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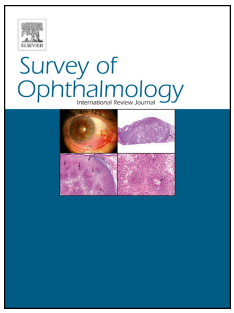

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Multiple Deprivation, Vision Loss, and Ophthalmic Disease in Adults: Global Perspectives

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Abstract

The association between socio-economic position and morbidity and mortality has long been recognised. We evaluate the evidence for an association between multiple aspects of deprivation and ocular health in a global context.

This is a systematic review of studies that evaluated deprivation in the adult population in the context of the major acquired causes of visual loss such as cataract, diabetic eye disease, glaucoma, age-related macular degeneration, and ocular trauma. The search strategy identified relevant studies reported between 1946 to August 2016, with randomized control trials, case control, cohort and cross-sectional study designs being selected for inclusion.

The studies identified in this review from across the world demonstrate the extent to which common themes such as low educational attainment and low income may be associated with increased incidence of various sight-threatening conditions and may adversely affect access to specialist assessment and delivery of treatment. Health inequality may always persist, but an increased recognition of the importance of the various impacts of deprivation may empower policy makers to target limited resources to the most vulnerable groups in order to deliver the greatest benefit.

I. Introduction

A. Definition of concepts

Multiple deprivation, a frequently utilized, yet poorly understood, multidimensional concept in medical research, includes economic, social, and political elements, but lacks a standardised international definition.[258] The concept evolved from the need to explore and understand long-recognised associations between poverty and ill health. It complements related, but more narrowly focused, concepts including; '*absolute poverty*', which implies an individual lacks the minimum resources for physical survival and *'relative poverty*' which relates an individual's resources to the average standards of living of a particular society at a particular time.[259; 263] These terms helpfully identify the minimum resources required to maintain the working population at a functional level.; however, they do not fully capture or elucidate the mechanisms through which an impoverished environment might adversely impact health outcomes and health equity at a population level.

In 1979 Townsend argued that the terms '*poverty*' and '*deprivation*' should no longer be used interchangeably. He articulated how a person could be said to be deprived if they lacked 'the types of diet, clothing, housing, household facilities, fuel, environmental, educational, working and social conditions, activities and facilities which are customary'.[257; 258] Whereas, a person could be said to be financially impoverished if they are unable to escape deprivation. Townsend proposed the term '*multiple deprivation'* to describe several types of deprivation occurring at once.[258]

Townsend's work was the catalyst for the model of small area deprivation in the United Kingdom (UK) and development of the Index of Multiple Deprivation (IMD). The IMD splits

deprivation into seven discrete, quantifiable domains--including income, employment, health and disability, education, crime, barriers to housing, and services and living environment. This approach has been used extensively in the UK since 2000 to identify areas in greatest need of targeted interventions.[138]

At the global level, indices combining multiple measures of deprivation have been used by the United Nations to compare the needs and potential of different countries. In 1990 the first United Nations Human Development Report included the Human Development Index (HDI), which could be used to rank countries according to key dimensions of human development, notably a long and healthy life, access to knowledge, and a decent standard of living. The HDI is therefore based on life expectancy at birth, estimated years of schooling and mean years of schooling, and the Gross National Income per capita.[8 262] The Human Poverty Index (HPI) was introduced in the 1997 Human Development Report to improve the assessment of deprivation in relation to these same dimensions, using measures of life expectancy, illiteracy, and living standards; living standards measures were either access to water and childhood malnutrition (low income countries) or income in relation to poverty line and unemployment (higher income countries).[260] In the 2010 United Nations Human Development Report, the Inequality-adjusted HDI (IHDI) was introduced which adjusts the HDI for inequality in the distribution of each dimension in that population, such that the IHDI falls in relation to the HDI in relation to increasing inequality.[106; 261; 262] In 2010 the Multidimensional Poverty Index (MPI) was also introduced.[7; 8] This uses data from household surveys to identify multiple deprivations at the household level based on ten indicators covering the same dimensions covered by the HDI: namely education, health and standard of living. More recently, the Global Burden of Diseases, Injuries and Risk Factors

Study 2015 (GBD 2015) developed the Socio-demographic Index (SDI). This derives from measures of educational attainment, fertility rate, and per capita income.[77]

Countries are categorised by the World Bank into high, middle and low-income economies, based on gross national income per capita, calculated by the Atlas method. The income thresholds were originally set in 1989 and remain constant in real terms over time, with annual adjustment based on inflation rates in a number of countries.[282]

B. Rationale

The association between socio-economic position and morbidity and mortality has been recognised since ancient times. Despite huge improvements in living standards, medical interventions and sanitation, health outcome inequalities associated with these factors persist.

GBD 2015 identifies important differences between countries and highlights priorities for achieving the 17 sustainable development goals.[63; 153] Research has identified a myriad of different pathways connecting multiple deprivations to the length and quality of life.[133] Resource limitation is a universal problem, and research to identify contributory factors and vulnerable subgroups in each population that have the greatest risk of poor health outcomes has the potential to have the highest impact and deliver the greatest return on investment for policy makers.

We attempt to ascertain the impact of these factors on the development and subsequent diagnosis and treatment of adult ophthalmic disease.

C. Objectives

We aim to explore the association between multiple deprivation and the prevalence of vision loss, eye disease, and utilisation of eye care services internationally. Relevant factors are categorised in terms of the patient journey from onset of disease through to treatment outcome. By structuring a synthesis of the evidence in this way, we highlight the important associations between multiple deprivation and vision and ocular health outcomes to better identify both challenges and potential solutions in this complex area.

We focus primarily on the major acquired causes of visual loss in adults over the age of 18 years such as cataract, diabetic eye disease, glaucoma, age-related macular degeneration, and ocular trauma. Refractive and pediatric disease is outside the scope of this review, but has been considered to some extent previously within this journal.[226]

Here, we present a synthesis of 229 relevant studies by vision state or ocular disease type. Where relevant the 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses' (PRISMA) criteria were used and have been incorporated within the article. A flow chart highlighting the literature search and selection of articles is also provided in Figure 1. Subsections are presented to reflect the patient pathway, and include Onset of Disease, Access to Health services, Delivery of Treatment, Outcome, and Prevention, where there were relevant studies.

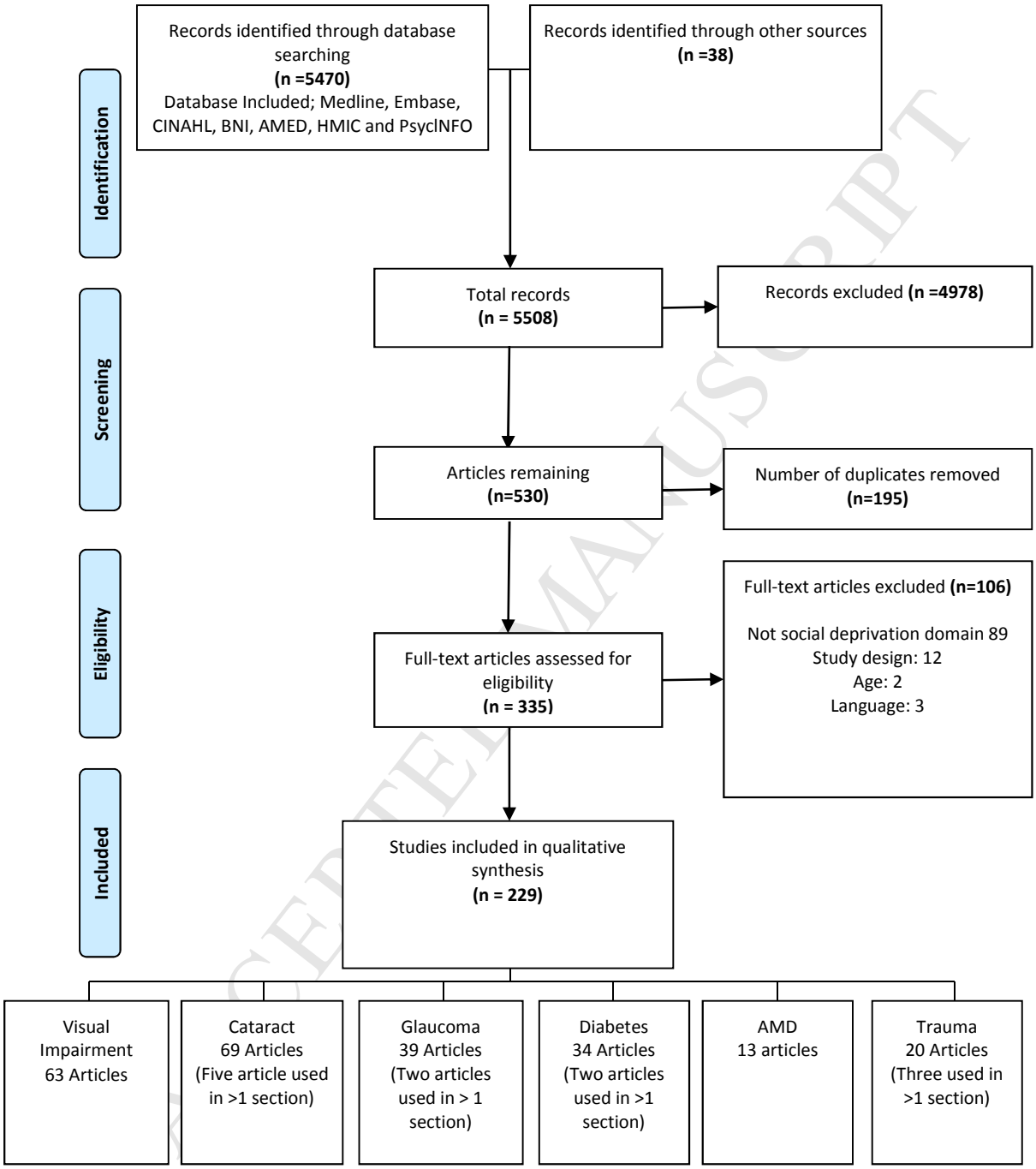


Figure 1 PRISMA flow diagram

II. Deprivation and Vision Impairment

A. Onset and outcome: Associations between vision impairment and multiple deprivation

i. A global overview

In 2017, the GBD 2015 Study estimated that there were 36.0 million blind people (presenting visual acuity < 3/60) and 216.6 million people with moderate or severe vision impairment (presenting visual acuity <6/18 but >=3/60), with marked geographic variation in prevalence.[17] Specifically, the age-standardized prevalence of blindness in older adults (>50 years) was ten times higher in low-income regions, including West Sub-Saharan Africa (5.1%), Eastern Sub-Saharan Africa (4.3%), and South Asia (4.0%), compared to high-income regions (< 0.5%).[17] The leading causes were cataract, uncorrected refractive error, and glaucoma, and women in all regions had an increased risk of vision loss.[61] The GBD 2015 study explores the association between the socio-demographic index and health outcomes relating to key Sustainable Development Goals, but this index has not yet been applied to vision loss.[63] An earlier review by Ho and coworkers identified similar associations between country income and blindness prevalence.[95]

Self-reported visual difficulty in recognizing a person's face across the road has also been found to vary by income level, from 24% in low-income countries to 13% in high-income countries. This finding, from a population-based sample of 260,958 adult participants in 70 countries in the World Health Survey, also identified additional risk factors for visual difficulty including older age, female sex, poor socioeconomic status, and lack of formal education. While older age showed little difference in effect size between low and high income countries, female gender was a risk factor for visual difficulty in low income

countries only, and lack of formal education was associated with greater risk in high income countries. High personal wealth index was most protective in high income countries. [72]

In total, 47 papers were identified which specifically considered aspects of deprivation as a risk factor for visual impairment. We identified 43 studies that found significant associations between aspects of deprivation and visual impairment, with 4 studies reporting no significant association. Factors associated with an increased incidence of visual impairment within these articles included: income (21 studies), educational attainment (28 studies), employment (8 studies), housing (3 studies), rural/urban environment (5 studies) access to services including lack of insurance (3 studies), composite score (IMD)/socioeconomic status (5 studies), and social class (2 studies). These studies are discussed in more detail below and are set in the context of their global or local relevance.

They highlight the complexity of the interactions between the multiple aspects of deprivation with vision impairment; indeed that there may exist a 'vicious cycle' of deprivation directly and indirectly increasing vision impairment and vision impairment leading to loss of income and worsening deprivation. Studies, particularly those which lack longitudinal data, often report association without causation being clear.

ii. Studies from North and South America

A number of major studies in the USA provide detailed strong evidence of the association between multiple aspects of deprivation and visual impairment. In the late 1980s the Baltimore Eye survey surveyed 5300 subjects found that visual impairment was significantly associated with lower educational level, lower income and employment status.[256] The National Health and Nutrition Examination Survey (NHANES) provides a wealth of data in this regard. Ko and coworkers compared the periods 1999-2002 (n=9471 adults) and 2005-8

(n=10,480 adults). Income was assessed using the poverty income ratio (PIR; <1 indicates family is below poverty threshold). Poverty increased the odds of having non-refractive vision impairment more than 2-fold (defined as VA < 20/40 aided by auto-refractor) in both the 1999-2002 and 2005-8 groups; lack of high-school education was a risk factor for non-refractive visual impairment in the 2005-8 group only.[129] In a separate report from NHANES, Zhang analysed the period 1999-2004 and found that uncorrectable visual impairment was more likely in the lower income (OR: 1.90) and lower educational attainment (OR: 1.9) groups. Having health insurance reduced the rate (OR:0.45).[298]

Another key national survey for the USA is the National Health Interview Survey (NHIS). Chiu-Fang and coworkers analysed data from the 2007-2010 NHIS comprising 69,845 adults and reported that non-refractive vision impairment were significantly higher in the lower educational attainment and lower income groups than the higher groups. Vision impairment was highest for farm workers (OR:1.41).[33]

A number of studies have specifically looked at the impact of multiple aspects of deprivation on groups perceived to be at particular risk based on gender, ethnicity, or other factors. Norris and coworkers reported on 7,708 women over the age of 40 years surveyed in the 2008 NHIS, and found that non-refractive visual impairment was associated with lower educational attainment and lower income.[192]

A cross-sectional study by Haymes was completed in 2006 of 3,793 native Alaskans also indicated that self-reported visual impairment was associated with lower educational attainment and low income.[91] Yonekawa and coworkers reported on over 4658 Latino participants aged over 40 years recruited as part of the Los Angeles Latino Eye Study (LALES)

and followed up for four years. Unemployment was a risk factor for developing visual impairment (OR: 3.5); income and educational attainment were not found to be risk factors.[294] Enlargement of the study population and further analysis indicated that 63% of participants had undetected eye disease. Both lower educational attainment (OR: 1.4) and being uninsured (OR: 1.6) were risk factors for unidentified eye disease.[265]

In Canada, Sit and coworkers analysed blindness registration for 1996 in relation to the national census data and found that prevalence of blindness was associated with lower median household income in all five geographical regions. For three of these regions higher education levels were associated with higher blindness registration rates.[235] In the 2000-2001 Canadian Community Health Survey (CCHS), self-reported vision impairment was also associated with low income, but in this study vision impairment was associated with educational attainment less than secondary school level.[198] Using the same survey data, Jin and coworkers noted that lower income in older adults who lived in regions without government-funded annual eye examinations was associated with higher rates of non-refractive vision problems.[109]

In a population-based study of 969 adults from Mexico examined between 2010-12, Jimenez-corona and coworkers reported that the prevalence of moderate visual impairment (VA better that 6/18 but worse than 6/60) was higher in less educated participants, and those from rural areas.[108]

In South America, the São Paulo Eye study, a cross sectional study of 3678 older adults in Brazil found that lack of education was associated with higher prevalence of blindness (OR: 0.25). Income was not noted as a risk factor in this study.[220]

iii. Studies from Europe

In the UK in the early 1990s, Reinstein and coworkers highlighted the presence of 'correctable undetected visual acuity deficits' (CUVAD) in 34% of patients from inner city London attending their local emergency eye department. Importantly, they noted that half the patients with these CUVAD had not seen their optician in the previous two years because of financial considerations. Although they did not undertake a detailed study of other determinants of deprivation, they did comment that they did not find an association between CUVAD and 'social class'.[214] In a study from London conducted in the early 2000s, an analysis of self-reported visual function of 1072 patients attending their family physician did not find that educational attainment or income were risk factors for self-reported poor vision.[103] A more recent cohort study in the East of England, the EPIC Norfolk Eye Study (n = 8467 participants recruited and examined between 2004 and 2011) reported that vision impairment (VA ≤6/12 in the better eye) was independently associated with the index of multiple deprivation after adjustment for age, sex, education, social class and cataract surgery. Participants in the most, compared to the least, deprived IMD quintiles were 1.7 times more likely to have vision impairment.[291]

Brezin and coworkers reported on a cross sectional study of 16,945 French citizens undertaken in the 1990s. Mean monthly household incomes were lower for subjects with low vision (€1255) and blindness (€1587) than for subjects with no visual problems (€1851).[19] In the German National Health Eye Survey conducted in 1998 (n=6962), although correctable visual impairment was higher in those of higher social status, the prevalence of uncorrected visual impairment was greatest in younger males of lower social status.[242] In

Poland in 2012 Nowak and coworkers conducted a cross sectional study of 1107 subjects. Socioeconomic status (which was not defined in the paper) was not found to be a risk factor for visual impairment.[193]

One potential impact of visual impairment was explored by Verhaeghe and coworkers who conducted a study of the Belgian property market and noted that email requests from virtual participants with visual impairment (and the presence of an assistance dog) were frequently discriminated against compared to matched emails which did not refer to any visual impairment.[268]

iv. Studies from Asia

In India a 1976 cross-sectional survey of 20,134 participants in a rural setting noted higher levels of blindness and "partial blindness" in social classes III and IV compared to both class II (a higher level) and class V (lowest level). They noted, however, that this finding was not adjusted for age and that the apparent protective effect of social class V was likely from the much lower life expectancy in this group. It was also noted that 5 out of 11 beggars had blindness or partial blindness, highlighting the point that the association of deprivation with impaired vision may be bidirectional--both a cause and an effect of deprivation.[241]

In the population-based Andhra Pradesh Eye Survey in India (n = 10,293) conducted between 1996 and 2000, the overall prevalence of blindness (1.84% with VA <6/60 and central field < 20 degrees in the better eye) and moderate vision impairment (8.09% with VA <6/18 to 6/60) in the better seeing eye were associated with increasing age, decreasing socioeconomic status (based on income), female gender, and rural location.[44 50] Compared to individuals in the upper socioeconomic group, those with moderate vision impairment were 3 times more likely to come from the extreme lower socioeconomic group, and those who were blind were nearly 10 times more likely to come from this group. [49]

In another population-based survey including one district in each of the 15 states in India in 1999-2001 (n= 63,337), 8.5% were blind (presenting VA <6/60 in the better eye), and blindness was associated with increasing age, female gender, lower literacy/education, rural location, and not working (including household work).[180] In the Central India Eye and Medical Study (CIEMS), conducted in rural areas between 2006-2008 (n=4711), better best-corrected visual acuity was associated with younger age, higher educational attainment, and higher body mass index.[182] Lower educational attainment and lower literacy levels were also noted as a risk factor for blindness and visual impairment in several other studies encompassing tribal areas of the Andhra Pradesh area and in an Urban Indian population.[233; 269] Not all studies find a positive association: a relatively small study by Singh and coworkers did not find prevalence of visual impairment to be significantly associated with socioeconomic status or literacy status.[232]

In Pakistan, Gilbert and coworkers conducted a cross-sectional study of 16,507 adults over 30 years old in Pakistan between 1996 and 2000. They scored deprivation using measures of education, housing, employment and access to services. The prevalence of blindness (<3/60 in the better eye) in adults living in affluent clusters was 2.2%, compared with 3.7% in the medium clusters and 3.9% in the poor clusters. The prevalence of total blindness (bilateral no light perception) was more than three times higher in poor clusters than in affluent clusters.[80]

Two studies were conducted using data from the Singapore Malay Eye Study (SiMES) (n=3280), conducted between 2004-2007, and one using data from the Singapore Indian Eye Study (SINDI) (n=3400) conducted between 2007-2009. Lower education level, income level,

and occupational status were significant independent predictors of visual impairment in all three populations.[34; 302; 303] The SiMES study also found that patients were unaware of at least one of their eye conditions if they had lower education (OR 1.89), poorer literacy (OR 1.44) and lower income (OR 1.73).[100] Building on these earlier studies, Wah and coworkers published an analysis of 9993 individuals from Singapore comprising the three major ethnic groups. Individual low socioeconomic status (comprising factors such as education, income and type of residence) was associated with the presence of low vision (OR: 2.1) and blindness (OR: 2.53). Area-level deprivation score was positively associated with the presence low VI in the better seeing eye (OR: 1.07), but was not associated with blindness.[270]

In Korea, cross sectional data from the Korean National Health and Nutrition Examination Survey (KNHANES) identified that low vision was associated with poor educational attainment (elementary or less OR 2.30) and low household income (OR:1.37).[195] In Taiwan, a cross sectional study of 2034 participants conducted between 1993-1995 found that visual impairment was less common in those with higher educational attainment. Employment status was not significantly associated.[158] In Hong Kong, Michon and coworkers conducted a cross sectional study in 1998 of 3441 patients, noting that the risk of presenting with bilateral blindness or visual impairment was reduced in the presence of educational attainment of secondary school or above (OR: 0.6) and living in private accommodation (OR:0.7). Unilateral or bilateral blindness because of un-operated cataract was associated with lower educational attainment.[171] In China , the Beijing Eye Study of 4438 subjects found that lower level of educational attainment was associated with worse best corrected visual acuity.[287]

The Shahroud Eye Cohort Study (ShECS) in Iran (n=5190 aged 40 to 64 years) conducted between 2008-2009 reported that vision impairment (VA < 6/12 in better eye) was significantly higher in the low economic group (11.1%) compared to the high economic group (3.6%). Differences in educational attainment were estimated to account for a third of this gap.[58]

v. Studies from Africa

In a population-based study in Kenya of 4314 older adults (> 50 years) conducted between 2007-2008, lower prevalence of vision impairment (VA < 6/18) was associated with increased material wealth and higher educational attainment. The authors noted that the leading cause of visual impairment in Kenya is cataract, that these results indicate that affluent patients are more likely to be able to afford treatment, and educated patients are more likely to seek treatment.[201] In Nigeria, Ribadu and coworkers conducted a cross sectional study of 85 blind adults and found that 75% roamed the streets begging, 69% lived on less than a dollar per day, and 71% did not have any personal asset. More than two-thirds had no formal education, and over three-quarters had no access to health services.[215] In South Africa, Mabaso and coworkers found that low monthly income, but not educational attainment, was significantly associated with visual impairment and blindness in a study of 225 adult patients with diabetes.[163] In a population-based study of 3322 older adults from the Nile Delta of Egypt, 13% were blind (VA < 6/60 in the better eye). Independent predictors of blindness included lack of access to a sanitation network, older age, female gender.[69]

vi. Studies from Oceania

In a population-based survey of 1474 people in Papua New Guinea in 2005, blindness (presenting VA of 6/60 in the better eye) was present in 8.9%, and the odds of blindness were 3 times higher among those who were illiterate.[75] In 2007 Ramke and coworkers conducted a population-based cross-sectional study of 1414 patients in Timor-Leste to establish factors for visual loss. Illiteracy, unemployment, rural location, and older age were all associated with low vision (defined as VA ≥6/60 and <6/18) and blindness (VA <6/60). For blindness, ORs were calculated to be 6.8 for illiteracy, 28.3 for unemployment, 1.5 for rural location, and 29.2 for participants aged over 70 years.[210] It is notweworthy that the Melbourne Visual Impairment Project (VIP) which studied a much less deprived population noted much lower rates of visual impairment and did not find it to be associated with educational attainment or household income.[159]

B. Access: The association between measures of multiple deprivation and access to health care

Sixteen studies investigated the impact that measures of multiple deprivation have on the access to healthcare. Factors associated with a reduction in the uptake of eye services included; low income (8 studies), cost (1 study), low educational attainment (12 studies), access to services including lack of health insurance (3 studies), employment (1 study), rural location (1 study) and composite score (IMD)/socioeconomic status (2 studies).

It is noted that issues of access and delivery of eye services is a common feature in many studies discussed elsewhere in this review, but in this section we only consider those articles for which this is the primary focus.

i. Studies from North America

Baker and coworkers studied 152 patients aged over 40 from an urban, low-income multi-ethnic population in Los Angeles sampled in 1999. Sixty-two per cent reported that they had received an eye examination in the preceding two years, with higher rates being seen in those who recalled having been previously given advice about the need for eye examinations (OR: 3.9), those who had eye-care insurance (OR: 3.2), and those who had regular medical care (OR: 2.4).[9]

Similar themes emerged in a larger cross-sectional study by Zhang and coworkers based on 30,920 adults from the 2002 National Health Interview Survey (NHIS). In the group at greatest risk of severe visual loss, around half had seen an ophthalmologist in the previous 12 months, and half reported that they had a dilated eye examination at that time (overlap assumed). The rate of each of these variables was influenced by similar factors including health insurance, educational attainment and poverty. Uptake of seeing an ophthalmologist in the preceding 12 months was 42% in those with less than high school education, compared to 57% in those with education beyond high school and 39% in those with a poverty: income ratio (PIR) <1, compared to 55% in those with PIR ≥2. Around 8% stated that they could not afford glasses, but this increased to 32% among those with no health insurance.[299] Additionally, using data from the National Health and Nutritional Examination Survey (NAHNES), Zhang reported that, from 1999 to 2008, individuals with less education (high school or less) and lower income (PIR <1.00) were consistently less likely to have had an eye care visit in the past 12 months compared with their counterparts (education beyond high school or PIR of $\underline{\geq}$ 4.00).[297] Further work on this cross sectional study using data from the same database between 2002-2008 indicated that age related eye disease, including cataract, glaucoma, diabetic retinopathy, and age-related macular degeneration, was linked to both poverty and educational attainment. [296]

Chou and coworkers analysed the 2006-2009 Behavioural Risk Factor Surveillance System (BFRSS) data for 21 American states, focusing on the group of 28,129 adults over 40 years of age who were identified as having moderate to severe visual impairment based on questions designed to obtain functional visual ability rather than examination data. In this group, attendance for annual eye examination was associated with higher educational attainment (62% if more than high school level education, compared to 52% if less than high school education) and annual income (62% if ≥$35000 vs 52% if <$35000). There was considerable variation between states, which may reflect local healthcare policies, such as the provision of free eye care for at risk groups in some states.[36]

The impact of deprivation has also been explored in particular at risk groups within the USA, such as the rural population and the elderly. In a study of 4289 adults from Arkansas aged over 40 , rural residents had lower rates of dilated eye examination within the preceding 12 months (45% in rural vs. 49% in urban residents) and had lower rates of insurance (45% for rural vs. 55% for urban). Rural residents more frequently reported that cost or lack of insurance was the primary block to seeking an eye examination.[121] In the elderly population, Sloan and coworkers reported that, in a retrospective review of 2151 participants, educational attainment was positively correlated with more regular eye examinations.[236]

It is interesting to compare eye care utilisation in the USA to Canada, where most provinces provide health insurance plans to cover eye examinations if the patient has a medically diagnosed eye condition. Jin and coworkers conducted an analysis of the 2005 Canadian Community Health Survey comprising 132,221 respondents. They noted that eye care utilisation in people with self-reported glaucoma, cataracts, or diabetes was not influenced

by educational level or household income, whereas in those without any of these conditions reduced utilisation was associated with lower educational level and lower household income.[110]

Ii. Studies from Europe

Dickey and coworkers reported on a study from Scotland, which looked at the uptake of eye services from 1999 to 2008, with a particular focus on the impact of the free eye examinations introduced in 2006. A consistent finding was that eye care utilisation was influenced by educational level (lowest in those with no educational qualifications) and income level (lowest in the lower income group). The introduction of free eye examinations did increase utilisation by the population as a whole, but this effect was greater in those with higher income and higher education. This study suggests that the policy had least impact on those with low educational attainment and low income and that eye care service utilisation inequalities have widened in Scotland since the introduction of the free eye care policy.[53] In a qualitative study of adults over age 60 from socially deprived communities in Wales conducted during 2010-2011, Biddyr and coworkers found that the most commonly reported barrier to accessing sight tests was cost, particularly in relation to buying glasses, even though the eye examination itself is funded by the National Health Service.[12]

iii. Studies from the rest of the world

In Australia, the Blue Mountain Eye Study that surveyed 3654 patients during 1992 to 1994, noted that having higher socioeconomic status was positively associated with having seen an ophthalmologist in the last two years.[273] In Iran, Fotouhi and coworkers reported on a cross-sectional study of 4565 patients surveyed as part of the Tehran Eye Study. Risk factors for patients having never seen an eye care provider included low educational attainment

(each year increase in education OR: 0.93).[68] In Fiji, Brian and coworkers reported on a cross-sectional survey of 1381 adults in 2009,and noted that not having a household income was a risk factor for not seeking treatment for an ophthalmic problem. Educational attainment was not significantly associated with seeking treatment.[20]

Levels of awareness of eye disease are likely to be an important factor in appropriate health-seeking behavior. In Bangladesh, Islam and coworkers found that lack of formal schooling and lower socio-economic status were associated with lower awareness of common eye diseases. Higher education and socioeconomic status were associated with more frequent eye examinations.[104] A cross sectional study in Nepal by Gnyawali and coworkers found that low level of educational attainment (OR = 3.1) and poverty (OR = 2.0) were associated with poor awareness on eye diseases.[81] Conversely a small study in India in 2009 which noted generally low level of acceptance of eye-related treatments, reported that literacy was inversely associated with acceptance of eye medications.[244]

III. Cataract

Age-related cataract was the leading cause of blindness globally in 2015, responsible for an estimated 34.5% of all blindness and 24.1% of all moderate and severe vision impairment.[61] There is, however, marked geographic variation in the proportion of blindness attributable to cataract, ranging from 44.8% in Oceania to 20.0% in high-income North America.[61]

Cataract vision loss is correctable through surgery that has excellent visual outcomes. The cataract surgical rate (number of operations per million population per year) is a useful measure of eye care service availability in different areas. There is a huge variation ranging from an estimated 5000/1,000,000 in the USA to 200/1,000,000 in the whole of Africa.[283]

A. Onset: Deprivation and the epidemiology of cataract

Nineteen studies investigated the impact that measures of multiple deprivation have on the onset of cataract. Factors associated with an increased incidence of cataract within these articles included; low educational attainment (12 studies), employment (7 studies), income (10 studies), housing (1 study), and nutrition (3 studies). Since not all studies adjust for age, it is not always clear whether reported higher prevalence of cataract in particular groups are due to earlier onset of cataract in these groups or the result of delayed presentation and/or avoidance of surgery. Additionally the effect of age on socioeconomic factors such as educational level and income should also be considered.

I Studies from North America

From 1985-1988, Leske and coworkers completed a case-control study of 466 patients with cataract and 435 healthy controls. Risk factors associated with developing cataract again included low educational attainment (OR: 1.46 for < 12 years of education). An increase in cataract (nuclear type) was noted in patients with non-professional occupations--with an OR of 2.2 for nuclear cataract vs. no cataract amongst factory workers.[146] Subsequently Klein and coworkers reported on the 10-year incidence of cataract in Wisconsin, USA ,collected as part of the Beaver Dam Study, 1998-2000. After adjusting for age and sex, both educational attainment and income were negatively associated with the development of cataract, although this effect was only present for nuclear cataract. Smoking was positively associated with nuclear cataract development. Ten-year cumulative incidence rate for nuclear cataract was 23.6% in those earning under$10,000 (hazard ratio: 1.00) compared to 19.5% in patients earning over $44,000 (hazard ratio: 0.65).[123]

In Canada, Wesolsky and coworkers conducted a case series of 1350 eyes that underwent phacoemulsification by one surgeon during 2006-8, enabling an estimation of cataract severity based on 'phaco time'. Socioeconomic status was derived from area-aggregate data including median income, education and employment rate. Cataract severity was associated with lower income and with unemployment, but not with educational attainment.[277]

Two studies from the West Indies looked at the prevalence of cataract (1988-1992 Barbados Eye Study) and the four year incidence of developing cataract (Barbados Incidence Study of Eye Diseases, BISED). The prevalence study comprised 4314 black participants aged 40 years or over, of whom 42% had cataract in at least one eye. Socioeconomic status was assessed as high, medium or low based on a combination of education (more or less than 9 years) and employment (professional vs. non-professional). Lower socioeconomic status was associated with cataract (OR: 1.42).[147] The incidence studies comprised 3193 black participants who had been free of nuclear (n=2609), cortical (n=2040) and posterior sub-capsular (n=2954) at baseline. Initially all results indicated that low socioeconomic status was associated with a higher incidence of all cataract subtypes. Following correction for age and sex, only cortical cataracts remained significantly associated (multivariate adjusted RR: 1.4 for the most deprived group).[148]

No socioeconomic risk factors are common to all studies, all locations and all cataract subtypes; however there are clear themes on the roles that poor educational attainment, income, occupation, housing, nutritional status, and health behaviours such as smoking play on the increased incidence of cataract.

ii. Studies from Asia and Africa

Between 1976-1977, Chatterjee and coworkers collected data for a cross-sectional study of 1269 patients in the Punjab, examining the prevalence of senile cataract (either present or operated), which was found to be 15.3% (n=195) in those over 30 years of age. Development of cataract was associated with low educational attainment (OR: 7.46 for illiterate vs. high school graduate in univariate analysis). Economic status and occupation were not found to be significant risk factors.[27]

In Singapore, the influence of deprivation in the major ethnic groups has been investigated. In 1997-1998 Foster and coworkers undertook an analysis of the Tanjong Pagar survey, a study of Chinese adults living in one particular district of Singapore (n=1206). The presence of cataract was associated with both non-professional employment (nuclear cataract) and lower income (posterior subcapsular cataract). With regard to developing nuclear cataract, production workers had an OR of 2.9 and laborers/agricultural workers an OR of 2.6 when compared to professionals.[67] Wu and coworkers analysed data on 2927 Singaporean Malay participants drawn from the SiMES study. The prevalence of cataract was found to be 46%, with a higher risk of nuclear cataract in those with lower educational attainment (OR: 1.7 if $\leq$ 6 years education) and low monthly income (OR: 1.43 if <Singaporean $1000). Living in small public housing was associated with an increased risk of posterior subcapsular cataract (OR: 1.7).[285] Both Singaporean studies positively associated smoking with nuclear cataract. More recently, Chua and coworkers reported on an analysis of the three major ethnic groups (Singaporean Malays, Chinese and Indians) and found that low income (OR: 1.53), low educational attainment (primary or below) (OR: 1.48) and current smoking (OR: 1.42) were associated with an increased prevalence of cataract. On deeper analysis, this

association was only present in the Chinese and Indian sub-groups and not in the Singaporean Malays.[38] As in all studies considering the influence of ethnicity, the possibility of genetic heterogeneity should be considered when interpreting conclusions.

A number of studies highlight the complexity of the interaction between deprivation and cataract, including the influence of gender. For example, Nam and coworkers performed a cross-sectional survey of 15,866 participants from South Korea, noting that low household income and low educational attainment were associated with an increased risk of cataract in both men and women in univariable basis. When they corrected for smoking, alcohol, physical activity, sunlight exposure, outdoor occupation and residential area, this finding only remained significant for females.[181]

In 2001, Minassian and coworkers completed a case-control study in central India investigating risk factors for the development of cataract in childbearing women. All pregnant women aged 35-45 years attending Chattisgarh Eye Hospital in a one year period were eligible for inclusion (n=357). 97 had bilateral cataract (cases) and 262 did not (controls). Prevalence of cataract in one or both eyes was 27%. Although occupation (outdoor work) and low income were risk factors for cataract in univariable analysis, when this was adjusted for age and other variables, only outdoor work continued to be significantly associated. The most significant risk factor for the development of cataract was number of children (OR: 2.0 in those with more than three babies) with an estimated increased risk of 20% for each additional birth.[172] A study from Chennai, India, provides data for the population with type II diabetes. In this cross-sectional study of 1283 patients with type II diabetes from India, educational attainment and socioeconomic status were not associated with cataract prevalence, although subgroup analysis suggested that being employed increased the rate of posterior subcapsular lense opacity.[207]

In Indonesia, a cross-sectional population-based study conducted in 2003 by Husain and coworkers of 919 people over the age of 21 years found that there was an increased prevalence of all types of cataract with decreasing education (48% prevalence in those with no formal education vs 7% in those with higher than primary level education). PSC cataract appeared to be more common in those with lowest income, but no other cataract types were associated with income. [101]

A population-based case-control study across three deprived settings during 2005-2006 found that there was a strong protective effect of literacy and education on cataract in Bangladesh and Kenya, but that this benefit was not seen in the Philippines.[135] In Ghana, an analysis of 4278 adults over the age of 50 from the 2007-2008 Study on global AGEing and adult health (SAGE) found that lower income increased the prevalence of self-reported cataracts in Ghanaian adults.[289]

Tarwadi and coworkers completed three papers with data drawn from a 2006 Indian case-control study, investigating nutritional and socioeconomic factors influencing the incidence of cataract. Cataract patients (n=140) aged 50 to70 years and age and sex-matched healthy controls (n=100) were subdivided into high income (monthly income >$240) and low income (monthly income <$100) groups. The average age of cataract onset was 57.5 years in the low-income group compared to 67.5 years in the high-income group. Findings in the low-income group indicated that factors contributing to this earlier age of onset include: lack of formal education (45% of men and 87% of women had had no education) and smoking (80%). One of the links between deprivation and cataract may be dietary, with higher intake of saturated fats and a lower intake of vegetables in those with cataracts. [250; 251] Analysis of

blood samples from these groups demonstrated reduced hemoglobin and lower levels of micronutrients in the low income group compared to the high income group.[249]

In Korea, a cross sectional study by Rim and coworkers of 11,519 participants identified from the 2008-10 Korea National Health and Nutrition Examination Surveys were assed for prevalence of cataracts. Lower monthly household income and lower education were associated with the development of cataract; subgroup analysis showed both these factors to be associated with both cortical and mixed cataracts; education but not income was associated with pure nuclear cataracts; neither factor was associated with pure posterior subcapsular cataracts. Residential area and occupation were not associated with any subtype of cataract. Again the possible modifier of diet was raised with hypercholesterolemia being higher in the cataract group.[217]

B. Access to healthcare: Deprivation and barriers to cataract surgery

41 studies have investigated possible socioeconomic factors that act as barriers to surgery for patients with cataract. 34 indicated that socioeconomic factors played a specific role; 7 demonstrated no relationship between deprivation and cataract surgery. The impact of poverty on access to ophthalmic care is multifactorial. Factors include not only the obvious variation in provision between countries and even within the same country, but also more complex social, demographic, and economic factors that may cause additional barriers that preventing patients accessing care even when it is available. For cataract this has been particularly explored in South East Asia and Africa, although there are also significant studies from the USA, Europe, and Australia. Factors that had an impact include income (13 studies), cost of services (8 studies), willingness to pay (5 studies), poverty (2 studies),

access to services (1 studies), rural/urban housing (3 studies), educational attainment/awareness (10 studies), health insurance (3 studies), social class (2 studies), employment (1 study) and composite score (IMD)/socioeconomic status (4 studies).

i. Studies from North America, Europe and Oceania

The variation among health care systems appears to be responsible for some interesting differences between the findings of studies in North America, Europe and Australia. In the USA, a study using 1986 to 1987 Medicare claims data by Javitt and coworkers found that being white and living in a neighbourhood where the mean annual income was over $15 000 was associated with greater likelihood of cataract surgery.[107] These ethnic differences were noted to persist in a similar study using 2003 to 2004 Medicare data, although this follow-up analysis did not include income data.[225] Other ethnic groups may also be vulnerable. Broman and coworkers undertook a study of 4774 Hispanics in Arizona and found that patients were more likely to undergo cataract surgery if they had medical insurance (OR: 2.9) and spoke English (OR: 1.8). The increased uptake of surgery was not significantly impacted by differences in income or educational attainment.[21] In the Los Angeles Latino study (LALES) the presence of a significant cataract that had not been operated on was more likely in the uninsured (OR: 2.8) and those with an annual income under $20,000 (OR: 2.60). Education and employment status were not independently associated.[216]

Interestingly, several studies such as the Beaver Dam Eye study from the USA report an upright 'U' pattern between income and cataract surgery, in which higher rates are seen in both highest and lowest income groups. The authors argued that this finding reflected the earlier onset of cataract in the lowest income group and earlier health-seeking behaviours, and higher levels of insurance and better access in the highest income group.[126] A study by

Ng and coworkers from Western Australia, found a similar 'U' pattern, although in this case the differences were most marked for the highest socioeconomic quartile in which the highest rates of cataract surgery were seen.[186]

In countries with free access to cataract surgery the situation may be more complex. In the UK, Keenan and coworkers found that the rate of cataract surgery between the dates of 1998-2003 was positively correlated with the index of multiple deprivation, with higher rates of surgery in the more deprived areas.[115] Similarly, Meddings and coworkers found that in Canada lower socioeconomic status was associated with an increased uptake of free cataract surgery at a younger age. These findings may be accounted for by a higher prevalence of cataract in these groups, a bias to earlier surgery in such patients, or the impact of not counting those more affluent who seek surgery in the private sector.[169] Studies which seek to address prevalence of cataract *per se* have already been discussed, but the influence of deprivation on delay, and the impact of the private sector require more consideration. In Scotland Chua and coworkers noted that lower rates of deprivation (measured by the Scottish Index of Multiple Deprivation) were associated with earlier cataract surgery indicated by visual acuity of 6/12 or better at surgery.[40] A large cross-sectional study in Sweden (n=102,532) reported longer waiting time for cataract surgery in those with lower income and lower educational attainment.[237]

The influence of the private sector in predominantly public health systems is difficult to evaluate. In a study from Finland during the late 1980s, Keskimaki and coworkers reported higher rates of cataract surgery in those with higher incomes, higher social class, and higher educational attainment. This finding was attributed to the influence of the private sector both within the public hospitals and private hospitals.[116] In the early 1990s a large UK study

looking at consultation and surgery in a range of conditions, noted that there was an inverse relationship between higher incomes, higher social class, and higher education and rates of cataract operations. It was proposed that this finding reflected a combination of tolerance of poor vision amongst patients from lower socioeconomic groups and the use of private health care for surgery in the higher socioeconomic groups (private operations were not included in this analysis).[28]

A number of studies report no significant associations between deprivation and incidence of cataract surgery. The Blue Mountain Eye Study did not find any association with occupation or other socioeconomic factors on the incidence of cataract surgery after five years of follow up in 3654 older Australians.[295] Similarly in another study from Australia, McCarty and coworkers found no association between prevalence of unoperated cataract and occupation, employment status or health insurance .[168] In Canada, Chan and coworkers reported that overall self-reported cataract was not affected by educational level or income, although it should be noted that it was lower in those residing in provinces without insurance, suggesting that this may be due to reduced detection.[25]

ii. Studies from Asia and Africa

An important study undertaken in 1995 by Vaidyanathan and coworkers analysed data on 3259 patients in Southwest India who had unilateral or bilateral blindness (VA <3/60) from cataract . This study specifically explored the reasons why these patients had not undergone surgery. In the sub-group of patients with bilateral blindness, reasons included: not being able to afford the operation (7.2%), service delivery reasons (54%) and attitude-related reasons such as, “This is a curse from God” (25%).[264] These results were compared to an

earlier unpublished study conducted in Tamil Nadu in 1986 where the primary reasons for patients not undergoing surgery were different. Not being able to afford the operation was the primary reason in 17% cases, and attitude-related reasons were quoted as the primary reason in 54%. One study conducted in India and one in Malawi identified the major barriers to surgery as poverty, lack of transportation, patient perception that the operation is not needed, and gender related issues.[42; 267] In 2000 a large cross sectional study (n=15265) in India reported by Nirmalan and coworkers found that illiteracy significantly reduced access to cataract surgery in both urban (OR: 0.3) and rural settings (OR 0.5) and that illiterate women were most vulnerable. A smaller study by Nirmalen and coworkers also found that surgical coverage was inversely associated with illiteracy and with female sex in rural areas. [190; 191] In 2002 a study of 1505 participants in a rural south India population identified inability to afford the operation as the main barrier to surgery (23%).[26] In 2007 a small survey on a deprived population in northern India by Dhaliwal and coworkers noted a number of barriers identified earlier including the common perception that this was the 'will of God' and lack of family income to fund surgery.[52] During 2011, Kovai and coworkers reported on 398 participants who had declined cataract surgery in a remote tribal area of India, of whom 80% were illiterate. Odds of seeking treatment were lower among the unemployed (OR:0.4; vs employed) and in the lowest family income group (OR: 0.5 for income <INR1000 vs >INR1000).[132]

Similar findings are noted elsewhere. In Nepal, Snellingen and coworkers reported in the early 1990s on 96 patients who had declined cataract surgery, finding that the most frequent reason for not accepting surgery was economic.[239] In 2002, Sapkota and coworkers examined 5002 patients aged over 45yrs, finding that the prevalence of blindness (<6/60 in the better eye) from cataract was significantly higher in the illiterate than the literate

population (4.6% vs 2.5%). This was in part due to the increased surgical rates in the literate patients. [222] In contrast in 2006, Sherchan and coworkers found no significant difference in cataract surgical coverage between literate and illiterate populations in a cross-sectional study of a different region of Nepal.[229] In Pakistan, a cross-sectional population based survey in the early 2000s noted higher levels of blindness (<3/60 in the better eye) and lower levels of cataract surgical coverage in those with higher levels of poverty.[80] In a further report by Jadoon and coworkers found that cataract surgical coverage was better in urban communities and in the literate and that cost was the main barrier to the cataract surgery.[105] In Iran, Hashemi found that cataract surgical rates were significantly lower in the poorest socioeconomic quintile (defined primarily by area-income), compared to the highest. [90]

In Tanzania Kessy and coworkers reported a prospective study of 198 patients who had declined surgery during 2005-2006, noting that 79% had reported that the main barrier to cataract surgery was lack of funds.[117] Similarly a more recent study from Ethiopia of 146 participants with mature cataract presenting to outreach clinics, found the commonest reasons for delayed cataract surgery were cost of surgery (92%) and insufficient family income (78%) [170]

As part of the Study on global Ageing and adult health (SAGE), Ackuaku-dogbe and coworkers completed a cohort study of 5571 adults in Ghana to assess the impact of deprivation (income and literacy) on the uptake on cataract surgery. Educational attainment and income did not significantly influence cataract surgical uptake.[4] In a study across Kenya, Bangladesh, and the Philippines, Syed and coworkers found that the most frequently reported barriers to cataract surgery were being unaware of having a visual impairment

(36% Kenya, 37% Bangladesh, 24% Philippines) and cost (31% Kenya, 38% Bangladesh, 32% Philippines).[246]

Several of these studies have also explored the impact of additional counselling. In a study from Tanzania it was noted that, after counselling, 20% of these patients accessed funds to allow cataract surgery. Also, many patients who cited poverty also had other reasons, and that only 22% took advantage of a free waiver to undergo cataract surgery .[117] In the study from Nepal by Snellingen and coworkers only a further 13% accepted surgery after a second counselling.[239]

The issue of cost and patient willingness to pay has been explored in a number of studies across the world. Wide variations have been noted between cultures. 58% of patients in a study in Nepal[230] and 62% in a study in Tanzania[150] were unwilling to pay anything towards their cataract surgery, whereas in China only 20% were unwilling to pay anything.[92] In the study by Syed and coworkers encompassing patients from Kenya, Bangladesh, and Philippines, when patients were offered free surgery, this was taken up by 59% in Kenya, 54% in Bangladesh and 47% in the Philippines. Higher take-up was positively associated with younger age in all three countries. Of those who continued to decline surgery, reasons for doing so included having nobody to accompany them (26% Kenya, 16% Bangladesh, 38% Philippines), inaccessible surgical services (39% Kenya, 15% Bangladesh, 47% Philippines), and fear (31% Kenya, 58% Bangladesh, 47% Philippines).[246]

There are a number of interesting studies that explore these issues within China. In 2007, Yin and coworkers conducted a population based study on barriers to cataract surgery in

China. They identified that the likelihood of undergoing surgery was related to patient knowledge of the condition and the perceived quality of the local services. Cost did not appear to be a significant issue.[290] This is also supported by the study by He and coworkersthat found that 80% of patients in a rural setting would be willing to pay for cataract surgery, and a survey in 2013 that showed that 90% patients in an urban setting would be willing to pay for cataract surgery. Of those unwilling to pay anything, the most common reason was 'not enough income'. [92,274] Conversely, Xu and coworkers reported that reducing the cost of surgery in rural China improved surgical uptake, and Lin and coworkers noted that participants in a free cataract surgery programme reported financial problems as the primary reason for not having sought surgery before; lower educational attainment was also seen to have been a barrier to seeking surgery .[286,154]

In Korea, Park assessed the prevalence for cataract in Korea and the factors associated with surgical uptake using data from the 2008-2012 Korean National Health Survey of over 20,000 participants over 40 years of age. Although the presence of cataract was increased in patients with lower than average household income (OR: 1.14 for income $\leq 50^{th}$ centile vs income $>50^{th}$ centile) and lower education attainment (OR: 1.2 for middle school or lower vs high school or above), these factors were not associated with differences in the rates of cataract surgery.[196]

C. Outcome: Effect of deprivation on surgical outcomes in cataract surgery

Of the six studies assesed the impact of deprivation on surgical outcomes, only three had significant findings. Factors associated with the outocome of cataract surgery include; education attaintment (2 studies) and socioeconomic status/affluence (1 study).

Between 2004-2005, Quintana and coworkers completed a prospective cohort study of 17 hospitals in Spain examining both visual acuity and patient scores on a visual function questionnaire. Statistically significant associations were reported for a number of socioeconomic factors, with the most consistent being an association between higher levels of education and better outcome post-operatively.[205]

Between 2007-2008, Ravindran and coworkers performed a retrospective cohort study of 42,426 cataract operations conducted in the Aravind Eye Hospital, India. The incidence of post-operative endophthalmitis was 0.09%, with no statistically significant difference between private and charity-funded patients, despite differences in the type of cataract operation performed (phacoemulsification in 76% of private patients vs. 4% of the charity patients).[212]

In a study of 478 patients undergoing cataract surgery in Iran, Hashemi and coworkers found that higher levels of education were associated with better post-operative uncorrected and best corrected visual acuity.[89] A cross-sectional study in 2006 in Nepal indicated that there was no significant difference in visual outcome after cataract surgery based on age, sex, literacy, or institution.[113] Similarly in Kenya, Bangladesh and the Philippines, although adverse outcomes were common, there was no significant association between adverse outcome and literacy or poverty.[155] In Pakistan, a cross-sectional population based survey in the early 2000s noted that the rate of intraocular lens insertion was higher in the affluent compared to poor, who were more likely to be left aphakic.[80]

D. Outcome: The impact of cataract surgery on deprivation

The impact of cataract surgery in relieving poverty has been demonstrated in four studies across the world. Cataract surgery improved per capita expenditure (2 studies), assets (1 study), self-rated wealth (1 study), income (2 studies), and employment (1 study).

A study from the Philippines, Kenya, and Bangladesh of 466 patients aged over 50 years with VA <6/24 in the better eye secondary to cataract were offered free or subsidised cataract surgery. At baseline, operated cases were found to be significantly more likely than controls to be in the poorest quartile of per capita expenditure (PCE) in Kenya (OR: 3.3), Bangladesh (OR: 3.2) and the Philippines (OR: 4.4). Surgery resulted in improvements in assets and PCE. Benefits were apparent at both one year (all three countries) and six years (data only available for Bangladesh and the Philippines). The scale of impact is impressive as exemplified by the data on PCE from the Philippines: cases (vs controls) improved from $21.7 (vs. $29.1) at baseline to $27.1 (vs. $28.1) at 1 year and to $38.9 (vs. $37.4) at 6 years.[51; 136]

A prospective cohort study from India by Finger and coworkers found that, at one year, the patients that had received cataract surgery were more likely to be in work, and the proportion of households with a monthly income of less than 1000 Rupees decreased from 51% to 21%.[60] Similarly in Vietnam, Essue and coworkers found that cataract surgery was associated with a significant improvement in household economic circumstances, with an increase in median annual income, reduction in economic hardship and reduction in the number of people with catastrophic health expenditure (treatment that exceeds 30% of household income).[59]

IV. Glaucoma

Glaucoma is an umbrella term used to describe a group of optic neuropathies, often associated with high intraocular pressure (IOP), in which there is a potentially avoidable characteristic pattern of optic nerve damage and visual field loss. In 2015, glaucoma was responsible for 8.3% of all blindness globally (3rd most prevalent cause), and 1.9% of all moderate and severe vision impairment.[61] The proportion of blindness attributed to glaucoma varied markedly by geographical location, from 15.1% in Southern Sub-Saharan Africa to 5.7% in South Asia, in part reflecting differences in genetic risk in different populations.[61] The risk of vision loss in glaucoma can be reduced in many cases through pharmacological and/or surgical intervention and life-long ophthalmic follow up, making it a potentially avoidable cause of blindness.

Different types of glaucoma are more prevalent in different populations, and include (1) acute primary angle-closure glaucoma (APAC), (2) chronic primary angle-closure glaucoma (PACG) and (3) primary open-angle glaucoma (POAG). The influence of deprivation on the risk of vision loss from glaucoma manifests in differing ways in different populations with different disease burdens and health systems.

A. Onset: Deprivation and the epidemiology of glaucoma

Thirteen studies investigated the effect of measures of multiple deprivation on the epidemiology of glaucoma. Nine of the studies indicated a link to deprivation and four did not. The factors associated with glaucoma prevalence included; educational attainment (4 studies), composite score (IMD)/socioeconomic status (4 studies) and income (4 studies).

ii. Studies from North America

Ko and coworkers analysed data from the National Health and Nutrition Examination Survey that included 5746 participants. The study found that poverty was associated with prevalence of glaucoma (OR 3.39) for poverty income ratio of $\leq$ 1 vs >1); however, educational attainment, access to healthcare and type of insurance was not.[128] The Los Angeles Latino Eye Study found no significant association between income and educational level and OAG.[56]

ii. Studies from Europe

UK data collected in 2009 from a large industrial conurbation in the West Midlands by Nessim and coworkers investigated the relationship between social deprivation and the incidence of APAC. The study analysed data on 139 patients presenting with APAC to the supra-regional ophthalmic casualty department. Patients were divided into quintiles using the IMD and Townsend scoring systems. There was a strong association between level of deprivation and presentation with APAC, with 66% of patients coming from most deprived quintiles 1 and 2, compared to 9% from quintile 5.[185]

In 2011, Ramdas and coworkers reported on a sub-analysis of participants from the Rotterdam Study in the Netherlands. Of the 3939 eligible patients within the study, 2.7% (n=108) developed OAG during the 9.7 year mean follow-up. No significant association was identified with regard to income and educational attainment.[209] The authors note possible sources of bias, including the age of the subjects (>55 years), the homogenous income levels in the suburb of Rotterdam that was studied, and the fact that participants in the study with OAG at baseline were excluded.

In 2015, Shweikh and coworkers, on behalf of the UK Biobank Eye and Vision Consortium, identified that individuals with self-reported glaucoma had higher levels of deprivation than

other individuals in the Biobank cohort of 112,690 participants as measured by their mean Townsend deprivation index. In terms of income, self-reported glaucoma was higher in the lowest group (<£18 000/year) than any other income level [231]

iii. Studies from Asia

In India, Gogate conducted a case-control study between 2006-2007 to ascertain the effect of deprivation on the late presentation of primary glaucoma (open or closed angle). Primary angle-closure glaucoma was more common in lower socioeconomic groups.[82]

In a cohort study of 5021 participants undergoing screening in Korea (2005-2006), Kim and coworkers reported that a higher educational level was associated with likelihood of progressing from POAG suspect to definite POAG, (OR, 1.57); income was not significantly implicated.[122]

In Taiwan, Ko and coworkers analysed cases of POAG and PACG reported through the National Health Insurance research data-base (2006), noting that higher socioeconomic status and income were risk factors for the diagnosis of POAG whereas lower socioeconomic status and income were risk factors for the diagnosis of PACG.[130] In Mongolia, a cross-sectional study on 1892 Mongolian volunteers found that patients with no formal education were seven times more likely to develop PACG when compared to those with more than 8 years of formal schooling (OR: 7.27)[292] Interestingly, this effect was independent of IOP level and known biomorphic risk factors such as narrow angles and axial length.

Not all studies report positive associations. Dondana and coworkers looked at an urban Indian population and found no association between socio-economic status (based on income) and open-angle glaucoma.[46] More recently Kyari and coworkers assessed risks of

open-angle glaucoma in Nigeria. The main factor relevant to socioeconomic status, illiteracy, was not associated with glaucoma when corrected for other factors.[137]

A number of studies have looked at IOP across the wider population. In China, the Tanjong Pagar study found that in 1090 Chinese adults aged 40-79, participants with lower levels of educational attainment and income had higher mean IOP.[293] A study in India by Jonas and coworkers suggested a weak positive association with educational level and IOP.[111]

B. Access: Deprivation and patient awareness of glaucoma

Five studies investigated the impact of social deprivation on glaucoma awareness, including the impact of employment (1 study), education (3 studies) and composite score (IMD)/socioeconomic status (1 study). Together they give important insights into how to promote timely glaucoma detection.

i. Studies from North America and Europe

In the USA, a survey of 1197 participants visiting a general eye clinic in 1998 found that awareness of glaucoma was reduced in those with less than a college education (OR:1.67).[76]

In 2006, a cross-sectional study of 166 patients in the Netherlands concluded that patients from areas of less social deprivation were more aware of the implications of glaucoma (OR: 2.5) and how the condition is treated (OR: 1.8).[96] It was highlighted that patients with greater social deprivation need improved access to targeted glaucoma information that includes the importance of family history. In contrast a larger study from Switzerland found

that awareness of glaucoma was generally poor across the whole population, but was not statistically associated with educational attainment or household income.[165]

ii. Studies from Asia

Saw and coworkers in Singapore in 2001 performed a prospective cohort study of 105 patients who had presented with their first attack of PAAC. The study indicated that about 23% of Chinese patients presenting with PAAC had previously heard of the disease. Factors associated with lack of awareness included unemployment (OR: 3.2 vs employed) and not receiving a university level education (OR: 13.8 for 'pre-university' and above vs secondary and below).[223] An interesting observation from the study was that patients who spoke Chinese as their sole language were also at higher risk of PAAC. In a Nepalese study by Thapa and coworkers it was found that literate patient were significantly more likely to know that glaucoma causes blindness.[252]

C. Access: Deprivation and service utilisation in glaucoma

Factors that influence access and service utilisation are particularly important in glaucoma, a condition that may be relatively asymptomatic at certain stages. Two studies examined this links to social deprivation included, health insurance (1 study), and access to services (1 study).

i. Studies from North America and Europe

In 2007, Hoffelt and coworkers examined the impact of a nationwide public service announcement that encouraged patients at high-risk of developing glaucoma to attend for an eye examination. Of a possible 1514 high-risk patients detected, only 44% (n=671) underwent an eye examination. The socioeconomic characteristics of those who did not

seek help included lack of health insurance (p=<0.001) and living >13 miles away from an ophthalmologist (p=<0.001, SD: +/- 21.5).[97]

ii. Studies from Oceania

In Australia, Sandu and coworkers in 2012 reported a retrospective case-control study on 55 patients presenting with AAC to a hospital eye service (cases) and 43 patients referred from the community for peripheral iridotomy before development of AAC (controls). No significant difference was found between cases and controls for educational attainment, occupational class, residential location, housing status, motor-vehicle access or insurance cover;[221] however, a fascinating finding was that poor utilisation of eye care services was associated with a seven-fold increased risk of AAC, irrespective of the level of deprivation. It is important to consider that exclusion criteria (cognitive impairment, hearing problems, poor command of English language and failure to respond) may have introduced significant bias in this study.

D. Access: Deprivation and late presentation in glaucoma

Seven studies provide supporting evidence that socioeconomic deprivation is associated with more advanced glaucoma at presentation. Factors associated included; composite score (IMD)/socioeconomic status (3 studies), education (5 studies), access to car (2 studies), occupation (1 study), housing (1 study), income (1 study) and social support (1 study).

i. Studies from Europe

In 1997, an important paper from Fraser and coworkers described a case-control study in London, involving 220 patients with glaucoma (any 'chronic' glaucoma type included) who

were classified as being early or late presenters based on the severity of their disease. Patients presenting with severe disease were more likely to be of a lower occupational class (OR: 20.1), have no access to a car (OR: 2.2), have left full time education before the age of 14 years, (OR: 7.5) and live in rented accommodation (OR: 3.2).[71]

Subsequently Sukumar and coworkers described a retrospective cohort study in 2009 of 113 glaucoma patients in the UK examining this relationship. Patients were split into two groups--affluent and deprived--on the basis of the ACORN Index that estimates socioeconomic status from the residential postcode, using census data to give high fidelity resolution. The results showed that there was a strong association between levels of deprivation and presenting mean deviation visual field loss. Affluent patients were more likely to present with mild visual field loss (OR: 5.89). Conversely, 60% of patients presenting with moderate visual field loss, and 63% of those presenting with severe loss were from the deprived group (OR: 1.74). Patients in this group were less educated, less aware of glaucoma in their families, and had a poorer clinical attendance.[245]

Additionally, further evidence from a cohort study in 2006 in Scotland used prospective data on 126 glaucoma patients, scoring deprivation using the Scottish Index of Multiple Deprivation (SIMD). Forty-eight patients were diagnosed with severe glaucoma, with the majority of these living in areas of significant deprivation with the lowest SIMD rank ($p=0.026$).[187]

ii. Studies from North America

In 2013, Buys and coworkers reported a prospective, multicentre, cross-sectional study in Canada of 290 patients with newly diagnosed POAG, splitting patients into five quintiles based on linking the postcode to the median household income. The most affluent quintile

accounted for 21% of diagnoses; however, these patients had a lower risk of presenting with moderate or advanced glaucoma (prevalence ratio 0.66), when compared with the patients from the poorest neighbourhoods, specifically if aged above 65 years.[22]

iii. Studies from Asia and Africa

In India, Gogate conducted a case-control study in 2006-2007 to ascertain the effect of deprivation on the late presentation of primary glaucoma (open or closed angle). Primary angle closure glaucoma was more common in lower socioeconomic groups. Patients who had college level education were less likely to have a late presentation of glaucoma (OR:0.07). Housing status and income did not significantly affect when patients presented with glaucoma.[82] In Singapore in 2001, Saw and coworkers completed a case series of 105 patients investigating factors contributing to late presentation of PAAC and low disease awareness. These included not having a car (OR: 8.5), speaking Chinese as their only language (OR: 5.0), and having nobody to accompany the patient to hospital (OR: 3.3).[223]

In Nigeria, a study of 131 patients presenting with POAG found that, although a number of factors such as illiteracy and being unemployed were more common in those with late presentation of POAG, on multivariate analysis only older age and poor knowledge of glaucoma were independent risk factors.[2]

E. Delivery: Deprivation and adherence to glaucoma treatment

Eight studies examined factors influencing medication adherence in glaucoma treatment; Seven had significant finding including; income (4 studies), cost (1 study), education (1 study) and health literacy (2 studies).

i. Studies from North America

Large-scale data is available from the Medicare Current Beneficiary Survey for the years 2004-2008, Blumberg noted that the implementation of Medicare Part D enrolled the majority of beneficiaries who previously lacked prescription drug coverage, but that the 'near poor' group gained least.[15] Blumberg and coworkers also noted that non adherence to medication due to cost was significantly associated with lower annual income (under$30,000).[16]

A number of smaller studies provide further interrogation of the underlying risk factors for non-adherence to treatment. In the USA, a cross-sectional study in 2001 found that poor health literacy (the inability to understand written material in a health care context) was a strong risk factor for poor treatment adherence. Educational attainment was not a risk factor.[177] In Canada, Leung and coworkers noted in a retrospective cohort study (2011-2) that those who self-reported below average income were twice as likely to have episodes of non-persistence with therapy. [149] In contrast a small descriptive study from the USA in the USA found that adherence to glaucoma medication was not associated with education or income.[54]

It is also important to consider the differential impact of educational strategies. In 2008, Muir and coworkers conducted a randomised study providing extra glaucoma education vs standard care. Increased education appeared to reduce the number of days without medication, especially in groups with decreased health literacy.[178]

ii. Studies from Asia

Castel and coworkers completed a longitudinal study in Israel and found that patients with lower than average income had a lower adherence with glaucoma drop therapy.[41] A study from India by Nayak gives a detailed insight into the financial burden on patients with glaucoma, noting that the percentage expenditure on anti-glaucoma medications ranging

from 0.3% of their monthly income in the high income group to 123% in the low income group. This indicates that glaucoma treatment is a serious economic burden to socially deprived patients that have to pay for care and may be a prime reason for why there is poorer adherence in this group.[183]

F. Delivery: Deprivation and adherence to follow-up in glaucoma

Four studies based in North America and Asia examined the impact that socioeconomic deprivation has on follow-up after glaucoma treatment. Adherence to follow-up was affected by income (2 studies), access to services/car (2 studies,) and education and awareness (2 studies).

i. Studies from North America

In the USA, a cross sectional study of 273 African-American participants in a glaucoma screening programme conducted during 2002 found that not having a car more than doubled the risk of subsequent non-adherence with follow-up.[86]

ii. Studies from Asia

In India, Do and coworkers completed a prospective randomised control trial of 399 newly diagnosed glaucoma patients to assess the effect of counselling on follow-up. Patients with a monthly income over 2500 rupees were more likely to have appropriate follow-up compared to their poorer peers (OR:2.3). Educational status, literacy, access to services, and occupational status did not impact on follow-up.[55]

In 2006, Gupta and coworkers collected data for a retrospective case-control study examining five year follow-up for 312 patients after trabeculectomy. Only 30% of subjects completed the follow-up. Patients (n=90) were selected for further interview including, 45

cases (did not complete follow-up) and 45 controls (completed five year follow-up). The control group had a significantly better awareness of glaucoma (p=<0.001), a higher monthly income (p=0.01) and a smaller distance to travel compared with the defaulting case group (p=0.001). Having to travel >200km increased the risk of drop out by a factor of 1.5 (OR: 1.5).[85]

Lee and coworkers completed a second case-control study in 2008, examining follow-up of 300 patients over a 12-month period. Independent risk factors associated with poor follow-up included lack of formal education (OR: 4.13) and no use of prescribed glaucoma treatment (OR: 2.17). Other associations that were not statistically significant included distance travelled to clinic (OR: 0.71) and financial income <10,000 rupees (OR: 0.98).[143]

V. Diabetes

Diabetic retinopathy (DR) is the principal cause of sight loss in diabetic individuals and, in 2015, accounted for 1.1% of the global burden of blindness and 1.3% of all moderate and severe vision impairment.[61] The proportion of blindness attributable to DR increased globally between 1990 and 2015, and in 2015 varied from 5.1% in Eastern Europe to 0.18% in South Asia. Globally, the number of people with diabetic retinopathy is set to increase from 126.6 million in 2010 to 191.0 million by 2030, with the number of sight-threatening cases increasing from 37.3 million to 56.3 million.[301] Sight loss from diabetic eye disease is potentially avoidable through primary and secondary prevention. Glycemic and blood pressure control, population-level screening programs for DR, and timely intervention with various evidence-based treatments, each play important roles in reducing the population burden of disease.

A. Onset: Deprivation and the epidemiology of diabetic visual complications

Eighteen studies investigated the impact of measures of multiple deprivation on the prevalence of diabetic visual complications. Six of the studies had no significant findings related to multiple deprivation. Factors that were noted to be related to deprivation included; educational attainment (4 studies), occupation (2 studies), income (4 studies), housing (1 study), composite score (IMD)/socioeconomic status (3 study) and access to services (1 study). Eight of the studies indicated that there was no link to multiple deprivation and diabetic visual complications. These have shown mixed results, possibly reflecting population-based factors and limitations in study design and scale.

i. Studies from North America

West and coworkers noted a significant positive association of deprivation with prevalence of retinopathy; whereas the three smaller studies failed to identify a statistically significant association. The West study was an analysis of data from 4774 Hispanics aged 40 years and over, compiled as part of the Proyecto VER Study. In total, 21% were diagnosed with type 2 diabetes, of whom 47% had some level of retinopathy (30% were graded as moderate severity or worse). The presence of diabetes was associated with deprivation as measured by lower income and lower educational attainment; low income was also associated with the presence of proliferative diabetic retinopathy (PDR) (OR =3.6, for developing PDR if income <$20,000) after controlling for other factors.[278]

This study contrasts with a case-control study conducted by Haffner and coworkers on 343 Hispanic patients in Texas (vs. 79 non-Hispanic white controls). Although this study reported the prevalence of diabetes to be 2-3 times higher in the Hispanic group compared to the non-Hispanic whites, no associations were identified between low socioeconomic status and the presence of retinopathy. This may have been because in this study socioeconomic status was based purely on educational attainment.[88] Baker and coworkers reported on 118 patients from a Los Angeles inner city urban hospital with high levels of deprivation (55% Hispanic, 43% African-American) and noted that advanced diabetic eye disease was present in 21% of the population at presentation.[10] Lim and coworkers examined 1073 patients from the San Francisco mobile eye service (46% Asian, 21% Hispanic, 20% African American) and found that although the level of severe retinopathy was more than two-fold higher in the lowest income group, this did not reach statistical significance.[152] A limitation of these studies is that they are conducted on populations that are already known to have high levels of deprivation. Although this can be useful to highlight high-risk patients within deprived groups, to target service provision, it can lead to the studies being underpowered (primarily

through lacking sufficient participants of higher socioeconomic status) to detect the effect of deprivation on disease.

ii. Studies from Europe

A number of studies examined the relationship between social deprivation and retinopathy across Europe, specifically in the UK, France, Germany, and Italy between 1994 and 2012. Although there is no single socioeconomic factor associated across all studies, a number highlight the possible impact of lower educational attainment, a smaller degree of independence in attending clinics, manual occupation, and smoking. In 1995, Chaturvedi and coworkers analyzed a cross-sectional survey of insulin dependent diabetic patients (n=3250) from 31 centers across Europe and noted that low educational attainment was associated with the development of PDR in men (this did not reach statistical significance in women) and was associated with worse HbA1c levels in both sexes.[29] In the same year, Weng and coworkers undertook a more detailed analysis of deprivation in diabetic patients in the UK. A relatively small cohort (n=332) were ranked using the Jarman Underprivileged Area Score, an index for social deprivation that takes account of housing, unemployment and ethnicity. Although deprivation was associated with higher rates of systemic microvascular complications, this did not reach statistical significance for retinopathy alone.[276]

A much larger UK-based cross-sectional study by Scanlon and coworkers in 2003 identified over 13,000 patients as part of a diabetic retinopathy screening program and separated them according to their level of social deprivation (IMD score). Higher levels of deprivation were not associated with a higher prevalence of retinopathy per se but were associated with higher levels of sight-threatening retinopathy, which increased from 11.9% in quintile 1 (least deprived) to 14.2% in quintile 5 (most deprived).[224]

More recent studies from the UK support these findings. Kliner and coworkers noted that there was a higher prevalence of diabetic retinopathy in the more deprived parts of the population (as measured by the IMD score).[127] Low and coworkers found that the prevalence of diabetic retinopathy increased in the most deprived type 1 diabetics (OR: 2.40). Deprivation was measured by the postcode-based Scottish Index of Multiple deprivation.[160]

Other European studies included an Italian case-control study completed by Nicolucci and coworkers in 1994, a German cross-sectional study by Mulhauser and coworkers in 1994-96 and a French prospective case-control study by Binham and coworkers completed in 2007. In the Nicolucci study, 1888 cases with renal, eye, or lower limb complications were compared to 886 controls. Higher educational attainment, professional employment and ability to attend clinic without assistance were all found to be protective for specific subgroups. No factors were protective for all subgroups.[188] Mulhauser and coworkers surveyed 684 adults with type 1 diabetes and identified an association between diabetic retinopathy and lower social status. Once results were corrected for the established risk factors for diabetic retinopathy, this association was no longer significant.[176] The small study by Bihan and coworkers in 2007 (n=97 diabetic patients) noted a non-significant trend indicating that there were higher rates of diabetic retinopathy in the more deprived group (63% vs. 52%, p=0.29). Higher fasting blood glucose, obesity, and microalbuminuria were all associated with higher levels of deprivation.[13]

iii. Studies from Asia

In China between 1995-1999, Liu and coworkers studied 2131 patients with type II diabetes from Beijing. Occupation was significantly associated with non-proliferative retinopathy. No significant effect was noted for PDR.[157] In a more recent cohort study of 25,454 patients

seen between 2010-2011, Tao and coworkers found that educational attainment (OR 0.58 and $p < 0.001$) and a higher household net income (OR 0.65 $p < 0.001$) reduced the incidence of diabetic retinopathy.[248] This is also true in Singapore, where living in a smaller house and having a smaller income was associated with increased rates of sight threatening diabetic retinopathy.[304]

A number of studies however report no association or even a paradoxical effect. In an early cross sectional study in Taiwan, family income and educational level did not have a significant effect on the prevalence of diabetic retinopathy.[31] A small case-control study in Thailand in 2010 did not find income, educational attainment, or occupation to be significant factors in the prevalence of diabetic retinopathy.[30] An Indian study conducted on the urban poor of Madras found lower socio-economic status to be a protective factor against the development of diabetic retinopathy. Patients in the low income group had a significantly lower level of retinopathy (12%) compared to the high income group (22%).[206] One possible explaination for this finding is the variation in the diet of the socioeconomically deprived between different countries. In India for example, people with higher levels of deprivation are more likely to eat a diet low in sugar and saturated fat than their more affluent counterparts. The opposite is true in the Western countries of North America and Europe. As a result, in some areas of the world low income is protective against diabetes [201; 206]

B. Access: Deprivation and attendance at diabetic retinopathy screening

The UK can be used as a case study to demonstrate the importance and value of screening for diabetic retinopathy. Every year an estimated 1280 new cases of blindness are caused by the condition. Effective screening reduces this number by up to 30% and saves an estimated

400 people from blindness annually.[202] Thirteen studies examined the effect of deprivation on diabetic screening. Factors included; income (5 studies), cost (2 studies), educational attainment (5 studies), awareness (1 study), composite score (IMD)/socioeconomic status (5 studies), health insurance (4 studies), employment (1 study) ,and rural/urban housing (1 study).

i. Studies from North America

In the USA in the early 1990s, Brechner and coworkers conducted a major study of 84572 persons from the 1989 National Health Interview Survey and found that socioeconomic status affected likelihood of having had an eye examination within the last year, with higher rates in those with higher socioeconomic status.[18] More recently Paksin-Hall reported on 52,386 diabetic patients who took part in the national 2009 BRFSS telephone-based questionnaire. The likelihood of having had retinopathy screening in the previous 12 months was positively associated with higher income (OR=1.30 for the highest income group), higher educational attainment (OR=1.26 for the highest level) and having health insurance (OR=1.75).[194] Smaller studies that support these findings include those by Moss and coworkers who found that likelihood of having had an eye examination was increased in the presence of health insurance, but adversely affected by lower income [174] and Baker and coworkers who found that higher levels of educational attainment were positively associated with appropriate timely attendance for eye examination among diabetic patients.[10] Similarly in Canada, Hwang and coworkers reported that screening rates were higher in those with private insurance (OR 3.23) and reduced in those with income under $50,000 (OR:0.60). [102]

Further elucidation comes from a study of 27699 individuals, in which "cost or lack of insurance" was the second most commonly reported reason (32%) for not receiving eye care in the preceding 12 months; a perception of "no need" (40%) was the commonest reason cited. Although not the primary purpose, this study also supports the findings that less than high school educational attainment, income less than $35,000 and lack of insurance all reduced the probability of having attended for eye care in the last 12 months.[35]

ii. Studies from Europe

A number of UK studies investigated the relationship between social deprivation (graded using IMD data) and the uptake of screening in diabetic patients. Data from Gloucestershire during 2002-2003 (n=13,284) indicate that patients from the most affluent quintile are more likely to attend screening (76.7%) compared to the most deprived quintile (67.4%), with an OR of 1.11 for each upward quintile step.[224] An analysis of non-attendees to the retinopathy screening service in another rural part of the UK during 2009-2010 found that non-attendance was more common in the lowest quintile group (10.6% vs. 6.4% for single non-attendance and 3.4% vs. 1.2% for multiple non-attendance (highest vs. least deprived group).[275] Urban UK data is supplied by the South London Screening Service, who reported a similar association between increased deprivation and non-attendance.[84] In Scotland, Leese and coworkers looked at non-attendance to retinopathy screening using an alternative measure of multiple deprivation, the Carstairs Index. As with the other UK studies this found that non-attendance was associated with higher levels of deprivation (OR: 2.3 for most deprived vs. least deprived).[144]

iii. Studies from Asia

Byun and coworkers examined data for 1,288 diabetic patients from the Korean National Health and Nutritional Examination Survey (2007-2009), noting that the risk factors for not receiving ophthalmic screening in the last year included living in a rural area (OR: 0.65), less than high school education (OR:0.68) and careers that included manual labour, services, or being unemployed. Monthly family income was not associated with poor screening uptake.[23] In India, Rani determined that patients from the upper socioeconomic strata (based on monthly income and educational attainment) were more likely to have heard of diabetic retinopathy and to understand that it could affect their eyes (OR=1.85) and in turn that patients with increased knowledge were more likely to attend for regular eye exams, compared to those with no knowledge (93% vs 66%) (p<0.0001)).[211] A survey from Tanzania found that 35% of non-attenders for a recommended diabetic eye review cited financial reasons for their non-attendance.[175]

iii. Methods of improving screening uptake

Given the consensus regarding high non-attendance among those with higher levels of deprivation, it is unsurprising that some measures to improve screening have specifically targeted deprived high-risk groups. Two of the studies focused on increasing patient awareness and the third study focused on the impact of reducing the cost of screening.

In the USA, Walker and coworkers undertook a randomized controlled trial (RCT) to assess the impact of a telephone intervention on the uptake of diabetic retinopathy screening in 598 diabetic patients with an income <$15,000/year residing in the Bronx, New York City. The addition of a telephone call to standard care (provision of an information leaflet) led to a 74% increase in screening uptake.[271]

Further evidence of the importance of patient education in improving screening uptake comes from a retrospective study of 196 patients in Indonesia. Most patients (85%) had not

attended screening within the previous year; 50% of the non-attendees did not recall ever having been told that they needed an eye examination. Patients who were more aware of diabetic retinopathy (assessed using a diabetic retinopathy knowledge score) were more likely to attend for annual review (OR: 1.52).[5]

Lian and coworkers evaluated the possible impact of cost on uptake of screening in a randomized controlled trial in Hong Kong. A group of diabetic patients not previously under the care of an eye specialist were split into two groups; one group was offered free screening (n=1316, uptake of 88.5%) and a second group required a small payment (60HK$ equivalent to around US$8) to access screening (n= 1277, uptake of 82.4%). There was a higher uptake of screening in the group offered free screening (OR: 0.59). This study also noted that higher socioeconomic status (in this case based on income and type of housing) was associated with higher uptake of screening and lower levels of retinopathy.[151]

C. Access: Deprivation, late presentation and access to treatment in diabetic eye disease

Two studies assessed the impact of multiple depirvation on the late presetation on diabetic retinopathy.

In 2012, Lane conducted a retrospective 2:1 case-control study in the UK, to determine whether social deprivation (measured using IMD data) was a risk factor for the late presentation of patients with proliferative diabetic retinopathy requiring urgent laser therapy (n=102). Patients were more likely to present with R3 retinopathy (PDR) requiring urgent laser therapy if they were more deprived (p=<0.001, Mann–Whitney *U*-test) and had a high HbA1c (11.5% vs. 8.4%, p=<0.001, Mann–Whitney *U*-test).[139]

In the USA, Gibson and coworkers conducted a cross-sectional study examining the impact that the density of eye-care professionals have on screening, awareness of and treatment outcomes for diabetic retinopathy and age-related macular degeneration. Patients living in counties with the highest ophthalmologist availability quartile were more likely to be aware that they had diabetic retinopathy and were less likely to have sight-threatening diabetic retinopathy than individuals living in the lower three quartiles.[79]

D. Outcome: Deprivation and progression in diabetic retinopathy

Roy and coworkers reported on the six-year follow-up data for the New Jersey cohort study of 725 African American patients with type 1 diabetes. In the 483 patients who completed follow-up, socioeconomic status was not associated with progression of diabetic retinopathy; however, low socioeconomic status (based on employment) was associated with macular edema (multivariate adjusted OR=1.87). In this study, education, income and health insurance were not significantly associated with progression of retinopathy or development of macular edema.[218]

VI. Age-Related Macular Degeneration

Age-related macular degeneration (AMD) is the leading cause of blindness in adults older than 50 in developed countries.[124] Globally, macular degeneration (which includes both age-related and myopic macular degeneration) accounted for 5.6% of all blindness in 2015, and 4.0% of all moderate and severe vision impairment, making it the fourth leading cause of blindness and third leading cause of moderate to severe visual impairment.[61] Again, there is marked geographic variation, with the proportion of blindness attributable to macular degeneration ranging from 19.3% in Eastern Europe to 2.4% in South Asia. AMD is predicted to impact 196 million people by 2020.[280] Previously considered untreatable, the evidence-base now supports primary prevention to address potentially modifiable risk factors, including smoking and obesity, especially in those at higher genetic risk. Additionally for neovascular AMD (nAMD), the advent of intravitreal pharmacological therapy means that stabilisation or even improvement of vision is possible in many cases.

A. Onset: Deprivation and the epidemiology of AMD

Six studies explored socioeconomic risk factors that may contribute to the development of early or late AMD. Significant factors included educational attainment (5 studies), income (1 studies), occupation (2 study), composite score (IMD)/socioeconomic status (1 study) and rural/urban living (1 study). Low educational attainment was consistently identified to be an important risk factor for the development of early AMD.

i. Studies from North America and Europe

Klein and coworkers examined data on 2710-2835 American adults (actual number examined depended on measure of multiple deprivation under analysis, drawn from the Beaver Dam Eye Study, collected between 1988-1990. Associations that increased the five

year incidence of developing AMD included low educational attainment (OR range: 0.43-0.83 for varying higher levels of education vs. those with <12 years of education) and type of employment (OR: 1.8 for those in a service occupation vs. professional white collar workers). Low income appeared to be a strong risk factor for the development of AMD (unadjusted prevalence ranging from 4% in those with incomes over $40,000 vs. 15% in those with income less than $10,000). This association was no longer present when adjusted for age and sex (adjusted prevalence of 6.1% and 6.7% in the highest and lowest income groups respectively).[125]

A later study In the USA investigated 5878 patients aged over 40 as part of the Los Angeles Latino Eye Study conducted 2000-2003. In univariable analysis, an increased risk of early AMD was again associated with low educational attainment (OR: 1.5 for <12 years vs. ≥12 years education) and low income (OR: 1.5 for annual income of <$15,000 vs. >$40,000). Rates of non-insurance were higher in both early and late AMD groups, but this did not reach statistical significance.[70]

In Italy, Piermarocchi and coworkers noted in a cross sectional study (n=845) that less than 8 years of education was associated with prevalence of large drusen (OR: 1.45). Income was not associated.[199]

ii. Studies from Asia

In Singapore, Cackett and coworkers. analysed 3265 participants in the SiMES study from 2004-2007.The prevalence of low educational attainment and low income were significantly higher among those with either early AMD or late AMD; however, following multivariate analysis, which included adjustment for factors such as age, smoking, and Body Mass Index (BMI), only the association between lower educational attainment and early AMD remained

significant (multivariate OR: 2.2 if less than secondary school education).[24] In India, a cross-sectional study of 5459 participants found that AMD was more prevalent in rural communities and in the middle socioeconomic group.[208]

An analysis of the Korean National Health and Nutrition Examination Survey (2008 – 2011; n=14352) noted that lower educational attainment (OR: 1.32) and not being employed (OR: 1.60) were risk factors for early AMD, but that monthly income was not. None of these factors were significant risk factors for late AMD.[197]

B. Access and delivery: Deprivation and the treatment of neovascular AMD

Six studies were included. Four of the studies provide evidence that several of measures of multiple deprivation impact upon patient access to AMD services and the treatment received for nAMD. Links included; income (1 studies), service provision (1 study), and composite score (IMD)/socioeconomic status (1 study).

i. Studies from North America

Between 2000 and 2001, Chew and coworkers completed a Canadian case control study on 115 patients with nAMD, comparing those who selected the self-funded option of photodynamic therapy (PDT) and those who chose the 'standard' government-funded transpupillary thermotherapy (TTT). Individual patient postcodes were used to estimate income and educational level using 1996 Canadian census data. Patients who opted for the government-funded option had, on average, a lower income than those funding their own treatment ($21,547 vs. $23,695) and were found to have more severe disease prior to commencing treatment (worse visual acuity and larger lesion size). Educational attainment (measured as percentage with post-secondary school education) was not significantly different between the two groups.[32]

Patient knowledge is an important issue in ensuring appropriate health-seeking behavior. In the American discussed earlier in the diabetic section, in areas with a higher density of eye-care professionals, patients had a greater awareness of their AMD diagnosis.[79]

ii. Studies from Europe

In 2004-2005, a UK study of 240 patients consecutively diagnosed with nAMD did not find deprivation as assessed by the Scottish Index of Multiple Deprivation to be associated with the VA at presentation.[3]

In contrast a UK study by Sharma and coworkers using the IMD index, found that in 120 patients with severe sight loss secondary to AMD (dry or neovascular), deprivation was associated with worse visual acuity at presentation and shorter duration between presentation and time to be registered as legally blind. In this study there was no difference in delivery of treatment between the two groups, however, it should be noted this may be because in the UK anti-VEGF drug treatment for AMD is government funded.[227]

In a 2012 Polish study on 201 patients receiving anti-VEGF as a treatment for nAMD compared patients living in urban and rural settings. No difference was noted between these two groups with regard to access to treatment, defined as either time to clinic or time to treatment. Note that although this study did not directly look at deprivation, the authors commented that evidence suggests that those living in rural settings have lower levels of health expenditure.[140]

iii. Studies from Asia

Between 2001-2005, an Israeli cohort study investigated risk factors for the requirement of PDT for AMD based on a survey of 139,894 patients over age 50 in a health maintenance organisation. Within the timeframe 0.002% (n=283) of the cohort underwent PDT. Patients

with a low socioeconomic status (all those exempt from paying social security tax) underwent significantly fewer PDT procedures for their nAMD than the rest of the cohort population (0.13% vs. 0.21%), suggesting that increased social deprivation is a risk factor for reduced access to treatment.[112]

C. Outcome: Deprivation and progression in AMD

A German cohort study completed in 2012 evaluated the correlation of sociodemographic risk factors in 108 patients with second eye progression to end-stage AMD. Progression of disease was not significantly associated with educational attainment (the only direct component of deprivation studied), although it was associated with obesity and heavy smoking history.[142]

VII. Ocular trauma

Ocular trauma is a major public health issue. Worldwide 1.6 million people are bilaterally blind secondary to ocular injuries and a further 19 million have unilateral blindness or low vision.[184] Ocular trauma is associated with certain occupations, and many of the studies discussed below note that laborers are commonly affected. This association may be directly due to the increased exposure of laborers to activities that lead to ocular trauma, rather than their presumed lower socio-economic status. In order to ensure this review remains focused on measures of multiple deprivation, we have not discussed studies that only consider occupation without reference to multiple deprivation.

The sight loss resulting from ocular injury has been shown to have a significant economic impact both to the state and to the individual. National annual costs have been estimated at

$175-200million/year in the US ($370 million/year 2016-inflation-corrected)[255] and $155 million/year in Australia ($258 million/year 2016-inflation-corrected).[62]

Two cruel ironies of ocular injuries are that the cost is often highest in countries that can least afford it and that injuries even within these societies are more likely to occur among individuals who are least able to meet the resulting burdens. Data supporting these statements is confounded by the fact that data collection on ocular injuries is more comprehensive in affluent countries that have resources available to identify cases. Despite this, the rates of trauma-related blindness are three times greater in developing countries. Correcting for the larger populations the burden of trauma-related-blindness has been calculated to be 15 times greater in absolute terms in developing countries.[184]

There is strong evidence from both China[272] and the USA [162] that there is an increased incidence of ocular injury amongst those people with lower incomes.

Hence we have an unvirtuous circle in which poverty is a common risk factor for ocular injury, and injury itself leads to a financial burden. This is a classic 'trap' of social deprivation: diminished income adversely affects health and diminished 'health' adversely affects income. [141; 162] This should be considered carefully when attempting to determine the presence of a causal link. To discover if ocular injury is truly pre-disposed by deprivation and not merely an association, prospective studies that provide a measure of relative *incidence* in an impoverished or deprived group rather than *prevalence* are of particular value.

A. Onset: Deprivation and the epidemiology of ocular injury

Ten studies examined the incidence/ prevalence of ocular trauma and its relationship to measures of multiple deprivation. Eight of the studies found associations between ocular trauma and multiple deprivation including; educational attainment (3 studies), income (2 studies), employment (7 studies), rural vs. urban living (3 studies) and composite score (IMD)/socioeconomic status (1 study). We have largely omitted the evidence associating male gender with ocular injury [64; 118; 134; 189; 203; 204; 279] as this is a near universal finding and its omission allows us to describe other factors more clearly associated with multiple deprivation.

i. Studies from North America

Wilson and coworkers in 1988 looked at circumstances around severe ocular trauma in Los Angeles, California, and identified a number of factors associated with multiple deprivation, though statistical significance was not quantified. The associations included assault (47%), gang activity (6%), unemployment (75%) and substance abuse at the time of injury (27%).[279]
Forrest and coworkers. completed an American survey in 2002 using National Health Interview Survey Data on 28,913 participants. The overall lifetime prevalence rate of work-related eye injuries was 4.4%. Workers with lower educational attainment (less than high-school), the self-employed and those living in the mid-west region were more likely to experience eye injuries (p=< 0.001). Occupations of precision production, transportation, farming, mining and construction also increased the risk of ocular injuries at work.[64]
In 2012, Luo published a population based cross-sectional study that aimed to measure the link between social deprivation (measured by educational attainment and income) and the lifetime risk of self-reported workplace eye injury. Between 2005-2007, data was collected on 43,510 American civilian patients aged ≥18 years, using the Behavioural Risk Factor

Surveillance System (digital telephone surveys). A significantly higher prevalence of injury was noted among men (13.5% of injuries vs. 2.6% in women (p=<0.001)). Of these men, risk was significantly higher in those with lower educational attainment (p=<0.001) and lower income (income less than $15,000 vs. income over $50,000 (p=0.015)). Interestingly, among women these multiple deprivation related factors were not significant. Having eye-care insurance was not a significant factor in either group.[162]

ii. Studies from Europe

In 2007, Pundziuviene and coworkers. published a prospective study of 315 patients with severe open-globe ocular injuries presenting in Lithuania. Risk factors for males included living in an urban setting (p=0.001), alcohol use (p=0.001), unemployment (p=0.001).[204]

iii. Studies from Asia

Nirmalen and coworkers. completed a cross-sectional study in 2003 of 5150 individuals aged >40 years drawn randomly from the rural population of three districts in Southern India. The age-adjusted prevalence for blindness in any eye caused by trauma was 0.8%. The risk of trauma was greater for laborers (OR: 1.7) and lower for literate individuals (OR: 0.7).[189]

In a small case-control study in Taiwan (31 cases; 62 controls), Ho and coworkers found that temporary employment (OR, 10.7) and fewer than 10 years of education (OR, 4.44) were the major risk factors for occupational eye injuries.[94]

In 2006, Wang reported from the Beijing Eye Study population. This was a two-phase analysis conducted initially in 2001 (n=4439) and then in 2006 (n=3251). Three data sets were generated; that is, prevalence estimates at the two time points and also an estimate of incidence during the period of the study. Risk factors analysed pertinent to multiple deprivation were rural vs. urban living, alcohol consumption, income, occupational and

educational attainment. The three data sets did not reveal the same risk factors for ocular trauma to reach significance. For example in 2001 rural vs. urban residency was associated with injury prevalence but not in 2006 (p=0.04 vs. p=0.383 respectively); conversely lower income (<500 Yuan) was a risk factor in 2006 but not 2001 (p=0.01 vs. p=0.12 respectively). Educational attainment (being illiterate) was not a risk factor in either of the time periods (2001: p=0.11 and 2006 p=0.99); however, an important finding was that reduced income was clearly associated with the increased *incidence* of a new ocular injury during the study period (p=0.009).[272]

In 2008 Vats and coworkers. published a cross-sectional study from the urban slums of Delhi (n=6704). The prevalence of ocular trauma was 2.4% (n=163 episodes). Following adjustment for age and sex, no association was seen between trauma and educational attainment (p=0.21) or occupation (0.88) though this study has no control group.[266]

In 2009, Chua and coworkers completed a population based survey examining 3400 patients in Singapore. The prevalence of ocular trauma was reported as 5.1% (n=162) in the study population. Risk factors included male gender and a history of cigarette smoking (OR: 1.6). Housing type, education and income were not noted to be significant risk factors.[37]

In 2011, Khokah and coworkers completed an Indian cohort study of 150 patients with lens subluxation, with 71 individuals reporting subluxation secondary to trauma. Socioeconomic status was classified according to the Modified Kuppuswamy Scale (2007 revision considers educational attainment, occupation and family income per month). The rate of lens subluxation increased with decreasing socio-economic status; upper class (n=2), upper middle class (n=5), lower middle class (n=10), upper lower class (n=14) and lower class (n=40).[119]

B. Prevention: Deprivation and the use of protective eyewear

Protective eye wear has been clearly shown to reduce ocular injury during high risk activities including occupational hazards,[134] sporting activities[167] and in the theatre of war [253], though spectacles themselves can be a cause of injury especially when not designed for protective utility.[99]

Two studies examined the impact of multiple deprivation on the use of protective eyewear. Specifically they looked at employment status (2 studies), income (1 study) and educational attainment (1 study).

In the USA, the 2002 National Health Interview Survey on 30,894 individuals examined the rate of protective eyewear use during nonwork-related activities associated with eye injury. An estimated one third used protection. Despite the well-documented preponderance for injury among males, in this study men were found to use protective eyewear more than women (34.7% vs. 25.2% with an OR: 1.70). Significant risk factors for not using non protective eyewear included unemployment (OR: 1.55) when compared with the reference group of people outside working age. Low income (below the poverty income threshold) (OR: 1.78) was a significant association with not wearing eye protection. Authors report that individuals with a low educational level or a low family income were less likely to participate in activities that could cause an eye injury, such as recreational activities and those related to the maintenance of a home.[65]

In 2005, Gerente and coworkers completed a cross-sectional study of patients presenting to hospital with a superficial ocular foreign body in São Paulo, Brazil (n=123). Most injuries occurred in the workplace (86.2%), despite the majority of patients (58.4%) lacking legal employment registration. Protection was more frequently employed by patients with legal employment registration (p=0.008).[78]

C. Access and delivery: The provision and uptake of eye services

Two studies examined the impact of multiple deprivation on the provision and uptake of eye services, specifically looking at service provision (1 study), cost (1 study), awareness (1 study) and insurance (1 study).

In 2010, in a Chinese retrospective cross-sectional study of 56 patients with chemical burns, the median expense of medical treatment was CNY 40,000 (approximately US$5,900), far exceeding the GDP per capita ($3566). More than half of those with the condition (51.8%, n=29) paid all or the majority of the medical expenses themselves. Medical insurance covered the expenses of only 8.9% (n=5).[141]

The aforementioned Indian study completed in examined the incidence of lens subluxation after ocular trauma and noted that the mean time to presentation was 33.6 months (range 5 days to 40 years). The reasons cited for late presentation included long distance to services, lack of financial means, and lack of awareness about the curability of the problem.[119]

D. Outcome: Effect of multiple deprivation on outcomes after ocular trauma

Four studies from Asia examined the effect of measures of multiple deprivation on outcome after ocular trauma, links included educational attainment (1 studies), composite score (IMD)/socioeconomic status (1 study) and employment/occupation (2 studies). Incidence studies often cannot demonstrate associations reaching statistical significance between blindness and multiple deprivation because of small case number though often there is correlation as detailed below.[272]

In Nepal, between 1995-2000 in a cohort study of 525 cases of ocular trauma most common types of injury were lacerating and blunt, with the majority occurring at home or in the fields. Increased socio-economic status (denoted by literacy) was found to be a protective factor for end visual acuity, with OR: 0.20 for having an end VA of <20/60 and OR: 0.05 for having an end VA <20/400. [118]

In 2000, Dandona and coworkers published an Indian cross-sectional study of 2522 patients, with 113 reporting a history of ocular trauma. An eye was considered to be blind secondary to trauma if best corrected distance visual acuity was <6/60. Risk factors for blindness following trauma included lower socioeconomic status (OR: 3.74) and labouring occupation (OR: 2.50; labouring vs other occupations).[45]

A second similar Indian cross-sectional study in 2000 included 7771 individuals, with 824 reporting ocular trauma. Prevalence of blindness (VA<6/60) and traumatic visual impairment were higher amongst the lower and extreme lower socioeconomic groups; however, this was not statistically significant.[134]

In the Chinese study by Wang and coworkers, of the 72 patients identified with ocular trauma, 4 had visual impairment (best-corrected VA <20⁄60 and >20⁄400) and 3 eyes were blind (best-corrected VA <20⁄400) in 2001. In 2006 when some of the study participants returned there were 5 patients diagnosed as blind from ocular trauma. Again there was no significant link to education or income, however 80% (n=4) were in the lowest two income groups [272]

E. Outcome. Consequence of ocular trauma: post-injury- deprivation

Two studies examined the impact of ocular trauma on an individual's level of deprivation post-injury, specifically examination impacts upon employment (1 study), income (1 study)

and educational attainment (1 study). For further analysis on national and international trends please refer to the ocular trauma introduction.

Using data collected from 1980-1986 in Finland, Punnonen and coworkers investigated 387 consecutive perforating eye injuries treated at the Helsinki University Eye Hospital. Following treatment 5% of economically active patients became permanently disabled and unable to work, 4% had to change profession, and 91% were able to return to their pre-accident employment.[203] In the aforementioned Chinese study of ocular chemical burns, both the personal and household income-per-capita decreased significantly. The authors note the impact on the family unit beyond the immediate victim. Family members are obliged to take on caretaking roles, compromising further the income of the household. The loss of income rose with injury severity and time of care required. 53.6 % (n=30) patients reported that their injury negatively impacted upon the family unit.[141]

VIII. Other eye conditions

Our systematic review identified a number of other areas of investigation regarding the impact of deprivation on different aspects of eye disease. These areas are listed below to give an indication of the spectrum of work that has been undertaken on the impact of deprivation in eye disease.

Uncorrected refractive error was the second most important cause of blindness (20.6%) globally in 2015.[61] In 2007, the estimated global productivity loss associated with uncorrected distance refractive error was 268.8 billion international dollars. [238] An estimated 47000 additional full time refractionists and 18000 ophthalmic dispensers would be required to address this burden, at a cost of around US$20 billion.[73] In addition, there

were an estimated 1.04 billion people globally with presbyopia in 2005, 517 million of whom had no spectacles, and 94% of this burden was in lower-income countries.[98] A number of articles highlighted the link between deprivation and refractive error. [66; 83; 156; 179; 182; 214; 288 226]

Studies investigating the impact of deprivation on ocular surface and corneal disease include the following areas: the prevalence and treatment of trichiasis [1; 6; 114; 131; 247;57; 164; 166; 284] the prevalence of blinding corneal disease[48; 145; 228; 240; 243; 281; 300] outcomes after laser refractive surgery [43] and outcome after corneal transplantation.[39; 47; 234] In terms of intraocular conditions, areas of study included the impact of deprivation on: the prevalence of uveitis [14]; the characteristics of patient with retinal dystrophy,[11] and the onset and severity of rhegmatogenous retinal detachment.[173; 213]

IX Conclusions

A. The challenges of studying deprivation

Multiple challenges emerge when studying deprivation, and we recognise these as limitations within this review. Firstly, some smaller surveys including aspects of multiple deprivation as potential explanatory variables may lack power to obtain precise effect size estimates.[10; 88; 152] Secondly, causation cannot be inferred from the associations observed in a prevalence study, and much of the data presented in this review derives from cross-sectional surveys undertaken at a single point in time. The potentially bi-directional nature of deprivation and sight-threatening ocular disease highlights the value of cohort studies which examine incident vision loss and ocular disease by baseline level of deprivation.[257; 258]

Thirdly, variation in study design and the way deprivation is defined, lead to challenges in comparing studies. The adoption of standardised indices of multiple deprivation for use in epidemiological research would help to address this and facilitate evidence synthesis.

In this study we have explored what has been reported in relation to health service utilisation and the different eye diseases covered in this review. Inequitable access to health services, resulting from differing levels of deprivation within and between countries, is likely to have a significant impact on global eye health. A full exploration of this was beyond the scope of the current review.

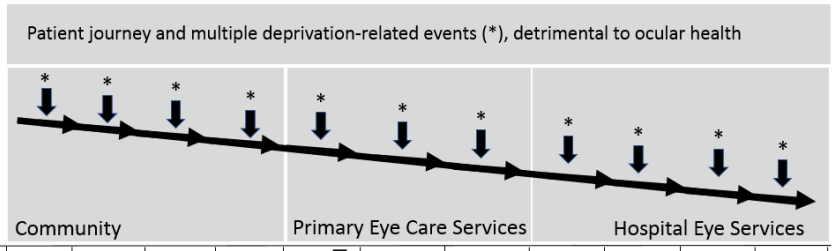
B. The problem of deprivation

The problem of deprivation can be conceptualized to impact upon visual health from two perspectives. Firstly, multiple elements of deprivation at any one time point for an individual have a *compound* effect on health. Secondly, over time, the sum of deprivational factors has a *cumulative* impact upon health. At any point in the lives of individuals and communities the effect of *compound* and *cumulative* deprivational impacts is dynamic and offers multiple opportunities to intervene. Taking these in turn, *compound* deprivations are the tendency for deprivations to cluster,[161] that is to be multiple for some individuals at a point in time, while other, wealthier individuals avoid multiple deprivations.[200] These deprivations include lack of access to affordable health care, transport, availability of family members to support through illness, understanding of disease and access to treatment and follow up and present multiple obstacles at a single time point. *Cumulative* deprivation describes a situation in which deprivation in its many forms impacts longitudinally throughout life. There is much evidence globally that trajectory towards worse vision

outcomes is correlated with multiple deprivation; from Africa,[69] Australasia ,[75; 210] Europe,[74; 242; 291] Middle East [58] , North America[198] and South East Asia. [44; 49; 50; 302; 303]

Visual disability and blindness further disadvantage individuals through loss of autonomy, financial independence, [51; 136] and ability to access health care, creating a 'slippery slope'. This is sometimes referred to as the bi-directional relationship between deprivation and impaired vision and is a feature of a 'poverty trap'.[141; 162,241]

Figure 2 illustrates how the cumulative effects of deprivation during the patient journey through the three domains of healthcare; community, primary eye care services (PECS) and hospital eye care services (HECS).



Deprivation-related obstacles to good ocular health	Poor nutrition	Earlier onset of disease	Reduced awareness of disease	Reduced participation in screening	Later presentation with more severe disease	Reduced access	Reduced access to follow up	Ability to pay for transport /treatment	Remote hospital	Reduced adherence/follow up	Equipment/ staffing issues
Supportive evidence	250,251	125,144, 162,185, 231,272, 292	79,201 246	97,299	10, 32, 186,223, 245	97,121, 246,290	85,143	42,150, 230,267	120	41,85, 143	87

Figure 2. Model of the cumulative effect of multiple deprivation upon ocular health

Deprivation has associations that are important within communities, including poor nutrition,[250; 251] earlier onset of disease[125; 144; 162; 185, 231, 272; 292] awareness of disease [79, 201,

[246], time to presentation,[32,223] reduced participation in screening [97; 299] and more severe disease at presentation.[10; 186; 245]

At the level of primary eye care barriers include lack of access to interventions [97, 121,246; 290] and timely follow up.[85; 143] There is evidence that optometry practices co-locate with areas of affluence with under provision in less affluent/remote areas.[120]

Without adequate hospital eye care services there is an inability to meet the demand for intervention generated by effective community and primary eye care screening. Issues include ability to pay,[42; 150; 230; 267] adherence to treatment,[41] access to follow up,[85; 143,] and provision of medical staffing and equipment.[87]

Additionally there are over-arching risk factors affecting all domains of health care including environmental, cultural[264] and geopolitical issues.[219]

C. Looking forwards

Multiple deprivations can be addressed by redistribution of elements of national and global wealth. Solutions need to be tightly targeted at the population in greatest need. When strategies are not targeted there is a tendency for the benefit to be preferentially felt by the less deprived.[53]

There is some evidence that, in affluent countries, there is protection against the effect of relative deprivation[25] when compared with less affluent countries. Global initiatives such as "The End of Poverty",[219] if successful, would undoubtedly have enormous benefits for ocular health; however the vast literature of relative deprivational disadvantage even within wealthy countries is testament to the difficulties of creating equitable systems.

There are three areas of key importance in ameliorating the effect of multiple deprivation: patient involvement in health care, sociocultural inclusivity, and advocacy.[254] Specific efforts are needed to access hard to reach patients. Creating a system with an ethos of social sensitivity is key factor in promoting inclusivity across different regions. Organisations need to demonstrate 'cultural competency', being able to deliver effectively in cross-cultural contexts such that diversity, including gender, is valued and those barriers which occur when cultures interact are understood and negotiated. Cultural competency and, in particular, gender-awareness are crucial factors in overcoming exclusion.[93]

At the most practical level one can ensure that health care literature and information is representative of all sections of society. We must facilitate the patient voice of disadvantaged groups and act as their advocates at all political levels. After reviewing the world literature we recommend that health care professionals should lead the way in understanding the importance of multiple deprivation in ocular disease. To achieve this it is crucial that the concepts of deprivation are embedded within health care curricula in order to train future health care professionals primed to meet the challenges of deprivation. Each of us has a role to play in reducing the burden of multiple deprivation and helping those trapped by poverty.

X. Method of Literature Search

We searched the published literature in August 2014 and updated the searches in August 2016. We searched Medline, EMBASE, CINAHL, PsycINFO, AMED, BNI and HMIC with a date limit of 1946 to the present for Medline; 1974 to present for EMBASE; CINAHL from 1961 until present; PsycINFO from 1969 until present; AMED from 1985 until present; BNI from 1985 untill present and HMIC from 1979 until present. Search terms focused on three domains: (1) 'deprivation', 'social class' 'poverty', 'socioeconomic factors', 'indices of multiple deprivation' and terms relevant to multiple deprivation - 'income', 'employment', 'health deprivation', 'education', 'crime', 'barriers to housing', 'health services accessibility' and 'living environment', AND (2) 'vision disorders', 'blindness', 'low vision', 'ophthalmic surgical procedures', 'eye abnormalities' OR (3) 'eye disease' including the specific diseases highlighted within this review. Two reviewers screened the titles and abstracts of the search output to identify potentially relevant studies, and the full text was obtained for all relevant studies. We included randomized control trials, case control, cohort and cross-sectional study designs; systematic reviews and meta-analyses were not included in the primary analysis but were included in the general discussion where relevant. We excluded studies containing fewer than 10 participants, participants less than 18 years of age and non-English language publications. Studies dealing exclusively with refractive error as a cause of visual loss were excluded as this was outside the scope of this review; additionally articles which dealt solely with quality of life issues were not included in this review.

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