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Glaucoma treatment and deprivation: Time-series analysis of general practice prescribing in England

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Abstract

Background: Despite advances in glaucoma management, topical eyedrop treatment has been paramount, with prostaglandin analogues (PGAs) being first-line agents. While late presentation is linked with deprivation, there is no recent research examining associations between deprivation and prescribing within primary care.

Aim: To explore PGA prescribing in general practice over a 6-year timeline, assessing for associations with deprivation.

Design and Setting: Analysis of NHS Business Services Authority data for general practice prescribing in England from April 2016-March 2022.

Method: Glaucoma treatments by GP prescriber were extracted, identifying ~9.11-9.58 million prescriptions/annum. Data were linked to indices of multiple deprivation (IMD) quintiles of GP practices. Crude rates per 1,000 population were calculated using population data from NHS Digital. Time-series analyses facilitated comparison in prescribing nationally and in deprived areas. Autoregressive Integrated Moving Average (ARIMA) modelling facilitated measurement of synchrony between time-series using cross correlation.

Results: PGAs and fixed combination eyedrops account for approximately two-thirds of glaucoma-related prescribing. Prescriptions per month increased slightly over a 6-year timeline, but rates per 1000 of population reduced in 2020-21. PGA prescriptions dispensed in deprived areas is lower than all other quintiles. Cross-correlation analysis indicates a lag of ~12 months between average PGA prescribing nationally versus more deprived areas.

Conclusion: The rate of PGA prescribing in primary care is substantially lower in deprived versus affluent areas, with delayed uptake of PGAs in more deprived areas of ~12 months. Further research is needed to explore reasons for this discrepancy, permitting strategies to be developed to reduce unwarranted variation.

Key words:

Glaucoma, prescribing, primary care, time-series, cross-correlation.

How this fits in:

- Glaucoma is a leading cause of avoidable sight loss where prostaglandin analogue (PGAs) eyedrops have traditionally been first-line treatment, formally embodied in recommendations within NICE glaucoma guideline when first updated in 2017.
- Deprivation is linked to late presentation in glaucoma and has also been associated with a reduced likelihood of being treated with glaucoma medications, although no recent study has evaluated associations of glaucoma prescribing with socioeconomic status.
- PGAs and related fixed combinations account for approximately two-thirds of glaucoma-related prescribing, with prescriptions per month increasing slightly over the 6-year timeline 2016-2022, while prescribing rates per 1000 of population reduced in 2020-21 during COVID-19.
- The rate of PGA prescribing in general practice is substantially lower in deprived versus more affluent areas and with delayed uptake of PGAs in more deprived areas, a matter requiring further research to develop strategies to reduce inequality.

Introduction

Glaucoma remains the second largest cause of sight loss in the UK, with a prevalence of ~4% in those over 50 years[1], and with glaucoma care accounting for ~20% of hospital eye service workload[2]. The Royal College of Ophthalmologists' 'Way Forward' project predicted the UK glaucoma population would increase 22% from 2015-2025 and 44% from 2015-2035, conceding projections might underestimate demand if improved detection resulted in more prevalent cases converting to diagnosed cases requiring treatment[3].

The purpose of glaucoma treatment is to slow ganglion cell loss and preserve patients' vision and quality of life. Only lowering intraocular pressure has proven effectiveness in slowing progression[4]. While surgery and selective laser trabeculoplasty (SLT) are important when appropriate, with the latter being recommended as first line treatment within the updated National Institute for Health and Care Excellence (NICE) guideline in 2022[5], medical treatment has been the mainstay of treatment[6]. Once diagnosed, prescribing typically remains in primary care supported by secondary care. Interestingly, while the first NICE guideline[7] introduced recommendations for managing ocular hypertension (OHT) and chronic open angle glaucoma (COAG), this guideline did not change prescribing per se, potentially owing to recommendations embodying pre-existing practices[8]. Indeed, prostaglandin analogues (PGAs) were established as first-line treatment by 2003[9], and the impact of NICE updates[10] in 2017 and 2022 have not yet been established. A recent Australian study[6] observed prescribing rates remaining stable from 2001-2017, with PGAs being the most prescribed class. The expected hierarchy is PGA first line eyedrops, betablockers second line, with carbonic anhydrase inhibitors and alpha-agonists third line choices[11].

In relation to socioeconomic status (SES) and prescribing, one early study demonstrated those from more deprived areas were 8% less likely to be prescribed topical treatment for their glaucoma than those in more affluent areas[9]. Heng et al[12] looked at geographical variations in glaucoma prescribing in England from 2008-2012. Using the Index of Multiple Deprivation (IMD) they found the upward trend of prescribing glaucoma medications was negatively associated with IMD. There is, however, a paucity of recent information on how SES is associated with glaucoma prescribing and whether earlier findings have changed during evolving NICE guidance. In this paper, we report on glaucoma prescribing in general practice over ~6 years in England, focussing on PGA eyedrops, examining for associations with SES.

Methods

Using prescribing data published by NHS Business Services Authority (NHSBSA)[13] from April 2016 to March 2022, we extracted data relating to glaucoma treatment by GPs using British National Formulary (BNF) codes, reflecting ~9.11-9.58 million prescriptions per annum. These data, for both PGA monotherapy and PGA-combination eyedrops, were linked to IMD GP practice quintiles in each year. The Office for Health Improvement and Disparities (OHID) calculates a deprivation score for each GP practice in England using IMD[14], used here to place practices in quintiles, where quintile one is least and quintile five the most deprived. We also used the GP registered population published by NHS Digital[15], allowing calculation of crude rates per 1,000 population.

To compare the national trend in prescribing with that in more deprived areas we undertook time-series analysis within Python to calculate moving averages, plotted against monthly data to ensure a good fit. We used "statsmodel" to fit an Autoregressive Integrated Moving Average (ARIMA) model to both time-series, a method appropriate for understanding time series, allowing accounting for seasonality within data, with the autoregressive component recognising current values are based on historic data, while the moving average component assumes regression errors are linear. ARIMA models for overall national and most deprived data allow measurement of synchrony between these time-series using cross-correlation. The time-series cross-correlation permits understanding similarity of data in both time-series and any delay in prescribing, which simple correlation would not permit, since it would compare correlation at the same time-point.

Results

National Analysis

The annual trend for number and rate of glaucoma-related prescriptions in England is shown in Figure 1, ranging from a monthly average of 759,592 prescriptions in 2016-2017 to 798,482 prescriptions in 2019-2020 (9.11-9.58 million prescriptions/annum). The number of prescriptions per month increased slightly over 6 years (Figure 1A). However, rate of prescribing per 1,000 population shows a downward trend (Figure 1 B). We categorised glaucoma medications as follows: PGAs; fixed combination PGA eyedrops; and 'other' medications. Figure 2 shows the annual trend in these groups, with PGAs and related combinations accounting for two-thirds of prescribing, proportions changing little over time. Given NICE recommendations and PGA dominance, our remaining analyses focuses on potential associations with SES examining these medicines.

Analysis by deprivation quintile

Figure 3 shows prescribing over the last 6 years. Figure 3A demonstrates the number of prescriptions dispensed in the most deprived areas is lower than other quintiles. Furthermore, disparity in prescriptions dispensed between most and least deprived increases slightly over time. The highest number of prescriptions dispensed occurs in quintile 2. Figure 3B illustrates the prescribing rate per 1000 population, demonstrating a slight decrease across all quintiles. The greatest decline in prescribing occurred during 2019-20 to 2020-21, coinciding with COVID-19. There is a clear disparity in prescribing between the fifth and other quintiles; however, the difference between the quintile with the highest (2) versus the lowest (5) prescribing rate has remained relatively constant, with 75 fewer people per 1000 population in quintile 5 being prescribed PGAs. Rate of prescribing PGA in quintiles 1, 3, and 4 becomes more equitable over time, with a difference of 16 per 1,000 population in 2016-17 reducing to 9 per 1,000 population, resulting in little disparity between groups by 2021-22; however, the gap has widened between the two most deprived quintiles (4 and 5), with the difference in prescribing increasing from 39 per 1,000 population in 2026-17 to ~45 per 1,000 population in 2021-22.

Time Series Analysis

Time series analysis allows us to understand the trend in the uptake of PGAs in primary care and in particular if the rate of uptake was slower in more deprived areas compared to the England average. The chosen analysis has 3 parts. Analysis of stationarity using the augmented Dickey-Fuller test (null hypothesis of non-stationarity and an alternative hypothesis of stationarity) showed the monthly trend data was stationary (p=0.33 for national data and p=0.22 for most deprived area data). Since these data were stationary, we fitted the ARIMA model with the 12-month rolling moving average data, removing random fluctuations in prescribing over the days in the month. The national moving average rises from ~475,000 to just over 500,000 an increase of ~6%, while in the most deprived quintile the moving average rises from ~70,000 to just over 80,000, a rise of ~14%. However, in the last months of the series, the trend is similar. Using ARIMA modelling allows us to undertake further analyses. Figure 4 shows cross-correlation analysis, permitting visualisation of whether there is a lag between these two time-series over time (i.e., that for overall national versus that for the most deprived data), rather than using simple correlation which returns a single value at a point in time. Interestingly, national data is held in place and creates both lags and leads for data from the most deprived area, providing a more holistic view of the relationship between the time-series. The highest positive correlation coefficient of ~0.7 occurs at a time lag -12, suggesting a relatively strong positive correlation between prescribing in more deprived areas ~12 months after national prescribing. Based on this analysis, there appears to be a lag of ~12 months between average prescribing in the more deprived areas versus prescribing nationally.

Discussion

Summary:

Our study demonstrates PGAs account for approximately two-thirds of general practice prescriptions for glaucoma-related diagnoses in England over 6 years. After the first NICE guideline update in 2017, use of PGAs increased for the next 3 years to ~640,000 prescriptions per month, a ~10% increase. When analysing prescribing per 1000 population, there is an overall downward trend over the 6-year period, a finding potentially contrasting to the expected increase in at risk cases needing treatment. In April 2020 there was a more rapid prescribing decline as COVID-19 impacted upon sight-testing, with subsequently reduced referrals and fewer new diagnoses. Significantly, in more deprived areas, crude prescribing per 1,000 population is substantially lower than in more affluent areas, suggesting matters have not improved since Owen's early study[9]. Factors influencing this finding may include lower referral from primary care optometry within areas of deprivation, more advanced presenting glaucoma within deprived areas (leading to surgery as part of primary treatment or escalation to surgery after initial PGA prescribing), and poorer medication adherence. The latter may be linked to inadequate patient education and/or language provision, impacting upon attendance and culminating in failure to refill prescriptions.

Strengths & Limitations:

A strength of this work is collation of large-scale glaucoma prescribing in the NHS in England. Arguably these data (>9 million prescriptions per annum) reflects an unbiased source. However, while these data provides a complete picture of primary care prescribing in England, secondary care prescribing, even when community dispensed, is not captured. Further, the dataset is not a record level dataset, meaning it does not include demographic information, for example age or ethnicity. Further, the analysis relies on the GP practice base for deprivation, rather than providing a view of deprivation for individuals receiving prescriptions. The IMD score was updated in 2019 and deprivation scores are relatively up to date descriptors of deprivation status. We acknowledge that this 2019 version may be outdated. Furthermore, allocation of one IMD score per practice may not adequately reflect populations, which likely has patients with different IMD levels, an acknowledgement of the well-reported complexity of SES, neighbourhood deprivation and health[16]; however, despite limitations, IMD remains the best readily available method for examining deprivation, while accepting some areas may have seen improvements in SES, for example, "gentrification" masking existing population requirements, causing apparent improvement in deprived areas.

A further limitation is that our analyses were restricted to PGA prescribing, and future analyses may usefully include all glaucoma medications. Furthermore, we concede the historic nature of the data. We were not able to identify individuals, duration of using PGAs, or glaucoma stage at diagnosis. People presenting with advanced glaucoma may be managed differently, with NICE recommending early surgery, hence overall PGA prescribing may be lower owing to surgical versus medical management; however, this explanation is not borne out by a study of SES in cases undergoing trabeculectomy[17], where drainage surgery was carried out less frequently in patients from areas of greatest deprivation. Whilst it is uncertain whether surgical management impacts PGA prescribing in areas of deprivation, there is evidence patient adherence may be influential. A study looking at demographics of patients registered severely sight impaired from glaucoma[18] found those with advanced disease and those with poor adherence were more likely to have greater deprivation. Arguably the corollary is increased sight testing in affluent areas generates more glaucoma referrals and greater repeat prescribing within primary care. Further research is necessary to better understand these differences, although since initial prescribing is largely in secondary care (covering populations from the most and least deprived areas) with repeat primary care prescribing supported from secondary care, it seems likely differences in deprived area versus national data includes fewer referrals, more advanced presenting disease, and prescription refill factors.

Comparisons:

The majority of glaucoma cases are detected through case finding in primary care optometry. Day et al[19] showed a mismatch between areas of deprivation and location of optometrists, a finding supported by our own recent analysis[20], with both studies supporting the view that the optometry business model may deter practice establishment within deprived communities[21], creating a barrier to sight-testing, impacting on detection. Several studies have looked at access to eyecare and SES. Knight et al's review[22] noted seven of eight high quality studies concluded there *was* a significant positive association between lower SES and glaucoma stage at presentation, and a significant negative association between SES and secondary care attendance. An early case-control study examining deprivation and stage of presentation[23] found deprivation was associated with late presentation, an important risk factor for subsequent blindness. A cohort study in Manchester investigating SES and vision loss in glaucoma[24] found patients from deprived areas presented with more advanced loss, while SES has been shown as a risk factor for patients with acute primary angle closure[25]. More recently the relationship between late presentation of glaucoma and deprivation has been revisited, with Rathore et al[26] confirming the association between IMD and advanced visual field loss at diagnosis, while concluding rapid worsening of glaucoma during follow-up was not associated with IMD, suggesting equity of care and outcomes once patients were referred into the English HES. This latter suggestion is supported by King et al[27], who observed in their treatment of advanced glaucoma study that while SES at baseline is correlated with poorer vision it did not impact on the success of treatment at 24 months.

Some previous studies have described associations between primary care prescribing and deprivation in general medical prescribing. A recent study by Mooney et al[28] found drug categories most strongly correlated with deprivation included analgesics. Conversely, both HRT and combined oral contraception was prescribed more in affluent areas. Ophthalmic drugs did not feature in reporting of stronger associations between either deprivation or affluency, although interestingly Latanoprost was weakly positively correlated with deprivation. Overall, Mooney et al found SES is correlated with *higher* rates of prescriptions for a large number of drugs, with only a few drugs being correlated with affluency. For glaucoma and our study, it is pertinent to note that in contrast to conditions noted in Mooney's study, patients with glaucoma typically remain asymptomatic, potentially even where disease is advanced but asymmetric, and care seeking behaviour before presentation may influence prescribing in a scenario different to the management of chronic pain, for example.

In relation to the downward trend in prescribing during COVID-19, contemporaneously reduced activity in secondary care resulted in backlogs, arguably a scenario influencing patients' behaviours around continuation with glaucoma medications, owing to follow-ups being cancelled or delayed, an explanation supported by a study assessing the impact of COVID-19 on patient reported outcomes[29], showing care perceived as being less well organised. Uncertainty amongst patients may have resulted in adherence failures. It is also possible that, from 2020 onwards, growth in PGA prescriptions slowed because first-line treatment was changing towards SLT. Although the timeline for our analyses pre-dated the updated guideline in January 2022 recommending SLT as first-line treatment, it is likely some ophthalmic units in England were already offering SLT following publication of high-quality evidence of effectiveness[30].

Implications for Research and Practice

The present analysis adds to earlier use of large datasets in glaucoma. For example, Saunders et al[31] showing the likelihood of patients suffering visual impairment in their lifetimes being linked to visual field loss at presentation, and Kelly et al[32] observing the conversion rate of OHT to glaucoma in a retrospective examination of over 45,000 electronic glaucoma records. Our time-series analysis has shown a 1-year delay in the uptake of PGAs in more deprived areas versus national data. Whilst lower prescribing in deprived areas may be explained by a number of factors, observing quintile 2 has the highest rate of PGA prescribing is perhaps counterintuitive. It is uncertain if these findings reflect prescribing being unexpectedly high in quintile 2, or whether prescribing is lower than expected in quintile 1. We have no evidence to suggest prevalence differs between groups, and since quintile 1 represents affluent areas, access to sight-testing should not present a referral barrier. Arguably patients in quintiles 1 and 2 may be better informed regarding health, and may seek alternative management, such as SLT or minimally invasive glaucoma procedures. Furthermore, some in quintile 1 may obtain private prescriptions, data which would not be captured in this study, although it would be surprising if this factor accounted for the difference of 24 prescriptions per 1000 people between quintile 2 and quintile 1 in 2021-22.

Some evidence suggests GP practices tend to be in more affluent areas, while pharmacy achieves better levels of activity in deprived areas[33]. Data for optometry in England is more aligned to the GP practice trend, with double the number of optometrists in the most affluent versus most deprived quintiles[34]. In Scotland, where there is a different GOS contract, distribution of optometry practices is relatively balanced across SES, with Legge et al[35] proposing differences in eye-examination uptake across social strata is beyond service availability alone. The ophthalmology workstream "Getting it Right First Time"[36] recommends an optimal glaucoma care pathway; however, inequitable distribution of eyecare has potential consequences for implementation of this approach. Integrated Care Boards and Local Authorities must ensure eyecare services are in all areas. Lower prescribing of glaucoma medications in areas of greater deprivation is an unwarranted inequality. While further studies may help establish reasons for this variation, helping development of strategies to reduce inequality, GPs working in more deprived areas can play a role in promoting the uptake of sight testing for their patients at greatest risk of glaucoma.

Contributions: JH, CHF, JR, and RAH conceived this article. JH collated and analysed the data with contextual analysis by CHF, JR, and RAH. JH, CHF and RAH wrote the manuscript and JR provided critical review of the manuscript.

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Ethical Approval: None applicable.

Competing Interests: JH and JR have previously undertaken work for Allergan in relation to eye care, work completed in 2021 and unrelated to this analysis. RAH has received single lecturing honoraria once each from Allergan and Santen in 2020/2021.

References:

1) Chan MBY, Broadway DC, Khawaja AP, Yip JLY, Garway-Heath DF, Burr JM et al. Glaucoma and intraocular pressure in EPIC-Norfolk Eye Study: cross sectional study. *BMJ* 2017; 358: j3889.

2) Harper RA, Gunn PJG, Fenerty CH, Spry PGD and Lawrenson JG. Care pathways for glaucoma detection and monitoring in the UK. *Eye* 2020, 34: 89-102.

3) The Way Forward: Options to help meet demand for the current and future care of patients with eye disease: Glaucoma. The Royal College of Ophthalmologists, January 2017.

4) Weinreb RN, Aung T, Medeiros FA. The pathophysiology and treatment of glaucoma: a review. *JAMA* 2014; 311: 1901–1911.

5) https://www.nice.org.uk/guidance/ng81/chapter/recommendations

6) Perera, N, Pinnuck, BC, Jamieson MP, Ling D, Williams M, Chen O. Prescribing trends of topical glaucoma medications in Australia from 2001 to 2017. *J Glaucoma* 2020; 29: 175–183.

7) NICE. 2009.Glaucoma: diagnosis and management, Clinical guideline [CG85] https://www.. Nice.org.uk/ guidance/ CG85

8) Connor AJ, and Fraser SG. Glaucoma prescribing trends in England 2000 to 2012. *Eye* 2014; 28: 863–869.

9) Owen CG, Carey IM, De Wilde S, Whincup PH, Wormald R, Cook DG. The Epidemiology of medical treatment for glaucoma and ocular hypertension in the United Kingdom: 1994 to 2003. *Br J Ophthalmol* 2006; 90: 861-868.

10) https://www.nice.org.uk/guidance/ng81/evidence/full-guideline-pdf-4660991389

11) Fajgenbaum M, Ansari E. Prescribing Trends in a Glaucoma Clinic and Adherence to EGS Guidelines: A Retrospective, Non-Interventional, Single-Center UK Study. *Adv Ther*; 2017: 34:2033–2042.

12) Heng JS, Wormald R, Khaw PT. Geographical variation in glaucoma prescribing trends in England 2008–2012: an observational ecological study. *BMJ Open* 2016; 6: e010429. Doi:10.1136/bmjopen-2015- 010429

13) NHS BSA English Prescribing Dataset (English Prescribing Dataset (EPD) – Datasets – Open Data Portal BETA (nhsbsa.net) https://opendata.nhsbsa.net/dataset/English-prescribing-data-epd

14) Office for Health Improvement & Disparities (OHID), National General Practice Profiles, practice deprivation scores https://fingertips.phe.org.uk/profile/general-practice

15) NHS Digital Registered Population Data (Patients Registered at a GP Practice – NHS Digital) https://digital.nhs.uk/data-and-information/publications/statistical/patients-registered-at-a-gp-practice

16) Stafford M and Marmot M. Neighbourhood deprivation and health: does it affect us all equally? *Int J Epidemiol* 2003; 32:357–366.

17) Sepetis A, Balendra S, Meredith P, Kirwan J, Lockwood A. Socioeconomic deprivation status of patients undergoing Trabeculectomy surgery. A 9-year review at Queen Alexandra Hospital, Portsmouth. *Acta ophthalmologica* 2017; 95 (S259):

18) Wallace, E. J., Paterson, H., Miller, S., Sinclair, A., Sanders, R., & Hinds, A. Patient profile and management in advanced glaucoma. *British Journal of Visual Impairment* 2008; 26(1): 7–23.

19) Day F, Buchan JC, Cassells-Brown A, Fear J, Dixon R, Wood F. A glaucoma equity profile: correlating disease distribution with service provision and uptake in a population in Northern England, UK. *Eye* 2010; 24: 1478–1485.

20) Harper RA, Hooper J, Fenerty CH, Roach J, Bowen M. Deprivation and the location of primary care optometry services in England. *Eye* 2023 DOI: 10.1038/s41433-023-02774-8

21) Shickle D, Davey CJ & Slade SV. Why is the General Ophthalmic Services (GOS) Contract that underpins primary eye care in the UK contrary to the public health interest? *Br J Ophthalmol* 2015; 99: 888–892.

22) Knight A and Lindfield R. The relationship between socio-economic status and access to eye health services in the UK: a systematic review. *Public Health* 2015;94-102.

23) Fraser S, Bunce C, Wormald R and Brunner E. Deprivation and late presentation of glaucoma: case-control study. *BMJ* 2001; 322(7287): 639-43.

24) Sukumar S, Spencer A, Fenerty C, Harper R and Henson DB. The influence of socioeconomic and clinical factors upon the presenting visual field status of patients with glaucoma. *Eye* 2009: 23; 1038-1044.

25) Saxby E, Cheng K, O'Connell N, Sanders R, Agarwal PK. Is there an association of socioeconomic deprivation with acute primary angle closure? *Eye* 2022; 36:1246–1252.

26) Rathore M, Shweikh Y, Kelly SR and Crabb DP. Measures of multiple deprivation and visual field loss in glaucoma clinics in England: lessons from big data. *Eye* 2023) 37:3615–3620

27) King AJ, Hudson J, Azuara-Blanco A, Kirwan JF, Goyal S, Lim KS, Maclennan G, TAGS research group. Effects of socioeconomic status on baseline values and outcomes at 24 months in the Treatment of Advanced Glaucoma Study randomised controlled Trial. *Br J Ophthalmol* 2024 Jan 29;108(2):203-210.

28) Mooney J, Yau R, Moiz H, et al. Associations between socioeconomic deprivation and pharmaceutical prescribing in primary care in England. *Postgrad Med J* 2022; 98:193–198.

29) Pujari R, Chan G, Tapply I. The impacts of COVID-19 on glaucoma patient outcomes as assessed by POEM. *Eye* 2022; 36(3): 653-655.

30) Gazzard G, Konstantakopoulou E, Garway-Heath D et al. Selective laser trabeculoplasty versus eye drops for first-line treatment of ocular hypertension and glaucoma (LiGHT): a multicentre randomised controlled trial. *Lancet* 2019; 393: 1505–16.

31) Saunders LJ, Russell RA, Kirwan JF, McNaught AI, Crabb DP. Examining visual field loss in patients in glaucoma clinics during their predicted remaining lifetime. *Invest Ophthalmol Vis Sci* 2014; 55(1): 102-9.

32) Kelly SR, Khawaja AP, Bryan SR, Azuara-Blanco A, Sparrow JM, Crabb DP. Progression from ocular hypertension to visual field loss in the English hospital eye service. *Br J Ophthalmol* 2020;104(10): 1406-1411

33) Todd A, Copeland A, Husband A, Kasim A, Bambra C. The positive pharmacy care law: an area-level analysis of the relationship between community pharmacy distribution, urbanity and social deprivation in England. *BMJ Open* 2014;4:e005764. Doi: 10.1136/bmjopen-2014-005764

34) NHS England ODS Data for Optical Providers (ODS - Optical HQ and Optical Site - eoptsite.csv - NHS England Data Catalogue)

35) Legge R, Strang NC, Loffler G. Distribution of optometric practices relative to deprivation index in Scotland. *J Public Health (Oxf)* 2018 Jun 1; 40(2):389-396.

36) Ophthalmology GIRFT Programme National Specialty Report. https://gettingitrightfirsttime.co.uk/wp-content/uploads/2021/07/Ophthalmology_2021_07_09_Pathway_Glaucoma.pdf

Figure legends

Figure 1

Trend in the number (A) and the rate (B) of glaucoma related prescriptions in England (2016-2022). (Numbers from NHSBSA[12], Population data from NHS Digital[13]). Over the period the overall population grew by 15% (12%-19% being the quintile range), while overall prescribing grew by 9% (8%-11% being the quintile range). As the growth in population is greater than the growth in prescribing the rate (B) shows a reducing trend. The 95% confidence intervals are excluded here for clarity but are very small owing to large numerators/denominators. For example, the national trend for 2021-22 the rate is 154.38, with 95% CI being $\pm$ 0.10 (154.28 to 154.47).

Figure 2

Trend in the proportion of glaucoma prescriptions by grouping (PGA, PGA fixed combinations and 'Other') in England (2016-2022). (NHSBSA[12]).

Figure 3

Trend in number (A) and adjusted rate per 1000 of population (B) of glaucoma related prescriptions by deprivation quintile in England (2016-2022). The charts show prescriptions dispensed in the most deprived (MD) areas is much lower than the least deprived (LD) areas and all other quintiles. Furthermore, the disparity in prescriptions dispensed between the most and least deprived areas increases slightly over time. (Numbers from NHSBSA[12], Population data from NHS Digital[13]).

Figure 4

Cross-correlation analysis for National and most deprived area prescribing time-series. The highest positive correlation coefficient of ~0.7 occurs at around a time lag -12, suggesting a relatively strong positive correlation between PGA prescribing in more deprived areas ~12 months *after* national prescribing. (Numbers from NHSBSA[12]). The peak correlation coefficient being outside the 95% confidence interval suggests this correlation is unlikely to have occurred by random chance alone.

Figures

Figure 1

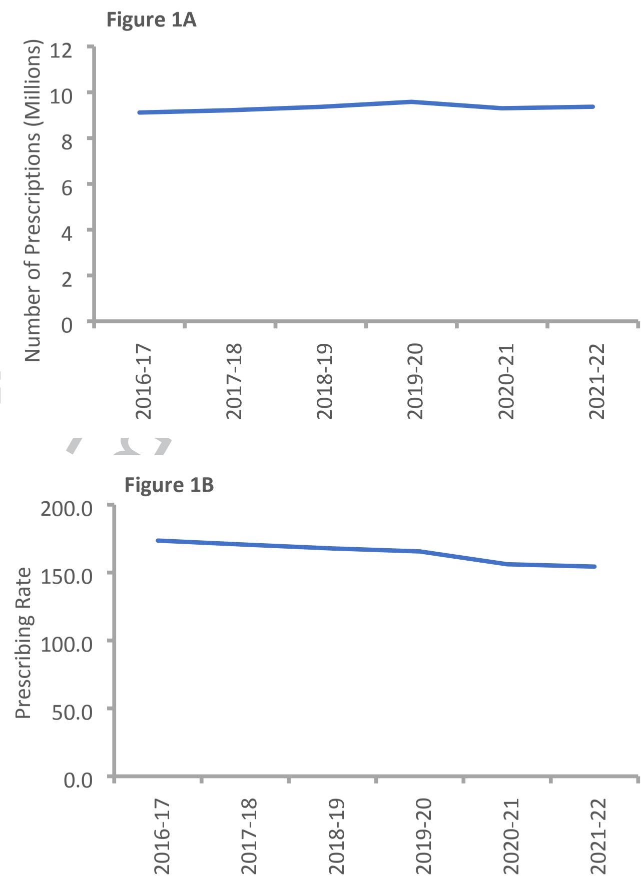


Figure 2

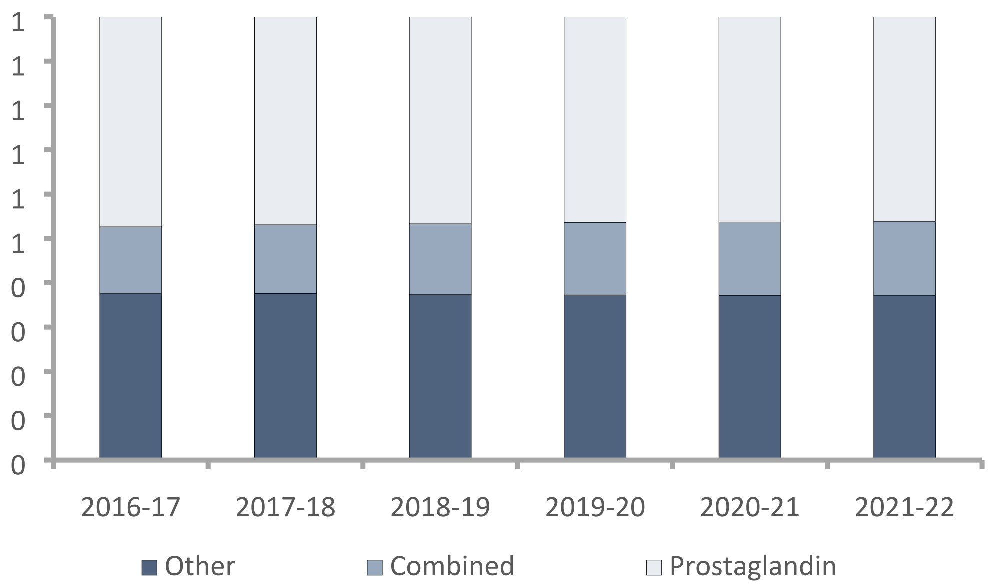

1
1
1
1
1
1
0
0
0
0
0
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
Other
Combined
Prostaglandin

Figure 3

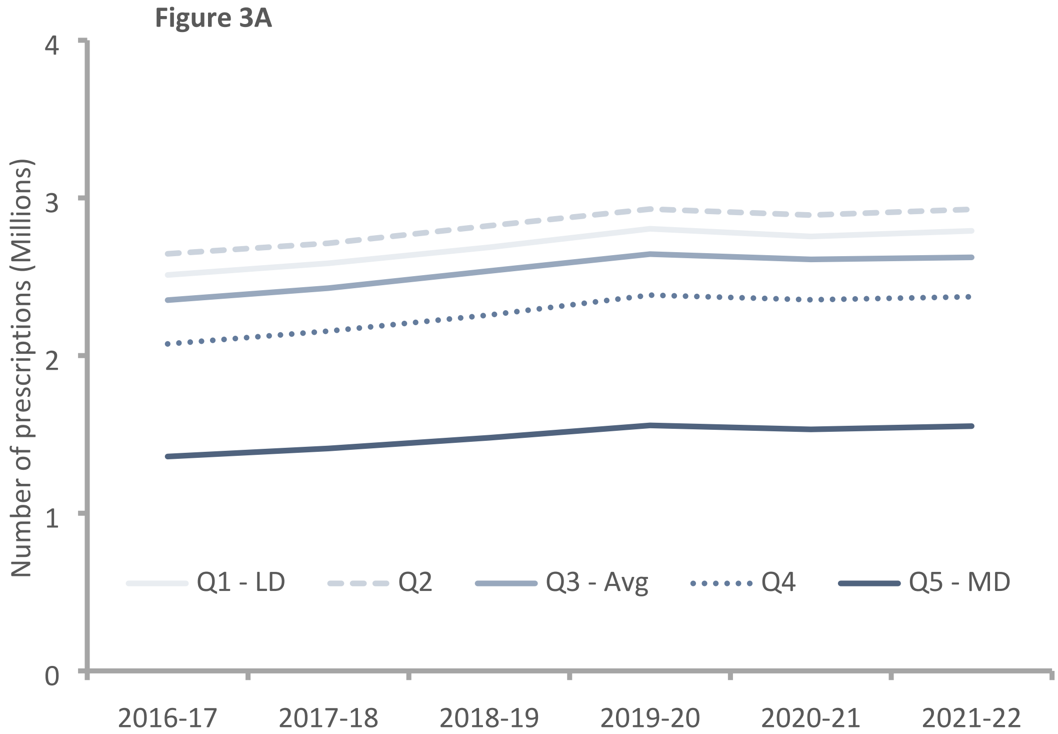


Figure 3A
Number of prescriptions (Millions)
0
1
2
3
4
Q1 - LD
Q2
Q3 - Avg
Q4
Q5 - MD
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22

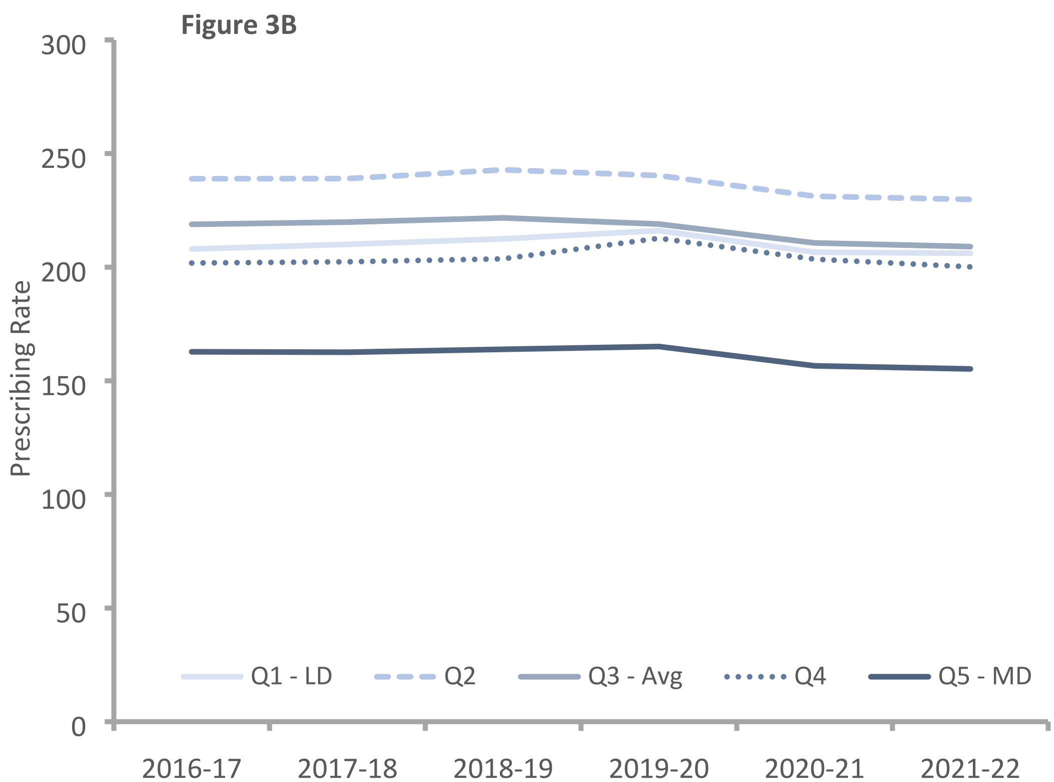
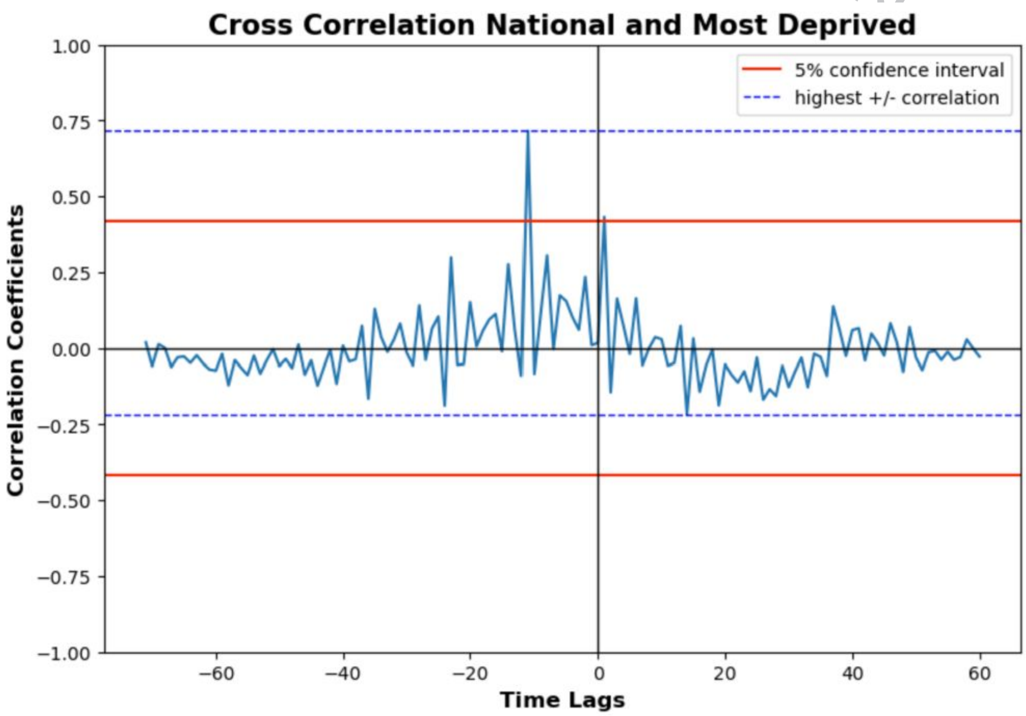


Figure 3B
Prescribing Rate
0
50
100
150
200
250
300
Q1 - LD
Q2
Q3 - Avg
Q4
Q5 - MD
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22

Figure 4


Cross Correlation National and Most Deprived
5% confidence interval
highest +/- correlation
Correlation Coefficients
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−60
−40
−20
0
20
40
60
Time Lags