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The relationship between multiple deprivation and severity of glaucoma at diagnosis

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BACKGROUND: Socioeconomic deprivation is associated with higher odds of chronic diseases, with many individuals living with more than one illness. This study aimed to examine the relationship between deprivation and severity of glaucoma at diagnosis, an important risk factor for glaucoma blindness.

METHODS: A retrospective study of 472 consecutive patients referred by community optometrists to the glaucoma clinic at a university hospital was performed. Glaucoma severity was determined by standard automated perimetry mean deviation (MD) in the worse eye. The Scottish Index of Multiple Deprivation (SIMD) was determined for each patient as a measure of deprivation based on postcode. Regression analyses were performed to determine the relationship between visual field MD and SIMD.

RESULTS: There was a significant relationship between higher levels of deprivation (lower SIMD) and worse severity of glaucoma at diagnosis. 32 of 472 patients (6.8%) had a MD of ≤−6 dB and 11 (2.3%) ≤−12 dB in their better eye. MD in the worse eye was 0.04 dB (95% CI 0.014 to 0.062 dB, $P = 0.002$) worse for each 100-point decrease in SIMD, with lower SIMD indicating a higher level of deprivation. A higher proportion of patients living in most deprived areas had a MD ≤ −6 dB or ≤ −12 dB at presentation compared to those living in the least deprived areas (14.3% versus 6.8% for ≤ −6 dB and 4.8% versus 0.8% for ≤ −12 dB).

CONCLUSIONS: Higher levels of deprivation were associated with worse glaucoma severity at presentation. The reasons for poorer outcomes in those from more deprived communities need further study so that inequalities can be addressed and the frequency of patients presenting with advanced glaucoma reduced.

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INTRODUCTION

Glaucoma is the leading cause of irreversible vision loss worldwide and it is estimated that by 2040 over 110 million people will be blind from the condition [1, 2]. Late diagnosis is a major risk factor for glaucoma blindness, however, as glaucoma is typically asymptomatic in its early stages, timely detection relies on opportunistic case finding. Even in high income countries where eye care services are more readily accessible than in low- and middle-income regions, a large proportion of patients present with advanced disease. Modelling of rates of change in visual field has indicated that while most treated patients are not at high risk of progressing to blindness, more advanced disease at diagnosis confers significantly higher risk [3]. Saunders and colleagues found that for patients attending UK clinics who were predicted to progress to statutory blindness, more than 90% had a visual field mean deviation (MD) worse than or equal to −6 dB in at least one eye at diagnosis [3].

People in lower socio-economic groups are more likely to have long-term health conditions and develop multiple long-term illnesses at a younger age [4]. In terms of eye health, large inequalities exist, both within nations and internationally [5]. Those from lower socio-economic backgrounds may experience barriers to accessing health care, for example due to direct costs such as transport or medication costs, or due to indirect costs such as loss of earnings due to time away from work [6–8]. In 2006, the Scottish Government introduced free eye examinations for all people living in Scotland, removing at least one cost barrier [9]. This eye-care funding model has resulted in a more equitable distribution of optometry practices across socio-economic areas in Scotland compared to England [10] although uptake of eye care services is still uneven across socio-economic groups [11].

Leamon and colleagues examined access to optometry services in vulnerable groups and concluded that making the eye examination free for all may not be sufficient to address barriers to accessing optometric services [12]. This may be why a study examining new glaucoma patients presenting in 2006 to NHS Hospitals in Scotland discovered greater severity of glaucoma at diagnosis to be associated with higher deprivation [13]. This study was however conducted the same year as introduction of the free eye examination, too soon to assess the impact of the change in practice, and moreover included only 126 patients.

The Scottish Index of Multiple Deprivation (SIMD) is used as a measure of relative deprivation in Scotland [14]. The SIMD ranking system records 7 domains: income, employment, education skills and training, health and disability, crime, housing, and geographic access to services [15]. 6976 data zones across Scotland are ranked from 1 (most deprived) to 6976 (least deprived) [14]. SIMD can provide a more comprehensive measure of the deprivation level

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of populations studied as compared to other deprivation indexes [13]. The aim of this study is to investigate the relationship between the severity of glaucoma at diagnosis and deprivation using SIMD.

MATERIALS AND METHODS

A retrospective cohort study was conducted at the Princess Alexandra Eye Pavilion, Chalmers Street, Edinburgh. All methods were prospectively approved by the institutional quality improvement committee and only anonymised, routinely collected data was used. The study included consecutive patients attending the new patient glaucoma clinics over a 3-month period between January 2019 and March 2019 inclusive. Only patients referred from a community optometrist due to a potential new diagnosis of ocular hypertension, suspected glaucoma or glaucoma were included. Those with a previous diagnosis of glaucoma and those already using treatment for glaucoma or ocular hypertension were excluded. Where glaucoma is suspected, community optometrists are required to refer the patient to the hospital eye service for confirmation of the diagnosis and where needed initiation of treatment. All patients had been referred using an electronic referral system linking primary care optometrists to the glaucoma specialist clinic.

All patients underwent a comprehensive ophthalmic examination as part of their routine new patient clinical assessment, including visual acuity, slit lamp examination, gonioscopy, Goldmann applanation tonometry and pachymetry. Optical coherence tomography measurement of the circumpapillary retinal nerve fibre layer (RNFL) was also performed (Glaucoma Premium Module, Spectralis OCT, Heidelberg Engineering). All patients also performed standard automated perimetry using the Humphrey Field Analyser (HFA) (Swedish Interactive Thresholding Algorithm Fast 24-2 test, Carl Zeiss) [16]. Demographic data extracted from the medical records included age, sex, and postcode. Refraction was recorded from the optometrist digital referral letter. Diagnosis was based on the clinical diagnosis made on the first visit by the consultant glaucoma specialist.

Visual field mean deviation (MD) was recorded for better and worse eyes from the baseline assessment. The better and worse eyes were defined by the eye with better and worse MD values respectively. Where the baseline visual field test was unreliable (fixation losses ≥20%, false positive ≥15%), the MD from the next visual field test was permitted, with the result from the test with highest reliability indices within 6 months of the initial visit selected. The deprivation index for each patient was derived from the Scottish Index of Multiple Deprivation 2020v2 postcode lookup file [17].

Table 1. Demographics and clinical characteristics of included patients.

	All patients ($n = 472$)
Age (years)	66.72 ± 13.21
Sex (*n*, % female)	242 (51.3%)
MD in better eye (dB)	−1.75 ± 3.69 (median −1.13, IQR −2.83 to 0.07)
MD in worse eye (dB)	−4.50 ± 17.63 (median −2.39, IQR −4.98 to −0.62)
SIMD (from 1 to 6976)	4604 ± 1997 (median 5180, IQR 2938 to 6419)
Refraction in better eye (dioptres)	−0.65 ± 3.62
Refraction in worse eye (dioptres)	−0.63 ± 3.56
Diagnosis at first visit	
No evidence of glaucoma (false positive referral)	122 (25.8%)
Primary open angle glaucoma	171 (36.2%)
OHT or glaucoma suspect	118 (25.0%)
Primary angle closure suspect or primary angle closure	40 (8.5%)
Primary angle closure glaucoma	13 (2.8%)
Pseudoexfoliative glaucoma	5 (1.1%)
Pigmentary glaucoma	3 (0.6%)

Statistical analysis

Scatter plots and linear regression were used to examine the relationship between deprivation index and MD and in better and worse eyes. Linear and logistic regression were also used to determine the relationship between MD and potential confounding variables include age, sex, and refractive error (spherical equivalent). Descriptive statistics included mean and standard deviation (SD) for parametric variables and median and interquartile range (IQR) for non-parametric variables. *P*-values of less than 0.05 were considered statistically significant. Data were analysed using Stata (Stata Corp, College Station, TX).

RESULTS

A total of 472 consecutive new patients were seen during the study period. The demographics and clinical characteristics are shown in Table 1. 171 of 472 patients (36.2%) were diagnosed with primary open angle glaucoma (POAG) at the first visit and 13(2.8%) had primary angle closure glaucoma (PACG) (Table 1).

Patients had a mean age of 67 ± 13 years. 242 patients were female (51.3%). The average MD in the better eye was −1.75 ± 3.69 dB compared to −4.50 ± 17.63 dB in the worse eye (Table 1 and Fig. 1).

The median deprivation index was 5180 (IQ range 2938 to 6419) (Fig. 2). 21 of 472 patients (4.4%) lived in an area with a SIMD score

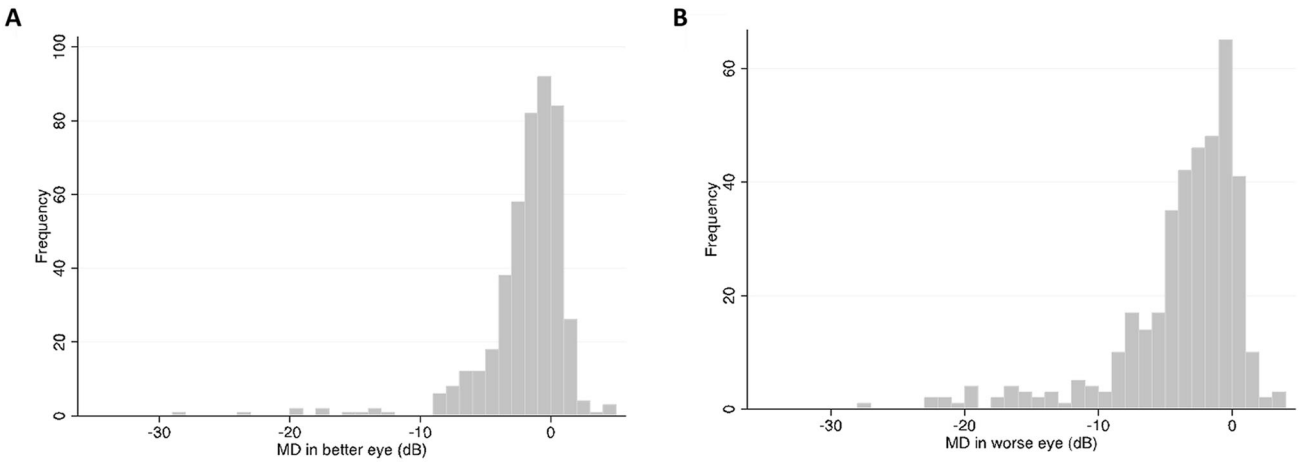

Fig. 1 Histogram showing the distribution of visual field mean deviation in better and worse eyes in decibels (dB). MD in better (**A**) and worse (**B**) eyes.

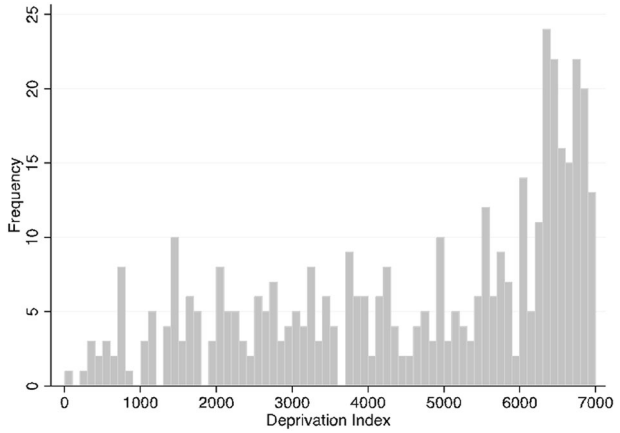

Fig. 2 Deprivation index scores for all included subjects. The Scottish Index of Multiple Deprivation is a relative measure of deprivation across 6976 data zones from most deprived (1) to least deprived (6976).

of 1 to 1000 (most deprived areas) and 162 of 472 patients (34.3%) lived in an area with a SIMD score of 6000 to 6976 (least deprived).

32 of 472 patients (6.8%) had a MD of −6 dB or worse in their better eye and 11 (2.3%) had a MD of −12 dB or worse in their better eye. 87 of 472 patients (18.4%) had a MD of −6 dB or worse in their worse eye, whilst 34 of 472 (7.2%) had a MD of −12 dB or worse (Table 2). A higher proportion of patients living in 0 to 1000 SIMD areas had a MD of worse than −6 dB or −12 dB at presentation compared to those living in other areas (Table 2).

There was no significant relationship between severity of glaucoma in the worse eye at diagnosis and age, sex, or refractive error (Fig. 3). In contrast, there was a significant relationship between lower SIMD and worse glaucoma severity in the worse eye. MD in the worse eye decreased by 0.038 dB (95% CI 0.014 to 0.062 dB) with each 100-point lower SIMD ($p = 0.002$). Figure 3 shows the relationship between SIMD and MD in the worse eye at time of diagnosis ($R^2 = 0.0257$, $p = 0.002$). Lower SIMD was also significantly associated with worse MD in the better eye ($R^2 = 0.013$, $p = 0.015$). There was no difference in severity of glaucoma at presentation among those diagnosed with POAG and PACG. There were too few patients with pseudoexfoliative glaucoma for meaningful analysis of pseudoexfoliative glaucoma as a risk factor for late presentation.

DISCUSSION

This study found that patients living in areas of higher deprivation had more severe glaucoma at the time of diagnosis. 14.3% of patients living in the most deprived areas (SIMD of 1 to 1000) had a MD equal or worse than −6 dB in the better eye at diagnosis, compared to only 6.8% of patients living in the least deprived areas (SMID 6001 to 6976). 4.8% of patients living in the most deprived areas had a MD ≤ −12 dB in the better eye at time of diagnosis compared to 0.8% of patients living in the least deprived areas. There was also a significant linear relationship between worse level of deprivation and worse glaucoma severity at diagnosis in better and worse eyes.

These findings support the results of Fraser and colleagues, who also found an association between higher levels of deprivation and more advanced glaucoma at diagnosis [18]. A limitation of Fraser and colleagues' study however was that deprivation was assessed using a measure containing fewer indicators, likely providing a less comprehensive assessment of deprivation than the SIMD [14, 19]. To the best of our knowledge, this is the first study examining the relationship between deprivation ranked by SIMD and visual field MD at time of diagnosis in both eyes in

Table 2. Summary of number of patients in each SIMD rank categorised by severity of glaucoma in the better and worse eyes at diagnosis.

SIMD Rank	1–1000	1001–2000	2001–3000	3001–4000	4001–5000	5001–6000	6001–6976	Total
Number of patients	21 (4.4%)	87 (18.4%)	48 (10.2%)	51 (10.8%)	46 (9.7%)	57 (12.1%)	162 (34.3%)	472 (100%)
Age	63 ± 9	65 ±14	65 ± 15	69 ± 13	64 ± 12	65 ± 11	69± 14	67 ± 13
MD ≤ −6 dB in the better eye	3 (14.3%)	6 (6.9%)	5 (10.4%)	2 (3.9%)	2 (4.3%)	3 (5.3%)	11 (6.8%)	32 (6.8%)
MD ≤ −12 dB in the better eye	1 (4.8%)	2 (2.3%)	2 (4.2%)	2(3.5%)	1 (1.8%)	0 (0.0%)	4 (0.8%)	11 (2.3%)
MD ≤ −6 dB in the worse eye	8 (38.1%)	15 (17.2%)	9 (18.8%)	10 (19.6%)	10 (21.7%)	11 (19.3%)	24 (14.8%)	87 (18.4%)
MD ≤ −12 dB in the worse eye	3 (14.3%)	10 (11.5%)	4 (8.3%)	2 (3.9%)	4 (9.0%)	2 (3.5%)	9 (5.6%)	34 (7.2%)

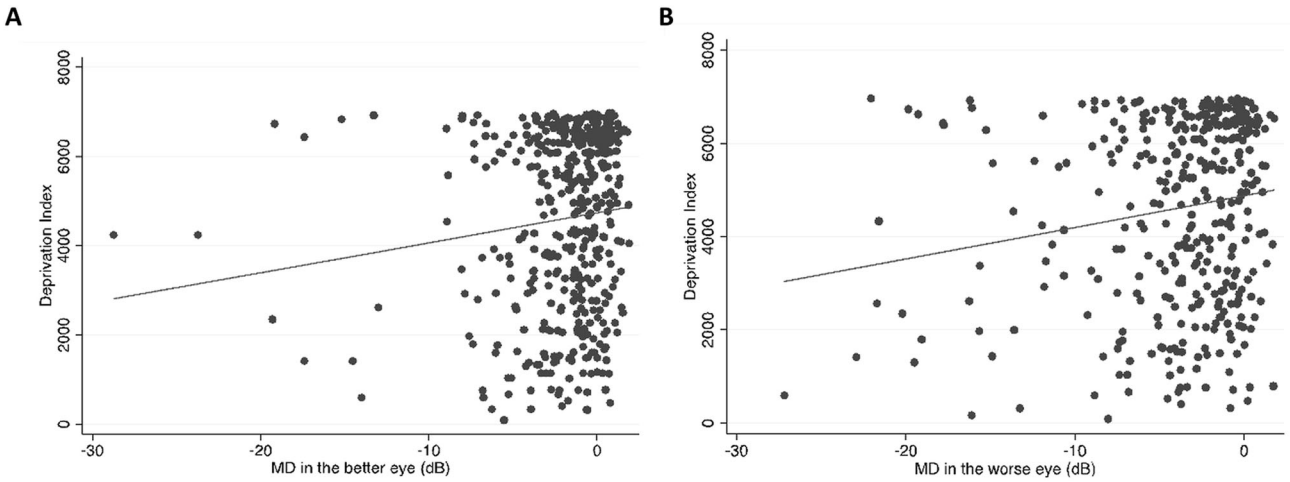

Fig. 3 Scatter plots showing the relationship between deprivation index and baseline visual field mean deivation (MD). Relationship between deprivation index and MD in (**A**) the worse eye ($R^2 = 0.0257$, $P = 0.002$) and (**B**) the better eye ($R^2 = 0.013$, $P = 0.015$).

patients with glaucoma. Ng and colleagues previously examined the relationship between deprivation and glaucoma severity in the worse eye at presentation, however, severity in the better eye was not analysed [13]. The assessment of glaucoma severity in both eyes is important, as the burden of glaucoma on quality of life is greater when the better eye is affected [20, 21].

Overall, one third (34.3%) of patients referred during the study period lived in areas in the least deprived quintile SIMD rank, that is the least deprived 20% of the population. Conversely, just 4.4% of patients referred during the study period lived in areas in the most deprived quintile. This observation, coupled with the on average more advanced severity of glaucoma at presentation in those living in most deprived areas, may indicate that those living in deprived areas are less likely to access eye care services; however, the SIMD ranks are compiled nationally, and as this study did not have national coverage, the proportion of patients referred from each SIMD quintile may reflect the distribution of SIMD areas in the region of Scotland typically referring patients to the study centre.

A potential reason for the association between socioeconomic deprivation and worse severity of glaucoma at presentation is cost or perceived cost of healthcare. In Scotland primary eye tests are free for all residents, annually for those aged under 16 or 60 years and over, those with diabetes, or in those who are sight impaired or severely sight impaired; and biennially in those aged between 16 and 59 years; however, costs may still be a barrier due to the potential costs of spectacles or ancillary tests such as optical coherence tomography, which is not included as part of the NHS funded examination in primary care [22].

A further potential reason for the association between deprivation and worse severity of glaucoma at presentation might include poorer access to health services in more deprived areas. Access to services forms one of the seven domains of SIMD, including key indicators such as average drive time and public transport travel time to essential services [14]. Households in areas with lower SIMD are also less likely to have access to a car and have poorer access to public transport, potentially making it more difficult to access care [23, 24]. It has previously been reported that those who lacked access to a motor vehicle were 14% less likely to attend primary eye examinations [25]. Despite efforts to improve accessibility to eye care services our results indicate further efforts are needed to reduce inequalities.

Differences in ethnicity may have also contributed to our findings. Although we did not collect data on ethnicity, previous analyses of Scottish demographic and socioeconomic data have shown a disproportionate number of people from minority ethnic groups (African, Caribbean, or Black) live in areas with higher deprivation [26]. Self-reported African ancestry is also a strong risk factor for primary open angle glaucoma [27, 28], which compounded with socioeconomic deprivation may further increase risk of late presentation [29].

Education level also forms a component of SIMD. People living in the most deprived areas are less likely to have attended university than those from less deprived areas [30]. Using the National Eye Health Education Program Eye-Q test patients with university qualifications were shown to have a better awareness of glaucoma than those without basic and higher-level school qualifications [31]. This has been substantiated in various other studies where the level of education was similarly proven to have a strong association with glaucoma awareness [32–34]. Increased awareness of glaucoma should be promoted to enable earlier detection, particularly in areas of higher socioeconomic deprivation.

Environmental factors could also contribute towards the relationship between SIMD and glaucoma. A recent analysis of UK Biobank data revealed an association between air pollution and self-reported glaucoma and structural characteristics of glaucoma on optical coherence tomography (OCT) [35]. Air pollution is often higher in areas with higher levels of deprivation [36].

This study has several limitations. Firstly, analysis was based on a population of patients attending a single university hospital (NHS Lothian Health Board) in Southeast Scotland. Lothian Health Board has disproportionately fewer people living in deprived areas, compared to other Scottish Health Boards [37]. For example, 11% of the population in Lothian Health Board live in the most deprived SIMD quintile, by comparison, 34% of the population in Greater Glasgow and Clyde Health Board live in the most deprived SIMD quintile. A study on a wider population across Scotland would provide a more representative sample population to investigate the effects of deprivation on glaucoma severity. Secondly, SIMD is not a perfect indicator of deprivation. SIMD is an area-based measure, and so assumes that everyone living within a particular area will experience a particular level of deprivation. Whilst the area sizes used in SIMD are smaller than some other measures of deprivation, this could still mask variations in deprivation experienced at the individual level.

A further potential limitation was the reliance on visual field data to determine glaucoma severity. We relied primarily on the first visit visual field test to determine disease severity, however, where the baseline test was unreliable, inclusion of other tests performed within 6 months of the baseline visit was permitted. Where no reliable visual field test was available, the test with the most reliable indices was selected. Though inclusion of unreliable

visual field tests might introduce bias, we did not wish to exclude patients simply as they could not produce a reliable test. If the study were to be repeated it might be useful to also consider including a structural marker of glaucoma severity, however, there is imperfect correlation between structural measures of the optic nerve head and retinal nerve fibre layer and functional losses. It is also conceivable that socioeconomic deprivation might be associated with reliability of visual field testing, however, this was not explored in the study.

The study period included in this analysis was January 2019 to March 2019 inclusive, a period prior to the COVID-19 pandemic. There was a significant reduction in glaucoma referrals from optometry to ophthalmology services between 2019 and 2020 due to COVID-19 restrictions [38]. This reduction in referrals implies that more people with glaucoma remain undetected, which is likely to have a significant impact on severity of disease at diagnosis when these patients do eventually present. Whether this effect will be equitably or inequitably distributed across areas of deprivation is a matter for future study.

In conclusion, we found that multiple deprivation was associated with more severe glaucoma at presentation. The reasons underlying this association require further exploration, however, it is likely that multiple factors contribute; including, poor education, poor access to healthcare and perceived costs of healthcare. As late diagnosis is a major risk factor for glaucoma blindness, it is important that measures are taken to reduce inequalities in glaucoma diagnosis due to deprivation.

SUMMARY

What was known before

- There was a significant relationship between deprivation and glaucoma severity in the worse eye at presentation.

What this study adds

- This is the first study examining the relationship between deprivation ranked by SIMD and visual field MD at time of diagnosis in both eyes in patients with glaucoma.
- There was a significant relationship between lower SIMD and worse glaucoma severity in the worse and better eye at presentation.

DATA AVAILABILITY

The data generated and analysed during this study are available upon reasonable request from the corresponding author.

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AUTHOR CONTRIBUTIONS

TLW, JLA, SD and AJT contributed to study design. TLW was responsible for collecting data, interpreting data, and writing the report. JLA contributed to data collection and reviewing the report. FB and ADMcT contributed to the writing of the report and data analysis. AJT supervised the study, analysed data and reviewed the report.

COMPETING INTERESTS

AJT:Consultant—Santen, AbbVie, Alcon, Thea, Sight Sciences, Roche. Research Support—AbbVie. Speaker—Santen, AbbVie, Alcon, Thea. The other authors declare no competing interests.

ADDITIONAL INFORMATION

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