



Burden of Glaucoma in the United Kingdom

A Multicenter Analysis of United Kingdom Glaucoma Services

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Objective: To determine the spectrum of glaucoma-associated health care resource utilization among out-patients attending National Health Service (NHS) hospital glaucoma clinics and the costs of managing glaucoma in this setting.

Design: Retrospective observational cohort study using electronic medical record data.

Subjects: Patients aged ≥ 18 years attending 5 NHS glaucoma clinics in the United Kingdom (2013–2018) with ≥ 12 months of continuous electronic medical record data.

Methods: Deidentified Medisoft Ophthalmology electronic medical record data (January 2013–December 2018) from 43 742 eligible patients were categorized by year of clinic visit. Extracted information included patient demographics, glaucoma diagnoses, topical glaucoma medication prescription start/stop dates, types/numbers of glaucoma clinic visits, glaucoma investigations (visual acuity, intraocular pressure, visual field, and OCT), and glaucoma procedures received over 12 months after the first (“index”) visit of the specified year. Direct glaucoma-related health care costs (clinic visits, investigations, procedures, and ongoing glaucoma medication initiated in the clinic) were estimated from event volumes and unit costs (UK national tariffs) and expressed from the direct-payer perspective.

Main Outcome Measures: Glaucoma diagnoses and topical glaucoma medication use at the index clinic visit; numbers of glaucoma clinic visits, investigations and procedures; and glaucoma-related health care costs over 12 months postindex.

Results: For the 2016 cohort ($n = 21\ 719$), the estimated average total cost of NHS-provided glaucoma care over 12 months was £405 per patient (medical staff services £209, glaucoma investigations £126, glaucoma medication £40, glaucoma procedures £26). Among this cohort, 40.8% had ocular hypertension/suspected glaucoma, 70% had 0-to-mild visual field impairment, and 14% had undergone a glaucoma procedure. Over 12 months, patients received (mean) 2.0 glaucoma clinic visits and 1.5 visual field tests, and 7% underwent glaucoma procedure(s). Results were similar for the other years examined.

Conclusions: Cost estimates for managing patients with glaucoma in the UK are required for effective service planning. Appreciable proportions of patients managed in NHS glaucoma clinics may be considered at low risk of blindness (glaucoma suspects and those with ocular hypertension with mild visual field loss) and may be more appropriately managed with alternative, more affordable models of care. *Ophthalmology Glaucoma 2022*; ■:1–10 © 2022 by the American Academy of Ophthalmology. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).



Supplemental material available at www.ophtalmologyglaucoma.org.

Glaucoma affects approximately 4% of the population aged > 50 years in the UK, according to community-based findings (2004–2011) from the European Prospective Investigation of Cancer-Norfolk Eye Study.¹ The majority of affected individuals require regular active monitoring and management to prevent irreversible vision loss.

Glaucoma care currently accounts for an estimated 20% of hospital eye service outpatient workload in the UK,² with over 1 million glaucoma-related outpatient visits made each year to

hospital eye services in England.³ With an aging population, increased access to sight testing, and more rigorous optometry screening (including the use of retinal imaging),^{4,5} the number of glaucoma-related outpatient referrals can be expected to rise.⁶ Limited capacity within hospital eye service clinics has led to significant backlogs of patients awaiting follow-up appointments,^{7,8} and these have been exacerbated by the deferral of outpatient visits during the coronavirus disease 2019 pandemic. To cope with these pressures, future

delivery of glaucoma care is likely to involve a shift to risk-stratification approaches and triaging of patients between consultant-led face-to-face clinics, optometrist-led clinics, and technician-led “virtual” clinics.⁹

Understanding the spectrum of disease managed and the costs of service are important for optimizing the value of health care and enabling informed decisions on service planning. However, there is limited published information on the cost of managing glaucoma within the UK hospital eye service.^{10–12} To address this gap, we used electronic medical record (EMR) data from 5 hospital-based ophthalmology centers in the UK that collectively manage the majority of local patients with glaucoma within the National Health Service (NHS). The objectives of this study were to: (1) characterize the spectrum of diagnoses, disease severity, and associated health care resource use among outpatients attending selected NHS hospital glaucoma clinics and (2) apply health economic techniques to quantify the costs of glaucoma management in this setting.

Methods

Study Design and Data Source

This retrospective observational study was based on an analysis of Medisoft Ophthalmology (Medisoft Ltd) EMR data (January 1, 2013–December 31, 2018) from 5 NHS Hospital Trusts in the UK. Medisoft Ophthalmology is used by > 150 ophthalmology departments in hospitals across the UK to record clinic visits, ophthalmic investigations/procedures, and clinical outcomes. Data were recorded within 9 specialist modules, including a glaucoma module.¹³ Data extracted from Medisoft Ophthalmology EMRs at each participating center were deidentified at source before analysis. Patient demographics were obtained from the Patient Administration System at each participating center using Medisoft EMR software. The study was conducted in accordance with the guidelines of the European Network of Centres for Pharmacoepidemiology and Pharmacovigilance and the International Society for Pharmacoepidemiology.^{14,15} Because the study did not directly involve human subjects, identifiable human material, or identifiable human data, it was exempt from the requirement for institutional review board/ethics committee approval. All research adhered to the tenets of the Declaration of Helsinki.

Participant Selection

Patients attending a glaucoma clinic during the period from January 1, 2013 to December 31, 2018 were identified from the EMR dataset and were assigned to 5 study cohorts categorized according to the calendar year of clinic attendance (2013, 2014, 2015, 2016, and 2017). A patient with clinic visits in > 1 calendar year would be eligible for inclusion in > 1 cohort. A glaucoma clinic visit was defined as a clinical encounter that: (1) involved an intraocular pressure (IOP) measurement obtained with applanation tonometry and (2) was coded with the clinical category descriptor “Glaucoma” or “General.” For study inclusion, patients were additionally required to be: (1) ≥ 18 years of age at the time of their first recorded glaucoma clinic visit (“index visit”) in the specified calendar year and (2) to have ≥ 12 months of Medisoft EMR follow-up data from the date of the index visit.

Study Measures

Parameters of interest included patient demographics, glaucoma diagnosis, topical glaucoma treatments at the time of the index visit, numbers of glaucoma clinic visits, investigations and procedures recorded over the first 12 months postindex, and associated glaucoma-related health care costs over the same period. To provide a cross-sectional picture of treatment patterns and health care resource use, outcomes of interest were assessed in the individual 2013, 2014, 2015, 2016, and 2017 index-year cohorts. The 2016 cohort was selected as the primary year for representative results because it was the most recent year allowing at least 2 years of follow-up data, thereby minimizing the exclusion of participants without the required 12 months of follow-up. Detailed results for the 2016 cohort are presented here, together with summary findings for the other index-year cohorts.

Glaucoma diagnosis at the index visit (or, if unavailable, the most recent diagnosis before the index visit) was established at the patient level, with “mixed diagnosis between or within eyes” indicating either nonmatching diagnoses in the left and right eyes or multiple glaucoma diagnoses in the same eye.

Glaucoma investigations of interest comprised visual acuity (VA) measurement with habitual correction or pinhole, IOP measurement (applanation tonometry), visual field (VF) testing (limited to the Humphrey 24-2 test program for summarizing mean deviation), and OCT examination. Visual field impairment was classified as mild (mean deviation > -6 dB), moderate (mean deviation -6 dB to -12 dB) or advanced (mean deviation < -12 dB).¹⁶ Only VF results with false-positives $< 20\%$ were considered in analyses. Glaucoma procedures were identified by name in the EMR dataset and assigned a corresponding Health care Resource Group code for the purpose of costing.

Glaucoma-Associated Health Care Costs

Direct glaucoma-related health care costs, including costs of glaucoma clinic visits, glaucoma investigations (VA, IOP, Humphrey 24-2 VF tests, and OCT examinations), glaucoma procedures, and glaucoma medications, were estimated from unit costs (based on UK national tariffs¹⁷) and event volumes and expressed at the patient level. Glaucoma-related health care cost was further stratified by VF impairment and diagnosis at index event, collapsed into one of the following categories: “primary open-angle glaucoma,” “ocular hypertension,” “glaucoma suspect,” “primary angle-closure glaucoma,” “other glaucoma diagnosis” (encompassing primary dispersion syndrome/glaucoma, pseudoexfoliation syndrome/glaucoma, other secondary open-angle glaucoma, secondary angle-closure glaucoma, acute angle-closure glaucoma, congenital glaucoma, juvenile glaucoma, aqueous misdirection, and glaucoma—other/undetermined), “no evidence of glaucoma,” and “mixed diagnosis between or within eyes.”

Cost estimations were conducted from the direct-payer perspective: patients’ out-of-pocket expenses, costs for primary care (except for ongoing costs for glaucoma medication initiated by the clinic), and postprimary care outside the specialist glaucoma setting (e.g., accident and emergency department costs) were not considered. Annual costs covered events that occurred over the 12-month period after (and including) the index date.

Glaucoma clinic visits were categorized according to the health care professional (nurse or clinician) encountered by the patient and timing of the visit (initial or follow-up). In the UK, the specialist glaucoma nurse—acting under the supervision of a consultant ophthalmologist—is involved in screening and diagnosis of ocular hypertension and suspected glaucoma in newly identified patients, as well as monitoring and management of established glaucoma

Table 1. Demographic and Baseline Clinical Characteristics of Study Patients, Categorized by Index-Year Cohort

Characteristic	2013 Cohort (n = 17 985)	2014 Cohort (n = 22 566)	2015 Cohort (n = 21 863)	2016 Cohort (n = 21 719)	2017 Cohort (n = 22 807)
Age at index clinic visit (yrs)					
Mean (SD)	70.0 (13.0)	70.5 (13.0)	70.9 (12.8)	71.5 (12.7)	71.5 (12.7)
Range	18–102	18–103	18–104	18–105	19–104
Women, % patients	52.1	52.5	51.7	51.7	52.5
Ethnicity, % patients					
White	90.3	90.9	91.9	91.2	89.2
Asian	1.7	1.7	1.4	1.5	1.4
Black	1.0	1.1	1.2	1.3	1.0
Other	0.8	0.9	1.0	1.1	1.2
Unknown	6.2	5.4	4.6	4.9	7.2
Index of multiple deprivation, decile*					
Mean (SD)	6.3 (2.8)	6.2 (2.8)	6.2 (2.8)	6.3 (2.8)	6.1 (2.9)
Diabetes, % patients					
Type 1 diabetes	1.0	0.9	0.9	1.0	1.0
Type 2 diabetes	12.5	12.4	12.1	12.5	11.5
Nondiabetic	48.6	46.9	42.8	45.8	44.8
Status unknown	37.9	39.8	44.2	40.8	42.8
Hypertension, % patients	40.6	38.9	37.4	37.9	34.9
Smoker, % patients	6.2	5.9	5.4	5.4	5.1
Glaucoma family history, % patients	47.0	44.1	40.1	41.5	40.1

SD = standard deviation

*Index of multiple deprivation is a measure of socioeconomic status of neighborhoods in England; residential areas are ranked from 1 (most deprived) to 32844 (least deprived) and divided into 10 equal groups (deciles), where 1 represents the most deprived 10% and 10 represents the least deprived 10%.

patients.³ In all patient–doctor encounters, patients were assumed to have been seen initially by a nurse; however, patients could also have nurse-only appointments in which they only saw a nurse and not a doctor. Unit costs per encounter, based on the UK national tariff for 2019 to 2020,¹⁷ were the following: new patient–doctor encounter £133, subsequent patient–doctor encounter £59, first patient–nurse encounter £97, and subsequent patient–nurse encounter £42. Glaucoma investigation costs included a fixed outpatient tariff of £58 for each visit (irrespective of the number of investigations performed during the visit). Average annual costs per patient for glaucoma investigations were based on the number of unique days on which investigations occurred.

Glaucoma procedures were costed according to the UK national outpatient procedure tariff or, for those procedures requiring hospitalization, the combined day case/ordinary elective spell tariff for their specified Healthcare Resource Group code (Table S1, available at www.opthalmologyglaucoma.org). Multiple procedures performed on the same day, or multiple procedures recorded under a single entry, were costed according to the complexity of each procedure, the associated risks, and likely operational constraints (Table S2, available at www.opthalmologyglaucoma.org).

The Medisoft EMR database provides information on patients' prescribed eye drop medication, prescription start and stop dates for each medication, and the number of prescriptions dispensed, but not on medication pack size. For costing purposes, pack size (i.e., days' medication supply) was calculated from prescription frequency and dosing frequency. Prescription medication costs were obtained from UK drug tariffs for 2019/2020 (Table S3, available at www.opthalmologyglaucoma.org).¹⁸ Patients' time on each eye drop medication during the 12-month postindex period was calculated from prescription start and stop dates. This method provides an indication of duration of treatment with each medication but makes no assumptions about the patient's level of adherence with medication.

Data analyses were conducted using R (R Foundation, Vienna, Austria) (<https://www.r-project.org/>).¹⁹

Results

Cohort Demographics and Medical History

In total, 43 742 unique patients were identified as attending a glaucoma clinic at a participating NHS Hospital Trust between 2013 and 2018 and meeting the study eligibility criteria; of these, 21 719 patients had a clinic visit in the selected representative index year (2016).

The 2016 cohort had a mean age of 71.5 years (range, 18–105 years), comprised similar proportions of men (48%) and women (52%) and was predominantly (91%) of White ethnicity (English, Welsh, Scottish, Northern Irish, British, Gypsy or Irish traveler, Roma, or any other White background). A substantial proportion of patients had a recorded cardiovascular risk factor, including diabetes (13.5%), hypertension (37.9%), and smoking (5.4%), or a family history of glaucoma (41.5%). Demographic and clinical characteristics of the 2016 index-year cohort closely matched those of the other index-year cohorts (Table 1).

Clinical Features

For those patients in the 2016 cohort with a recorded glaucoma-related diagnosis (n = 17 737), the most frequent diagnosis was primary open-angle glaucoma (36.4%), followed by ocular hypertension (21.8%), “glaucoma suspect” (19.0%), “mixed diagnosis between or within eyes” (12.4%), “other glaucoma diagnosis” (7.8%), “no evidence of glaucoma” (2.0%), and “primary angle-closure spectrum” (0.5%) (Fig 1). A more detailed breakdown of glaucoma-related diagnoses is presented in Table 2.

Intraocular pressure measurements conducted at the 2016 index clinic visit (n = 21 563 patients) indicated a mean (standard deviation [SD]) value of 16.6 (4.8) mmHg in the eye with higher

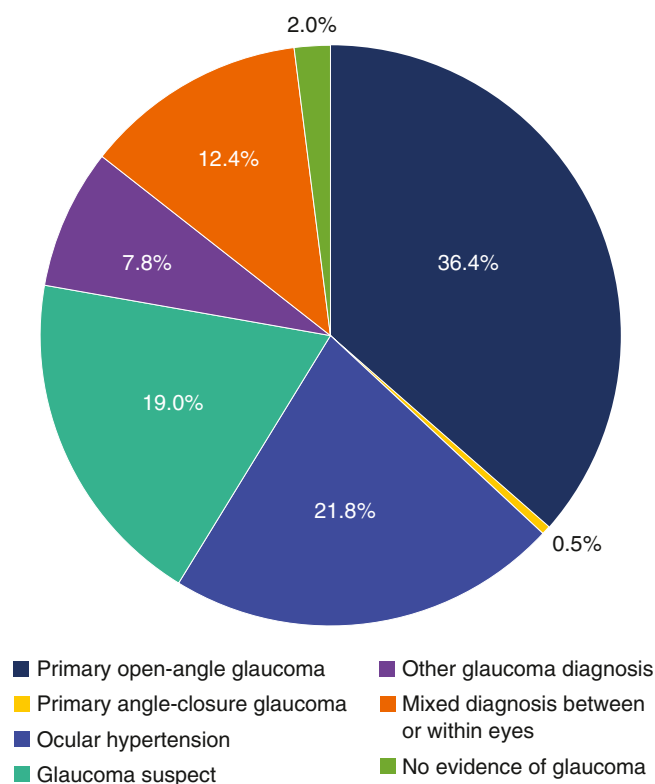


Figure 1. Index diagnosis among patients in the 2016 cohort with a recorded glaucoma diagnosis (N = 17 737).

pressure, with 75.8% of patients having IOP \leq 21 mmHg, 16.4% having IOP 22 to 26 mmHg, and 7.8% having IOP \geq 27 mmHg. Similarly, VF recordings obtained either at the index clinic visit or within the first 12 months postindex (n = 14 361 patients) showed mean deviation to be, on average, -2.68 dB (SD 4.39 dB) in the better eye and -5.38 dB (SD 6.32 dB) in the worse eye. Within this cohort, the majority of patients (69.9%) had mild (“early”) VF impairment in the worse affected eye; a minority of patients (15.8% and 14.3%, respectively) had moderate and advanced VF impairment in their worse eye (Fig 2). In terms of IOP, VF, and VA findings and pattern of glaucoma diagnoses at the index visit, the 2016 index-year cohort was similar to the other index-year cohorts (Table 2).

Patient Management over 12 Months Postindex

Over the course of 12 months’ follow-up (inclusive of the index clinic visit), patients in the 2016 cohort underwent a mean (SD) of 2.04 (1.63) clinic visits (range, 1–24). The number of clinic visits (inclusive of the index visit) over this period varied according to glaucoma severity (ranging from mean [SD] 1.75 [1.18] in patients with early VF impairment to 2.60 [2.17] in those with advanced VF impairment) and baseline IOP (ranging from mean [SD] 1.88 [1.49] in patients with IOP \leq 16 mmHg to 3.73 [2.54] in those with IOP \geq 32 mmHg) (Fig 3).

Over the course of 12 months’ follow-up (inclusive of the index clinic visit), patients in the 2016 cohort were recorded as undergoing on average 1.52 (range, 0–28) VA tests, 2.08 (range, 1–29)

IOP tests, 1.53 (range, 0–13) VF tests, and 0.07 (range, 0–8) OCT examinations. This latter figure is likely to be a gross underestimate of the actual number of OCT examinations performed because the Medisoft EMR system does not automatically capture OCT scanning events. The average numbers of clinic visits and glaucoma investigations received per patient over 12 months were similar across all index-year cohorts (Table 3).

In total, 7.3% of patients in the 2016 cohort underwent a glaucoma procedure over the 12-month postindex period, and the mean (SD) time from index clinic visit to the first glaucoma procedure was 3.9 (3.2) months. In total, 22 different types of single glaucoma procedure and 27 different combinations of multiple glaucoma procedure were performed during the 12-month postindex period, of which laser peripheral iridotomy (n = 588), selective laser trabeculoplasty (n = 297), and injection of bleb (antimetabolite) with trabeculectomy (n = 191) were the most common, accounting for 62.3% of total procedure volumes (N = 1726) (Tables S1 and S2).

At the time of their index clinic visit, 28%, 16%, 9%, and 2.5% of patients, respectively, in the 2016 cohort were receiving 1, 2, 3, and 4+ classes of prescribed ocular hypotensive medication, whereas 45% of patients had no current eye drop prescription. The most commonly prescribed medications were prostaglandin analogs (49%) followed by β -blockers (24%), carbonic anhydrase inhibitors (18%), α -agonists (5%), and pilocarpine (0.6%). In total, 12 750 prescriptions for topical glaucoma medication were issued to the study population during the 12-month follow-up period, with bimatoprost (26.3%), latanoprost (15.0%), bimatoprost/timolol combinations (11.2%), brinzolamide (10.1%), timolol (6.1%), and latanoprost/timolol combinations (5.3%) accounting for the bulk of prescription volumes (Table S2).

Glaucoma-Associated Health Care Costs

For patients in the 2016 cohort, the estimated average total direct cost of glaucoma-related health care was £405 per patient per annum. Approximately 50% of this cost was represented by clinical encounters (£209 per patient per annum), comprising £100.0 for encounters with doctors and £109.9 for those with nurses. Nursing services accounted for a relatively high proportion of medical staff service costs as patients could attend nurse-only clinics where they would not be seen by a doctor; in addition, the cost analysis assumed that patients were seen by a nurse at all doctor visits. After medical staff services, costs were attributed to glaucoma investigations (£126), topical glaucoma medication (£40), and glaucoma procedures (£30). These values and relative proportions were approximately reflected in the corresponding costs of glaucoma clinic care for the 2014 and 2015 index-year cohorts (Table 4).

On stratification of costs by glaucoma diagnosis at the index event (2016 index-year cohort), the total annual direct cost of glaucoma-related health care was highest in patients with primary open-angle glaucoma (£444) followed by mixed diagnosis between or within eyes (£430), other glaucoma diagnosis (£415), ocular hypertension (£320), and suspected glaucoma (£289) (Table 5). Stratification of costs by severity of VF impairment in the worse affected eye indicated that patients with early (mild) impairment incurred the lowest cost (£352) followed by those with advanced (£500) and moderate (£512) VF impairment (Table 5).

Table 2. Distribution of Diagnoses and Summarized Baseline Intraocular Pressure, Visual Field, and Visual Acuity Findings, Categorized by Index-Year Cohort

	2013 Cohort (n = 17 985)	2014 Cohort (n = 22 566)	2015 Cohort (n = 21 863)	2016 Cohort (n = 21 719)	2017 Cohort (n = 22 807)
Diagnosis, % patients					
Acute angle-closure glaucoma	0.2	0.2	0.3	0.03	0.4
Aqueous misdirection	0.02	0.01	0.02	0.02	0.03
Congenital glaucoma	0.02	0.01	0.02	0.03	0.04
Glaucoma (other/undetermined)	0.5	0.5	0.6	0.6	0.6
Glaucoma suspect	15.7	15.6	15.7	15.5	16.7
Juvenile glaucoma	0.02	0.01	0.01	0.02	0.03
Mixed diagnosis between or within eyes*	12.3	10.6	9.5	10.2	11.2
No recorded diagnosis	32.3	28.2	23.1	18.3	6.7
No evidence of glaucoma	1.9	1.7	1.5	1.6	1.5
Ocular hypertension	13.3	14.6	16.5	17.8	18.0
Pigment dispersion syndrome or glaucoma	0.9	1.0	1.2	1.1	1.2
Primary angle-closure spectrum	2.8	2.5	2.6	3.1	3.2
Primary open-angle glaucoma	19.2	23.8	27.8	29.8	29.0
Pseudoexfoliation syndrome or glaucoma	0.3	0.4	0.3	0.5	0.5
Secondary angle-closure glaucoma	0.3	0.3	0.3	0.3	0.4%
Other secondary open-angle glaucoma	0.4%	0.5	0.6	0.7	0.7
IOP, mmHg	n = 17 985	n = 22 566	n = 21 863	n = 21 719	n = 22 807
Mean (SD) lower pressure eye	16.6 (4.4)	16.4 (4.4)	16.6 (4.6)	16.6 (4.8)	16.4 (4.7)
Mean (SD) higher pressure eye	18.5 (5.3)	18.3 (5.3)	18.7 (5.6)	18.8 (5.8)	18.8 (6.0)
VF, mean deviation, dB	n = 12 317	n = 15 567	n = 14 285	n = 14 361	n = 14 868
Mean (SD) better eye	-2.17 (4.10)	-2.37 (4.24)	-2.51 (4.21)	-2.68 (4.39)	-2.79 (4.34)
Mean (SD) worse eye	-4.49 (5.87)	-4.76 (5.97)	-5.06 (6.11)	-5.38 (6.32)	-5.53 (6.30)
VA, ETDRS letters	n = 11 476	n = 12 516	n = 12 806	n = 12 380	n = 13 139
Mean (SD) better eye	80.5 (11.1)	80.4 (11.1)	80.1 (11.1)	79.6 (11.5)	79.3 (11.8)
Mean (SD) worse eye	71.8 (21.2)	71.2 (21.7)	70.3 (21.9)	68.7 (22.8)	68.3 (23.0)

dB = decibel; ETDRS = Early Treatment Diabetic Retinopathy Study; IOP = intraocular pressure; SD = standard deviation; VA = visual acuity; VF = visual field.

*Nonmatching diagnoses in the left and right eyes, or multiple glaucoma diagnoses in the same eye.

Discussion

Using EMR data from a large cohort of patients (n = 21 719) representative of those attending hospital glaucoma clinics between 2013 and 2018, this retrospective cross-sectional analysis yielded a mean estimate for the annual direct cost of glaucoma-related health care within the UK hospital eye service of £405 per patient, ranging from (mean) £352 to £512 across the spectrum of disease severity. Of the patients comprising this cohort (2016 index-year), the majority (86%) had no history of a glaucoma procedure, and many were receiving either no topical glaucoma medication (45%) or at most a single class of topical glaucoma medication (i.e., monotherapy; 28%) on presentation for their index clinic visit of 2016. Over the following 12 months, these patients underwent on average 2.0 glaucoma clinic visits and 1.5 VF tests, and 7% received a glaucoma procedure. Approximately one-third were being managed for ocular hypertension or suspected glaucoma, and most (70%) had no worse than mild VF impairment (mean deviation > -6 dB), implying a low risk of progression to blindness. This is a sizable group that may be suitable for alternative, more affordable models of care delivery.

Published information on the direct cost of glaucoma care within the UK NHS is limited. An earlier study (2013) based on retrospective data from patients (n = 106) who had

initiated treatment for primary open-angle glaucoma, normal tension glaucoma, or ocular hypertension at the glaucoma clinic at Glasgow Royal Infirmary (Scotland) and had lifetime health care resource use data estimated the mean lifetime cost of glaucoma management at £3001 per patient (based on a duration of clinic attendance of 1–22 [mean 7.1] years), or £475 per patient annually, with nondrug costs (outpatient clinic visits, glaucoma surgical and medical procedures, and ophthalmology admissions) and drug costs accounting for 66% and 34%, respectively, of the overall lifetime cost, but provided no breakdown of cost by disease severity.²⁰ Patients with primary open-angle glaucoma had a significantly higher average lifetime cost (£3386) than patients with normal tension glaucoma or ocular hypertension (£1941–£2054).²⁰ A retrospective multinational European study (1995–2003) involving patients with primary open-angle glaucoma, normal tension glaucoma, ocular hypertension, or suspected glaucoma (n = 194) reported a significant linear relationship between total direct cost and disease severity, as defined by VF defect, with the mean annual cost for the UK subgroup ranging from 457 Euros (stage 0 disease) to 1065 Euros (stage 5 disease) per patient.²¹

Our finding of a high prevalence of ocular hypertension (21.8%) and suspected glaucoma (19.0%) among the NHS glaucoma clinic population is consistent with previous reports indicating that these conditions account for up to one-third of diagnoses associated with optometrist-initiated

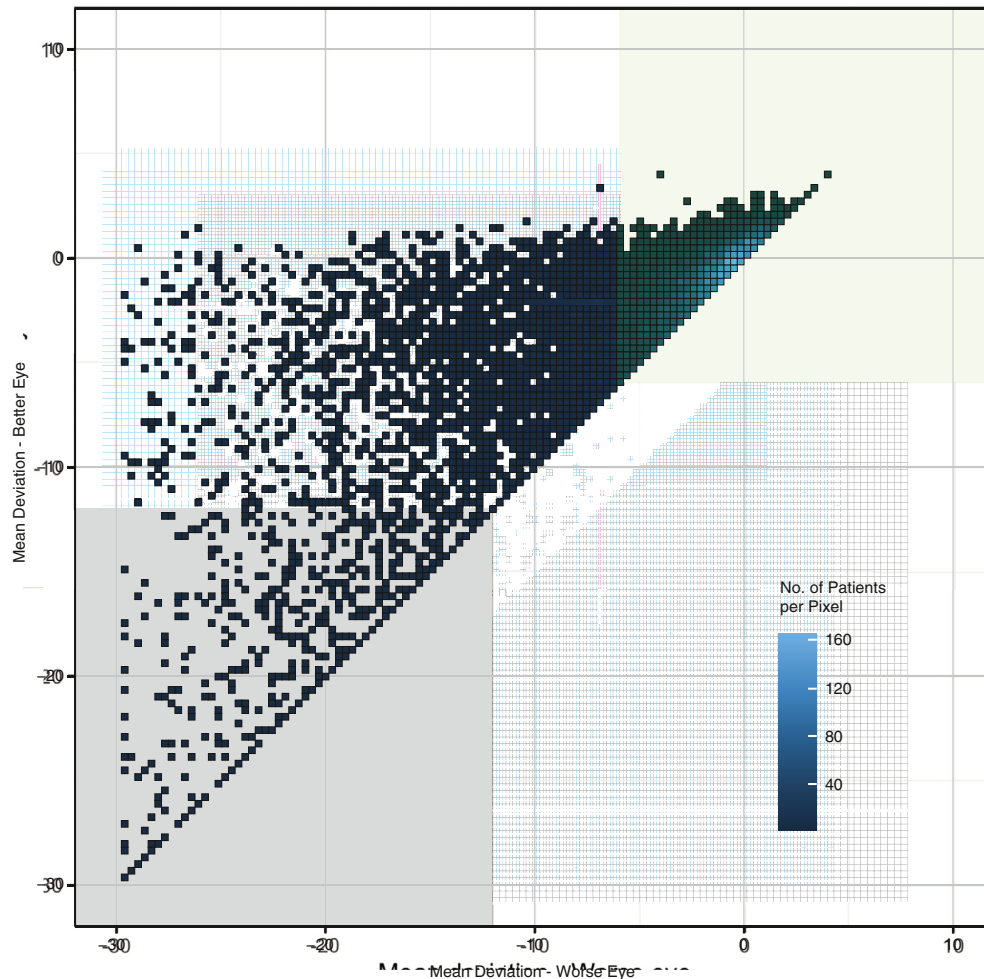


Figure 2. Scatterplot of paired (worse eye/better eye) baseline mean deviation values of patients in the 2016 cohort with a visual field recording obtained with the Humphrey 24-2 test program (N = 14 361). Baseline represents the index clinic visit or the first clinic visit with a visual field test to occur within the 12-month postindex period. Mean deviation is presented at the patient level; each patient contributes one data point (x-axis: worse eye; y-axis: better eye). For patients with visual field data for only 1 eye, mean deviation was assumed to be of identical value for the contralateral eye. Individual data points are represented by pixels. The color of each pixel denotes the number of patients with that particular set of mean deviation values (left and right eye), with black signifying the lowest numbers and light blue the highest numbers of patients per pixel (see color bar). Pixels within the green square represent patients with no worse than mild visual field impairment (mean deviation > -6 dB) in both eyes. Pixels within the gray square represent patients with advanced visual field impairment (mean deviation < -12 dB) in both eyes.

referrals to hospital glaucoma services in England.^{22,23} Community-based studies likewise attest to a high prevalence of ocular hypertension and suspected glaucoma in England. The European Prospective Investigation of Cancer-Norfolk Eye Study, a large community-based prospective observational study (2004–2011) involving 8623 unselected subjects aged 49 to 82 years who underwent systematic ocular examination for glaucoma (followed, in the event of abnormal findings, by referral to a consultant ophthalmologist), reported diagnoses of ocular hypertension (based on an IOP threshold of 21 mmHg) in 10% of subjects and suspected glaucoma in 7% of subjects.¹

Modeling projections suggest that the number of people in the UK with glaucoma is expected to rise by 44% between 2015 and 2035.²⁴ Assuming continued improvement in glaucoma detection rates, the corresponding growth in

demand for glaucoma services is likely to exceed this figure as unrecognized cases convert to diagnosed cases requiring long-term management. Under current workload, implementation of National Institute for Health and Care Excellence recommendations for glaucoma and ocular hypertension monitoring is not always feasible within the NHS health care setting.²⁵ At the same time, the adoption of a “one size fits all” approach to glaucoma management in England, as evidenced by close similarities in IOP and VF monitoring frequencies between ocular hypertension patients, glaucoma suspects, and patients with established primary open-angle glaucoma,²⁶ suggests that hospital care is disproportionately directed toward patients at low risk of immediate vision loss. Among the various measures proposed to reduce demand on the UK’s chronically oversubscribed hospital glaucoma clinics are

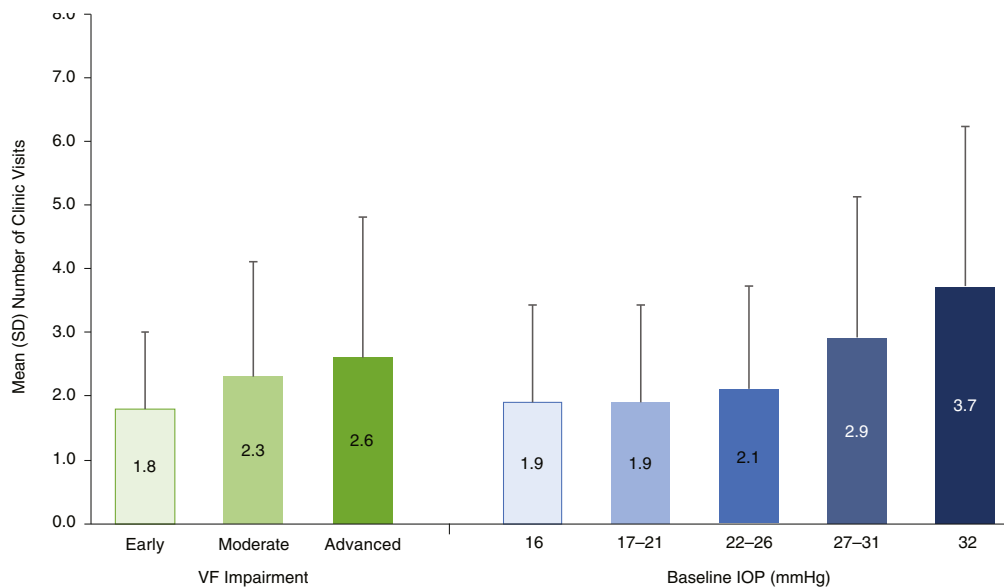


Figure 3. Mean (standard deviation) number of clinic visits over 12 months in the 2016 cohort, stratified by: (1) level of visual field (VF) impairment and (2) baseline intraocular pressure (IOP).

the following: (1) repeat-measure or referral-refinement schemes to reduce the number of unnecessary optometry onward referrals (i.e., false-positive and low-risk glaucoma suspects)^{27,28}; (2) “virtual clinics” that remove the need for face-to-face clinician consultation²⁹; (3) extension of the interval between follow-up appointments, where clinically appropriate^{6,30}; and (4) discharge of low-risk patients (ocular hypertensive patients, chronic open-angle glaucoma suspects, and successfully treated patients with primary angle-closure and nonoccludable angles) to the care of community optometrists, with appropriate rereferral back to the hospital eye service when necessary.^{3,6,30}

The strengths of this study include its large patient population (> 43 000 patients, of whom > 21 000 were

represented in the 2016 cohort), making it the largest characterization to date of diagnostic subtypes and associated health care resource use among outpatients attending hospital glaucoma clinics in England, and its use of data from an ophthalmology-specific EMR system with highly structured data fields. A feature of this EMR system is that any data entry triggers a mandatory prompt to the clinician to confirm whether the patient’s glaucoma medication is to be continued or discontinued. In this regard, medication discontinuation data acquired through the Medisoft EMR system is superior to that obtained through data systems that rely on the operator’s diligence in updating the patient’s medication record. Study limitations include potential shortcomings in data entry accuracy and completeness,

Table 3. Clinic Visits and Glaucoma Investigations per Patient over 12-Month Periods (2013–2018), Categorized by Index-Year Cohort

	2013 Cohort (n = 17 985)	2014 Cohort (n = 22 566)	2015 Cohort (n = 21 863)	2016 Cohort (n = 21 719)	2017 Cohort (n = 22 807)
Glaucoma clinic visits					
mean (SD)	1.95 (1.34)	1.95 (1.34)	1.98 (1.50)	2.04 (1.63)	2.01 (1.65)
range	1–23	1–19	1–22	1–24	1–25
IOP examinations					
mean	1.98	1.97	2.00	2.08	2.04
range				1–29	
VA examinations					
mean	1.46	1.32	1.43	1.52	1.54
range				0–28	
VF examinations					
mean	1.83	1.72	1.52	1.53	1.59
range				0–13	
OCT examinations					
mean	0.04	0.07	0.10	0.07	0.09
range				0–8	

IOP = intraocular pressure; SD = standard deviation; VA = visual acuity; VF = visual field.

Table 4. Estimated Average Annual Glaucoma-Associated Health Care Costs per Patient for the 2014, 2015, and 2016 Index-Year Cohorts*

	Average Annual Cost per Patient (£)		
	2014 Cohort (n = 22 566)	2015 Cohort (n = 21 863)	2016 Cohort (n = 21 719)
Doctor	97.9	95.7	100
Nurse	120.1	109.3	109
Total medical staff services	218.0	205.0	209
Glaucoma investigations	124.0	125.0	126
Glaucoma procedures	20.0	26.0	30
Topical glaucoma medication	37.0	40.0	40
Total glaucoma-related care	399.0	396.0	405

*Complete (12-month) cost data are available for the 2014, 2015, and 2016 index-year cohorts only.

which are inherent to any EMR system. For example, the surprisingly low number of recorded OCT examinations (average 0.07 per patient over the course of 12 months' follow-up) suggests the incomplete capture of this metric in the EMR. Moreover, by selecting patients with adequate follow-up, the cost of patients with inadequate follow-up is not calculated. Additionally, patients relocating from their hospital catchment area may be lost from the Medisoft EMR system, whereas those entering from a previous catchment area may be double-counted in the EMR system as both existing and new patients.

In conclusion, this study characterizes, using a large “real-life” UK-based dataset, the diagnostic profile, health care resource use, and attendant costs of patients attending the NHS hospital glaucoma clinics in England. Projected demographic changes can be expected to increase future clinical load across the spectrum of glaucoma severity, further challenging the ability of the UK hospital eye service to deliver adequate care. Planning of UK glaucoma services for the future will require a clear understanding of the current situation and imaginative solutions to deal with the growing clinical demand. Solutions might include review of

the glaucoma clinical risk threshold that mandates hospital-based treatment; our analysis suggests that glaucoma care within the NHS hospital eye service is disproportionately directed toward patients with mild, low-risk glaucoma, who may be more appropriately managed using alternative models of care. Further developments might include increased adoption of more “automated” virtual clinical review, whereby patients attend for a series of investigations (all performed at the same visit), and the results are subsequently reviewed remotely by the glaucoma specialist.

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Table 5. Estimated Average Annual Glaucoma-Associated Health Care Costs per Patient for the 2016 Index-Year Cohort, Stratified by Glaucoma Diagnosis and Severity of Visual Field Loss

	Average Annual Cost per Patient (£)				Total Glaucoma-Related Health Care
	Medical Staff Services	Glaucoma Investigations	Glaucoma Procedures	Topical Glaucoma Medication	
Stratified by glaucoma diagnosis at index visit					
POAG	214	138	44	48	444
OHT	175	105	12	28	320
Glaucoma suspect	163	98	9	19	289
Other glaucoma diagnosis	215	127	40	33	415
Mixed diagnosis*	209	133	40	48	430
Stratified by severity of VF loss at index visit					
Mild	179	116	23	34	352
Moderate	240	154	61	57	512
Advanced	238	149	54	59	500
Unknown	252	136	33	45	466

OHT = ocular hypertension; POAG = primary open-angle glaucoma; VF = visual field.

*Nonmatching diagnoses in the left and right eyes, or multiple glaucoma diagnoses in the same eye.

Footnotes and Disclosures

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Abbreviations and Acronyms:

dB = decibel; **EMR** = electronic medical record; **IOP** = intraocular pressure; **NHS** = National Health Service; **SD** = standard deviation; **VA** = visual acuity; **VF** = visual field.

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