaucoma, with the annual cost for monitoring patients with this chronic, and potentially blinding condition estimated to be £22 469 000.²⁻³

In the UK, most referrals for suspected glaucoma are generated through opportunistic surveillance during sight tests by primary care optometrists (hereafter referred to as an optometrist with no specialist interest in glaucoma, non-OSI).³⁻⁵

As part of a sight test, the non-OSI is required to perform an examination of the optic disc using funduscopy. If clinically indicated they may measure the intraocular pressure (IOP) typically using 'air puff' non-contact tonometry (NCT) which is prone to higher variability and overestimating the IOP (in individuals with thick corneas) compared with Goldmann contact tonometry used in hospital ophthalmology departments.⁶ VF testing is also carried out if clinically indicated and completes the established triad of examinations/tests to detect glaucoma.

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

The National Institute for Health and Clinical Excellence (NICE) guidelines for the diagnosis and management of chronic open-angle glaucoma and ocular hypertension (OHT; elevated IOP but no signs of glaucomatous optic disc damage or VF loss) were

published in April 2009.⁷⁻⁹ These guidelines however did not include in their remit guidance on the detection and referral of suspected glaucoma by community optometrists as it was felt this would make the guidelines unmanageably large.¹⁰

The representative organisation for the optometry profession and individual optometrists, the Association of Optometrists (AOP), response to these guidelines was as follows:

English and Welsh PCTs and Health Boards may not have the resources to cope with the numbers of referrals – many of which, because they will have had their pressures taken using NCT, will be false positives. Nevertheless, in the absence of funding to repeat pressures using Goldmann, the AOP believes strongly that optometrists have no choice other than to refer a patient who has a sign of ocular hypertension – e.g. pressures measured at over 21 mm Hg, using whatever tonometer they choose. To identify a sign of OHT and then not to act on it could be considered to be unprofessional, especially when the correct course of action has been well researched, by a panel of experts in the field, using evidence-based methods, and has been officially published by NICE.¹¹

Prior to this, an optometrist would use their clinical judgement as to whether a patient with normal ocular examination and a borderline IOP warranted referral based on other risk factors such as age and family history. However, after the AOP's recommendation, many of these patients are now being referred with a resultant surge in the number of referrals for suspected glaucoma and, consequently, an increase in first-visit discharges.^{9 12-14}

In December 2009, an attempt by the Royal College of Ophthalmologists and College of Optometrists to reduce the total number of first-visit discharges was made by issuing Joint College Guidance (JCG) in relation to patients with OHT with low risk of significant VF loss in their lifetime. It was recommended that optometrists consider not referring patients aged over 80 years with an IOP of less than 26 mm Hg with an otherwise normal ocular examination. For patients aged between 65 and 80 years this IOP criterion was less than 25 mm Hg, as current NICE guidance does not recommend offering treatment to these subsets of patients. For the latter group, it was recommended that these individuals be reviewed annually by a community optometrist.¹⁵ The most recent JCG, published in March 2013, recommended introduction of repeat IOP measurement schemes to reduce false-positive referrals to the hospital eye service, and recommended where possible to facilitate the implementation of glaucoma referral refinement schemes (GRRS) to further reduce the false-positive referral rate.¹⁶

GRRS have proliferated across the country over the past decade, often demonstrating marked variation in pathway design, referral criteria as well as the level of competency and training required by the participating optometrists.¹⁷⁻²⁴ This study, the largest and only multi-site review of GRRS in the UK, aimed to investigate if

specialist trained optometrists can effectively reduce the first-visit discharge rate (FVDR) of patients identified in primary care as being at risk of glaucoma and therefore reduce the burden on the hospital eye service. Using the data from this report, a safe and efficient model of glaucoma referral refinement is described that can be used to establish a much-needed national framework for GRRS. This study was carried out by the Department of Health's initiative called The North East, North Central London and Essex Health Innovation & Education Cluster (HIEC) Glaucoma pathway project.²⁵

METHODS

The outcomes of GRRS in Huntingdon, Manchester, Gloucestershire and Nottingham were retrospectively analysed during four 2-month time periods: pre-NICE (March and up to 22 April 2009, when the guidelines were published), post-NICE (November and December 2009), post-JCG (August and September 2010) and current practice (March and April 2011). Ethical approval at each trust was obtained prior to data collection.

Each scheme is organisationally distinct and reflects the range of variation between schemes nationally (figure 1). The Huntingdon, Manchester and Gloucestershire schemes are all community based, whereas the Nottingham

scheme is hospital based. A more detailed description of each scheme and a summary table 2 is found in an online supplementary appendix.

Each scheme requires participating optometrists to gain local accreditation of core optometric competencies (such as Goldmann contact tonometry, slit-lamp binocular indirect ophthalmoscopy and VF interpretation) through a hospital approved training scheme. A specialist qualification in glaucoma is not a prerequisite.²⁶⁻²⁸

The inclusion criteria for Huntingdon and Nottingham were referrals from non-OSIs as well the subsequent findings from the next eye health professional (for Nottingham and low-risk Huntingdon patients this was the optometrist with specialist interest in glaucoma (OSI) and for high-risk Huntingdon patients this was a glaucoma consultant). The inclusion criteria for Manchester and Gloucestershire were referrals from OSIs and the subsequent hospital visit. Referrals from any other source were excluded.

Statistical analysis

Data from electronic and paper patient records and paper referral letters were collated using Microsoft Excel; statistical analysis was performed in R (V.2.15.1, R Foundation for Statistical Computing, Vienna, Austria). Percentages of FVDR were compared using Fisher's

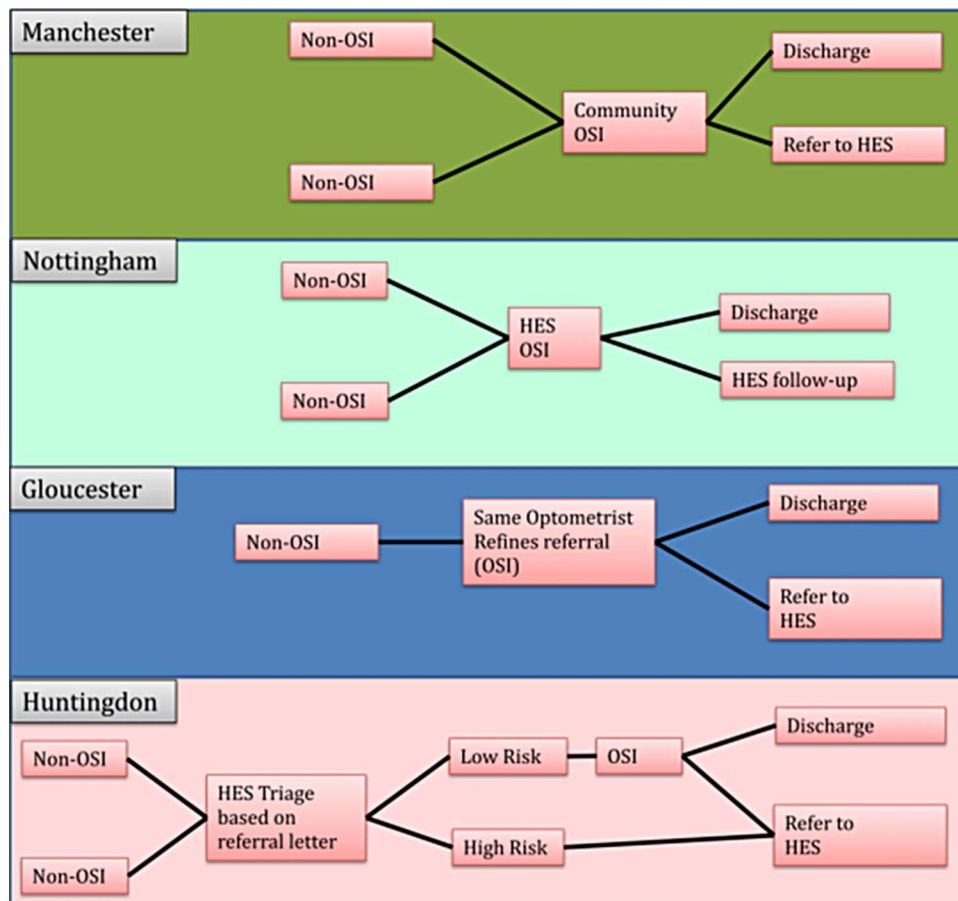


Figure 1 Schematic flow chart of the organisational structure of each of the four glaucoma referral refinement schemes. HES, hospital eye service.

exact test, and confidence limits for the differences between percentages were calculated using Newcombe's Hybrid Score Interval Method. Confidence limits and p values within a set of factor levels have been corrected for multiplicity using the Dunn-Sidak method.

FVDR, the main outcome metric for this analysis, is defined as the percentage of referrals from an OSI or a non-OSI that was discharged at the first visit to the final provider. FVDR was chosen in preference to 'false-positive rate', the chosen outcome metric in the published literature on this topic to date, as no inference of the appropriateness or falseness of referral is implied as this may be governed by local policy.

Agreement rates on diagnostic accuracy and FVDR always use the diagnosis given by the final clinician, and assume their findings to be the gold standard. For Nottingham and low-risk Huntingdon this is the OSI, and for Manchester, Gloucestershire and high-risk Huntingdon this was the consultant ophthalmologist.

RESULTS

Data of 1086 patients (48% men, mean age 63 years) were analysed: 190 (17.5%) pre-NICE, 338 (35.7%) post-NICE, 287 (26.4%) post-JCG and 271 (25%) from the current practice group; 434 (42% men, mean age 62 years) patients were from Huntingdon (304 high and 130 low risk), 179 (57% men, mean age 62 years) from Manchester, 204 (55% men, mean age 64 years) from Gloucestershire and 269 (46% men, mean age 62 years) were from Nottingham.

Fifty-six percent of patients referred from OSIs were men compared with 44% from non-OSIs. Mean age of patients referred by the OSIs was 63 years compared with 62 years for non-OSIs.

Reason for referral from non-OSI and OSI optometrists

The most common reason for referral by a non-OSI across all observation periods was for an elevated IOP only (36.1%). In the pre-NICE time frame, IOP-only referrals accounted for 19% of referrals, which increases to 45.1% in the post-NICE period. This was coupled with a decrease in many other stated reasons for referral by the non-OSI, particularly those not including IOP,

exemplified by disc-only referrals, which reduced from 15.9% (20 referrals) pre-NICE to 6.1% (12 referrals) post-NICE.

The most common reason for OSI referral across all observation periods was also for raised IOP only (28.8%), though a less marked increase (10.9% vs 28%) post-NICE was observed compared with non-OSIs. However, in terms of rate of increase for IOP only referrals post-NICE, this was similar for both groups (×2.6 increase for OSIs and ×2.4 increase for non-OSIs).

FVDR associated with non-OSI and OSI optometrists

The overall FVDR for referrals by a non-OSI was 36.1% and for OSI referrals was 14.1% (difference 22% CI 16.9% to 26.7%, p<0.001). FVDR for combination of each site and time period is given in table 1. When interpreting these data it is important to note that for Nottingham and Huntingdon, FVDR is for referrals from non-OSIs, while for Manchester and Gloucestershire, FVDR is that of referrals from OSIs.

FVDR pre-NICE was 21.9% compared with 35.4% in the current practice time period (difference 13.5%, CI -23.8% to -2.4%; p=0.006). For OSIs, FVDR was 6.3% pre-NICE and 17.2% current practice (difference 11.0%, CI -24.7% to 4.3%; p=0.18) and for non-OSIs FVDR was 29.2% pre-NICE and 43.9% current practice (difference 14.7%, CI -27.8% to -0.30%; p=0.03).

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

A referral for suspected glaucoma is characteristically based on the finding of an elevated IOP, an abnormal optic disc appearance, an abnormal VF or a combination of these findings. These patients are then classified as either having glaucoma, a suspicion of glaucoma ('glaucoma suspect') or as being normal. The largest source of first-visit discharges for both non-OSIs and OSIs was for IOP-only related referrals, with 83.5% and 55% of these, respectively, being discharged. Referrals based on more than one criterion, such as those for abnormal IOP, optic disc and VFs, resulted in fewer first-visit discharges (40.8% non-OSI and 25.7% OSI). More details are given in figure 2.

Table 1 First-visit discharge rate by site and by time period

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

JCG, Joint College Guidance; NICE, National Institute for Health and Clinical Excellence; non-OSI, optometrist with no specialist interest in glaucoma; OSI, optometrist with specialist interest in glaucoma.

DISCUSSION

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

Reason for referral from non-OSI and OSI optometrists

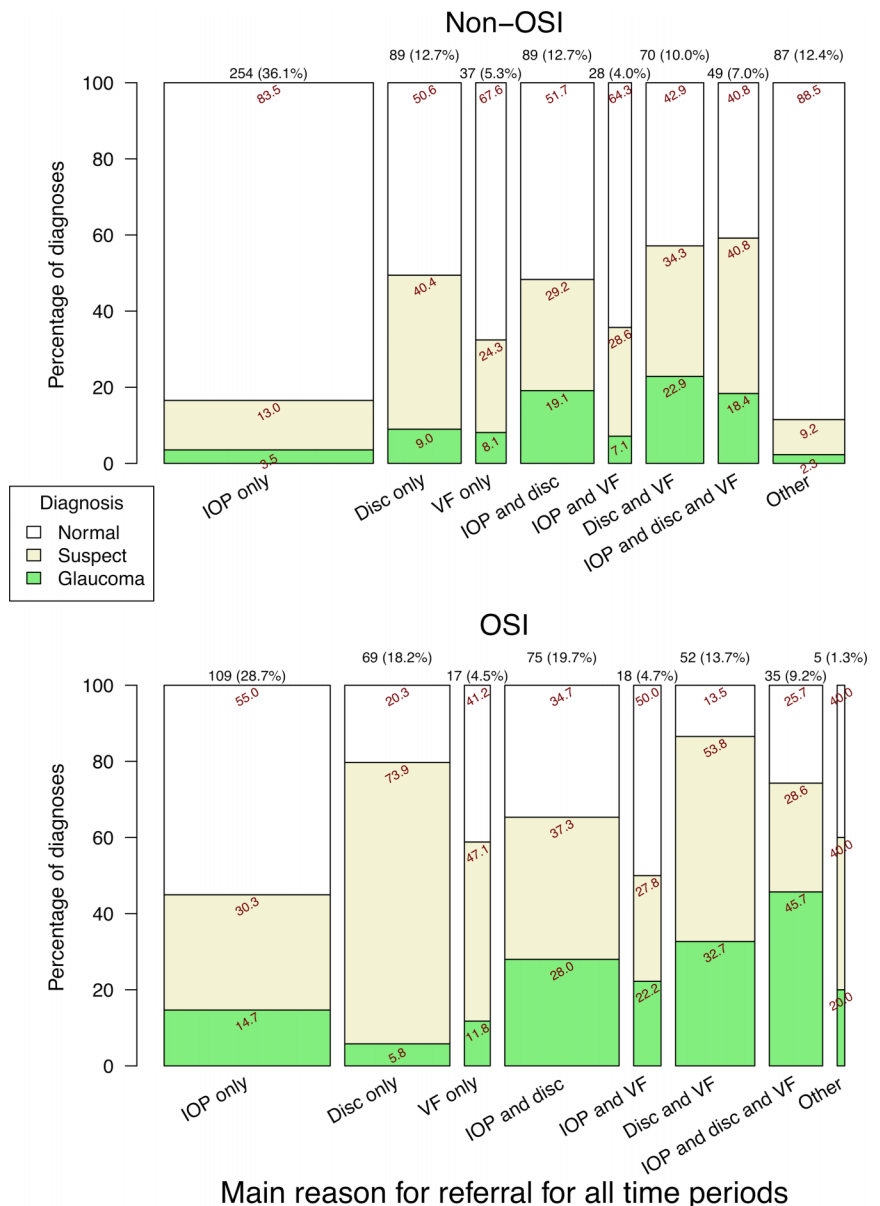
Both non-OSIs and OSIs demonstrated a similar trend for the stated reasons for referral with IOP-only referrals being the largest category for referral, 36.1% and 28.7%, respectively, followed by referrals for elevated IOP and abnormal optic disc, 12.8% and 19.6%, respectively. Disc-only referrals and disc and VF referrals were the next largest categories in both groups, with the smallest category being for elevated IOP and a suspicious VF.

In contrast, the temporal trend observed among the stated reasons for referral for the non-OSI and OSI

displayed marked variation. All referral categories by a non-OSI not involving IOP as a referral criterion demonstrated a decline post-NICE compared to pre-NICE. The reverse was seen for referrals involving IOP, particularly IOP-only referrals which increased from 19% (24 referrals) to 45.1% (96 referrals). The AOP's response to the NICE guidelines seems to have had much less effect on the temporal trend in referrals generated by OSIs. Exceptions being IOP-only referrals which increased 2.6-fold post-NICE (10.9% pre-NICE to 28% post-NICE), and referrals citing IOP, optic disc and VFs decreased from 26.6% (16 referrals) to 6.4% (7 referrals). This would suggest that, post-NICE, optometrists initiating referrals concentrate more on IOP as a reason for referral with less emphasis being placed on concurrent assessment of the optic nerve and VF.

It would seem that the introduction of JCG was successful in reducing the proportion of referrals by a

Figure 2 The outcomes of patients referred by optometrist with no specialist interest in glaucoma (non-OSIs, top) and optometrist with specialist interest in glaucoma (OSIs, bottom). The width of each bar is representative of the proportion of the total referral base.



non-OSI for only a raised IOP (45.1–32%) after the large increase post-NICE. This trend was not observed in the OSI group where the proportion of referrals for raised IOP only actually increased from 28% to 41.5%. This may seem surprising but may reflect the improved quality of referrals from non-OSIs.

FVDR associated with non-OSI and OSI optometrists

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

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

The introduction of JCG did not lower FVDR in either group, as would have been expected, with FVDRs unchanged from the post-NICE period. This may be because the undue perception of the importance of IOP over other aspects of the ocular examination still remained. However, the current practice FVDR in the Manchester scheme did reduce to 3% from 16.9% in the post-JCG time period, and may represent a delay in the full implementation of JCG criteria by its participating OSIs. Despite this for both OSIs and non-OSIs as a whole, the highest FVDRs were in the current practice time period, with the latter group reaching a statistical significant increase in FVDR compared with pre-NICE. This suggests the need for further multistakeholder guidance (such as the JCG) regarding detection and referral of suspected glaucoma to be used in conjunction with the NICE guidance on the diagnosis and management of glaucoma and OHT. In addition, if AOP's recommendation were withdrawn, this may have a significant impact on improving the quality of referrals and therefore lowering FVDR.

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

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

The width-adjusted bar graphs of outcome of referral based on reason for referral (figure 2) demonstrates the large proportion of IOP-only referrals and its low diagnostic yield. In the referrals by a non-OSI, only 16.5% of these patients were given a follow-up appointment, with

just 3.5% diagnosed with primary open angle glaucoma. These values were considerably higher for the OSI-initiated referrals (45% and 14.7%, respectively). These findings highlight that IOP-only referrals represent a waste of hospital outpatient resource. However, 14.7% of these IOP-only referrals by OSIs were subsequently diagnosed with glaucoma. This implies either the OSI had missed glaucomatous optic disc pathology, or the extra expertise of the consultant ophthalmologist assisted by additional imaging modalities available in the hospital was able to identify the optic disc pathology.

In total, 79.7% of OSI referrals compared with only 49.4% of non-OSI referrals for solely a suspicious optic disc appearance were followed up by the hospital, which suggests, the extra training received by OSIs resulted in more accurate referrals. However, the percentage of patients actually diagnosed with glaucoma at the hospital eye service was low in both OSI and non-OSI, 5.8% and 9%, respectively. This demonstrates that the consultant ophthalmologist classified the majority of these referrals as glaucoma suspect.

Multiple criterion referrals by OSI, such as an abnormal IOP, optic disc and VF, resulted in a higher percentage of patients being diagnosed with glaucoma, 45.7%. This leads the authors to question the effectiveness of OSI in such referrals as a substantial proportion will be subsequently referred to secondary care. The scheme in Huntingdon has adopted risk stratification through a paper triage of the referrals by a non-OSI carried out by the hospital, with only patients found to have one risk factor deemed low risk and therefore suitable for glaucoma referral refinement. Our findings would suggest that the stratification of the referral letter according to risk, a strategy that could be incorporated across all medical specialties, could be an effective method to ensure patients with a high probability of having glaucoma are seen directly by secondary care without the need for the additional examination by an OSI. This is reflected by the most recent glaucoma publication from NICE in March 2012: The NICE commissioners guide 'services for people at risk of developing glaucoma' which was produced to provide commissioners of eye services guidance as to how to safely and effectively manage patients at risk of glaucoma.²⁹ It recommends that patients with an IOP of greater than 30 mm Hg should be referred directly to secondary care.

Limitations

There are some limitations of this study which are important to consider. The false-negative rate, or percentage of patients who were inappropriately discharged by non-OSIs and OSIs, is not known. This will be addressed in an upcoming prospective study using the recommendations of this report.

The final provider in the schemes was not always a consultant ophthalmologist, and therefore a reference standard could not be applied across all the schemes

that were evaluated. Again this will be addressed in the upcoming prospective study.

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

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

Recommendations

This report of activity from four established referral refinement schemes of differing design has highlighted a continually increasing FVDR post-NICE. This study has also demonstrated that specialist trained optometrists (OSIs) can successfully refine the referrals from non-OSIs for suspected glaucoma leading to a statistically significant reduction in FVDR. It is the authors' recommendation that patients with a high chance of being diagnosed with glaucoma based on the examination findings of the non-OSI should be referred directly to secondary care and those at lower risk could effectively be reviewed by an OSI carrying out a comprehensive eye examination. The results of this analysis lead us to recommend that 'low risk' should be defined as referrals based on IOP only, optic disc only, VF only and IOP and VF, with all other referrals including any reference to a shallow anterior chamber angle better suited to a direct referral to secondary care.

The inclusion of VF and disc examination is clearly associated with a lower FVDR and, therefore, the authors recommend that detailed disc and VF examination form part of the referral refinement in conjunction with Goldmann/Perkins tonometry for measuring IOP. Using the referral criteria of the 2009 JCG crucially allows the optometrist to operate within a professional and legal framework, and can lower FVDR as shown by the Manchester GRRS in the current practice time frame.

Author affiliations

¹The North East, North Central London and Essex Health Innovation & Education Cluster

²Vision and Eye Research Unit, Postgraduate Medical Institute, Anglia Ruskin University, Cambridge, UK

³UCL Institute of Ophthalmology, London, UK

⁴Huntingdon Glaucoma Diagnostic & Research Centre at Hinchingbrooke Hospital, Huntingdon, UK

⁵NIHR Biomedical Research Centre at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology, London, UK

⁶Nottingham University Hospitals NHS Trust, Nottingham, UK

⁷Manchester Royal Eye Hospital and Manchester Academic and Health Science Centre, Central Manchester University Hospitals NHS Foundation Trust, Manchester, UK

⁸Gloucestershire Hospitals NHS Foundation Trust, Gloucester, UK

⁹Postgraduate Medical Institute, Anglia Ruskin University, Cambridge, UK
¹⁰Division of Optometry and Visual Science, City University London, London, UK

Acknowledgements The authors would like to acknowledge the optometrists and ophthalmologists involved in the referral refinement schemes.

Contributors GR and RB conceived the idea of the study. GR, WN, SAV, DH, AMN, LC, RH, RW, DGH and RB were responsible for the design of the study. GR and MP provided input into the data analysis. The initial draft of the manuscript was prepared by GR and then circulated repeatedly among all authors for critical revision. WN, SAV, DH, YW, AMN, LC and RB were responsible for the acquisition of the data and all authors contributed to the interpretation of the results. All authors read and approved the final version of the manuscript.

Funding The Health Innovation & Education Cluster provided funding for data collection.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement More detailed information including appendices can be provided by the corresponding author, at g.ratnarajan@gmail.com

REFERENCES

1. Quigley HA. Number of people with glaucoma worldwide. *Br J Ophthalmol* 1986;80:389–93.
2. <http://www.nice.org.uk/nicemedia/live/12145/44043/44043.pdf>
3. Davey CJ, Green C, Elliott DB. Assessment of referrals to the hospital eye service by optometrists and GPs in Bradford and Airedale. *Ophthalmic Physiol Opt* 2011;31:23–8.
4. Bowling B, Chen SD, Salmon JF. Outcomes of referrals by community optometrists to a hospital glaucoma service. *Br J Ophthalmol* 2005;89:1102–4.
5. Burr JM, Mowatt G, Hernández R, et al. The clinical effectiveness and cost-effectiveness of screening for open angle glaucoma: a systematic review and economic evaluation. *Health Technol Assess* 2007;11:1–190.
6. Vincent SJ, Vincent RA, Shields DRA, et al. Comparison of intraocular pressure measurement between rebound, non-contact and Goldmann applanation tonometry in treated glaucoma patients. *Clin Experiment Ophthalmol* 2012;40:e163–70.
7. <http://guidance.nice.org.uk/CG85/NiceGuidance/pdf/English>
8. Vernon SA. The changing pattern of glaucoma referrals by optometrists. *Eye* 1998;12:854–7.
9. Shah S, Murdoch IE. NICE—impact on glaucoma case detection. *Ophthalmic Physiol Opt* 2011;31:339–42.
10. Sparrow JM. How nice in NICE? *Br J Ophthalmol* 2013;97:116–17.
11. Association of Optometrists. 2010. Advice on NICE glaucoma guidelines. <http://www.aop.org.uk/practitioner-advice/enhanced-services/glaucoma-nice-guidelines/>
12. Ratnarajan G, Newsom W, French K, et al. Impact of glaucoma referral refinement criteria on referral to, and first-visit discharge rates from, the hospital eye service: the Health Innovation & Education Cluster (HIEC) Glaucoma Pathways project. *Ophthalmic Physiol Opt* 2013;33:183–9.
13. Ratnarajan G, Newsom W, French K, et al. The effect of changes in referral behaviour following NICE Guideline publication on agreement of examination findings between professionals in an established glaucoma referral refinement pathway. The Health Innovation & Education Cluster (HIEC) Glaucoma Pathways project. *Br J Ophthalmol* 2013;97:210–14.
14. Edgar D, Romanay T, Lawrenson J, et al. Referral behaviour among optometrists: increase in the number of referrals from optometrists following the publication of the April 2009 NICE Guidelines for the diagnosis and management of COAG and OHT in England and Wales and its implications. *Optom Pract* 2010;11:33–8.
15. Guidance on the referral of Glaucoma suspects by community optometrists. The College of Optometrists and Royal College of Ophthalmologists. 2010. <http://www.college-optometrists.org/en/utilities/document-summary.cfm/docid/B7251E0C-2436-455A-B15F1E43B6594206>
16. Commissioning better eye care. The College of Optometrists and Royal College of Ophthalmologists. 2013. <http://www.college-optometrists.org/en/utilities/document-summary.cfm/4B0BE038-E6B2-49B4-B913529D58F2F038>

17. Bourne RRA, French KA, Chang L, *et al.* Can a community optometrist-based referral refinement scheme reduce false-positive glaucoma hospital referrals without compromising quality of care? The Community and hospital allied network glaucoma evaluation scheme (CHANGES). *Eye* 2010;24:881–7.
18. Henson DB, Spencer AF, Harper R, *et al.* Community refinement of glaucoma referrals. *Eye* 2003;17:21–6.
19. Parkins DJ, Edgar DF. Comparison of the effectiveness of two enhanced glaucoma referral schemes. *Ophthalmic Physiol Opt* 2011;31:343–52.
20. Syam P, Rughani K, Vardy SJ, *et al.* The Peterborough scheme for community specialist optometrists in glaucoma: a feasibility study. *Eye* 2010;24:1156–64.
21. Devarajan N, Williams GS, Hopes M, *et al.* The Carmarthenshire Glaucoma Referral Refinement Scheme, a safe and efficient screening service. *Eye* 2011;25:43–9.
22. Ang GS, Ng WS, Azuara-Blanco A. The influence of the new general ophthalmic services (GOS) contract in optometrist referrals for glaucoma in Scotland. *Eye* 2009;23:351–5.
23. LOCSU glaucoma pathways. http://www.locsu.co.uk/uploads/enhanced_pathways_2012/locsu_glaucoma_rr_oht_monitoring_pathway_rev_june_2012.pdf
24. Hawley C, Albrow H, Sturt J, *et al.* UK Eye Care Services Project. College of Optometrists. <http://www.college-optometrists.org/en/research/commissioned-research-2/index.cfm/ServicesProject>
25. <http://www.necles.org.uk/whatwedo/eyesvision/index.html>
26. <http://www.college-optometrists.org/en/utilities/document-summary.cfm?docid=2E04330D-91F6-48DB-B39DC69D6737EF6A>
27. <http://www.wopec.co.uk/courses>
28. <http://www.city.ac.uk/courses/cpd/glaucoma#course-detail=0>
29. <http://www.nice.org.uk/usingguidance/commissioningguides/glaucoma/glaucoma.jsp>