ORIGINAL ARTICLES—Clinical science

The deficit in cataract surgery in England and Wales and the escalating problem of visual impairment: epidemiological modelling of the population dynamics of cataract

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Abstract

***Background*—The pool of old cases of cataract, the expected new cases, and the shortfall in cataract surgery and consequently the numbers dying with poor vision without the benefit of cataract surgery are regarded as escalating problems worldwide. Successive governments and the professional ophthalmic bodies have not had the wherewithal to estimate the magnitude or interaction of these elements in the population of the UK. This study has collected and applied the best available epidemiological data on cataract prevalence, incidence and service utilisation, and demography to address the problem of control of the cataract pool in the population of England and Wales.**

***Methods*—Data from recent surveys undertaken by the authors, both on prevalence of vision impairing cataract and on patterns of cataract surgery, were used together with demographic and service utilisation information obtained from government departments. These were integrated within a holistic model, which was run under varied assumed levels and patterns of service provision.**

***Results*—The study shows that there is a serious pool of unoperated vision impairing cataract in the population aged 65 and older, reflecting a shortfall in cataract surgery. Continuing with the present level and pattern of service provision, the pool will increase to over 2.5 million by the year 2001. In addition, more than 700 000 will die with unoperated impaired vision.**

***Conclusions*—Targeting of existing or new additional operations to those below the visual acuity of 6/12 will have relatively little effect on numbers dying without surgery, but should have a substantial controlling effect on the pool of vision impairing cataract in the population.**

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Cataract surgery represents the largest single component of the workload in ophthalmic units through the world. Recent literature from the World Health Organisation and other sources highlights yet again the huge magnitude of the accumulated backlog of vision impairing cataract worldwide, the large number of new cases expected annually,[1 2] and following on from this, the substantial number of cases who die without having received sight restoring surgery.

Epidemiology researches at the World Health Organisation Prevention of Blindness Collaborating Centre in London have taken up this lead from the international body to investigate the extent to which these problems apply to the population of England and Wales, and the conditions under which escalation into the next decade might be prevented.

The aim of this study on vision impairing cataract was to use contemporary epidemiological data and modelling techniques to:

(1) Ascertain the size of the cataract backlog in the elderly population of England and Wales.
(2) Ascertain the number of new cases coming into the population pool of cataract over a 5 year period.
(3) Estimate the change over a 5 year period in the total pool of cases in the population, in relation to volumes of cataract surgery at current levels.
(4) Estimate the number of cases expected to die over a 5 year period without having had the benefit of sight restoring cataract surgery.
(5) Investigate the changes in the population pool of vision impairing cataract over the 5 year period under various assumptions and proposed levels of cataract surgery.

Methods

The methods involved preparation of a conceptual framework within which a model could be defined and the necessary data on demography, prevalence and utilisation identified and collected.

A computer model was designed to simulate the changes in the population pool of vision impairing cataract over a 5 year period, taking into account the prevalent cases, the new cases

occurring during the period, and the numbers leaving the pool through cataract surgery or mortality. The model required the following main data as inputs:

- Best available age specific estimates of prevalence, and of incidence for the population aged 65 and older
- Age specific mortality for the general population and for cataract cases
- The number of cataract operations performed annually, by age and by level of visual acuity
- Proportion of operations performed on the second eye during the 5 year period of the simulation
- The number of residents in England and Wales and their age structure.

Methods used to obtain these and their integration into the model are described below.

CATARACT SURGERY RATES

Age specific cataract surgery data were obtained from the Department of Health in England and from the Welsh Office. The data source was Hospital Episode Statistics, coded C71-C72 (Finished Consultant Episodes) for 1994–5 and for 1995–6. The proportion of operations performed for visual acuity levels of <6/12 and for <6/18 in each age group was obtained from the National Cataract Audit II study.[3]

The proportions and expected numbers of cataract operations performed on the second eye before and during the 5 year period of the simulation were estimated from an analysis of data obtained from the National Cataract Audit II, in conjunction with the utilisation data from the Department of Health.

Based upon present operating theatre practice of the "five extracapsular cataract extractions per session" rule, and upon analysis of theatre time taken and theatre time that could be allocated per patient (30 minutes), the total capacity within the NHS for cataract surgery was estimated and the fraction of the total capacity represented by current practice was computed.

Neither the age specific nor the visual acuity specific proportions of operations performed in the private sector were available. These are at present not included in the model.

MORTALITY AND DEMOGRAPHIC DATA

The relevant death rates were derived from life tables in the Annual Abstract of Statistics 1998 (Table 2.22; 1994–6 data) and from the publications of the Office for National Statistics (1996 mortality statistics—series DH2 no 23, Table 7: deaths occurring in 1996 in England and Wales, and Table 1: estimated resident population 1996).

Cataract cases were assumed to have higher mortality than their age matched controls, as indicated by two population based studies, in the UK and in India[4 5] (the UK study estimated 1.5 times higher mortality for cataract cases, but robust data were not available for mortality in people without cataract in the age range of interest for the simulation model). The age specific general population mortality estimates (which include cataract cases) had to be used as proxy for the mortality in those without cataract, and the mortality for cataract cases was assumed to be 1.25 times higher.

SOURCE DATA FOR ESTIMATION OF THE PREVALENCE POOL: "BACKLOG"

The prevalence estimates were derived from the North London Eye Study (NLES),[6] which was a random sample of 1547 people aged 65 and older, drawn from a defined population registered with 17 general practice groups. The sample represented a fairly average (not extremes) of socioeconomic mix and health status, as indicated by the Jarman scores, which ranged from 36.06 to –0.88 across the wards of the geographic area.[6] People were classified as having "cataract causing visual impairment" when the visual acuity in one or both eyes was poorer than 6/12 and the impairment was attributable to a lens opacity. The NLES has used a visual acuity cut off level of 6/12 to define visual impairment. This corresponds with the minimum legal requirement for driving: the "fitness to drive" requirement is a binocular visual acuity of approximately 6/12 or better.[7] More than 94% of the sample were white, as are the elderly population of England and Wales. The major bulk of the cataract problem in the population occurs in the age group (65 and older) that we have been able to study.

ESTIMATION OF INCIDENCE FROM AGE SPECIFIC PREVALENCE: "NEW CASES"

The incidence of the disorder was computed by using the method proposed by Podgor and Leske,[8] taking into account the differential mortality. Assumptions in the application of the method include that the condition is irreversible, and that the disease *incidence* remains constant during the 5 year interval. The last assumption has to be made since more refined data on incidence are not available.

The 5 year incidence proportion (I_i) for each age group was multiplied by the total population in the age group (N_i) to arrive at number of new cases occurring in that group in the projection population. The sum of these age specific incident cases ($\sum C_i$) represented the total number of new cases occurring in 5 years, and the expression $(\sum C_i)/(\sum N_i)$ gave the directly standardised 5 year cumulative incidence proportion in the projection population. The 5 year incidence rate among those aged 85 and older could not be calculated directly and was assumed to be at least that of the younger (80–84 year) age class.

COMPUTATIONS IN THE MODEL

The age specific prevalence proportions were applied to the numbers in each of the 5 year classes in the age group 65 and older in the population of England and Wales, to compute the number of prevalent cases of vision impairing cataract in the age groups 65–69; 70–74; 75–79; 0 80–84; and 85 and older. The model calculated the number of new cases coming into the pool by applying the age specific 5 year

Table 1 The backlog of cataract causing visual impairment (visual acuity < 6/12) and the number of new cases expected over a 5 year period, for the population aged 65 and older in England and Wales

Age group	% Prevalence* of vision impairing cataract	Population of England and Wales	Cataract causing visual impairment: Baseline backlog of unoperated cases	Cataract causing visual impairment: New cases expected over a 5 year period
65–69	11.14	2 342 900	260 997	197 933
70–74	20.33	2 146 900	436 571	381 733
75–79	33.23	1 630 700	541 954	293 561
80–84	48.73	1 168 800	569 542	156 040
85+	56.47	969 500	547 482	91 675
Total		8 258 800	2 356 546	1 120 941

*Best available age specific prevalence data for the age group 65 and older.[4]

cumulative incidence to each population age group at risk (total age group population minus the prevalent cases). The relevant numbers of deaths expected in a 5 year period were then computed by application of age specific mortality to the cases who remained in the pool after removal of those expected to have had surgery during the 5 year period. The age specific and visual acuity specific cataract surgery rates were used for this purpose. These rates were assumed to increase proportionally to the annual increase observed in the Department of Health statistics between 1994 and 1995 and 1995 and 1996. The additional surgery that might be required for "second eye" operations among those who had the first eye surgery during the 5 year period was estimated and was incorporated into the simulation model.

To calculate the total pool of vision impairing cataract at the end of a 5 year period, the number expected to have had surgery and the number expected to have died were subtracted from the total pool of the prevalent and the new incident cases, in each of the 5 age groups. The remaining pool of unoperated cataract in each of the 5 age groups then represented the pool at the end of the 5 year period for the next older age group.

Not all operations were counted as effective in removing cataract cases from the pool. In patients who had surgery on both eyes during the 5 year period, only one of the cataract operations was counted as effective in removing them from the pool. Second eye operations performed during the 5 year period, on patients who had the first eye surgery before the 5 year period, were counted as effective.

Results

The age profile of the population of England and Wales to which the projections are made is shown in Table 1.

VISION IMPAIRING CATARACT IN THE POPULATION AGED 65 AND OLDER IN ENGLAND AND WALES

The current backlog of people with vision impairing (<6/12) cataract in the 65 and older population in England and Wales is estimated to be 2.36 million (approximate 95% confidence limits 2.2 to 2.5). About 70% of these unoperated cataract cases have more severe visual impairment (visual acuity <6/18). Over one million new cases will occur over a period of 5 years in the projection population. The age specific details are shown in Table 1.

A total of 132 866 cataract operations were performed on people falling in the age range 65 and older in England and Wales in 1995–96. The age specific number of operations for this and for the year 1994–95 is shown in Table 2.

The incremental increase in number of operations expected over a 5 year period are also shown in Table 2. The total number of operations on the 65 and older population expected over the 5 year period is 764 330. Of these, 560 571 (73%) operations are expected to be performed on people with visual acuity of < 6/12 (the fitness to drive requirement is a binocular visual acuity of approximately 6/12 or better). The remaining 203 759 operations are expected on people with better visual acuity (that is, 6/12 or better).

CHANGE IN THE POPULATION POOL OF VISION IMPAIRING CATARACT

Given that the current levels and pattern of surgery (with the observed annual increases) will continue, the current pool of people with visual impairment (visual acuity <6/12) will increase to over 2.5 million by the year 2001. By the year 2001 also, more than 700 000 who were visually impaired (<6/12) at the beginning of the period, are expected to have died without the benefit of sight restoring surgery (Table 3).

Table 2 Number of cataract operations in England and Wales and the numbers expected over a 5 year period

Age group	1994-95*	1995-96*	Yearly increase	Cataract operations in the 5 year period: Year 1	Year 2	Year 3	Year 4	Year 5	Total	Operations on cases with visual acuity <6/12
00–64	22 990	23 594	604	23 594	24 198	24 802	25 406	26 010	124 010	87 690 (71%)†
65–69	15 543	16 150	607	16 150	16 757	17 364	17 971	18 578	86 820	63 054 (73%)
70–74	25 504	26 313	809	26 313	27 122	27 931	28 740	29 549	139 655	99 807 (71%)
75–79	27 735	31 187	3 452	31 187	34 639	38 091	41 543	44 995	190 455	133 030 (70%)
80–84	30 481	32 805	2 324	32 805	35 129	37 453	39 777	42 101	187 265	136 539 (73%)
85+	23 603	26 411	2 808	26 411	29 219	32 027	34 835	37 643	160 135	128 140 (80%)
Total	145 856	156 460	10 604	156 460	167 064	177 668	188 272	198 876	888 340	648 261

*Actual number of cataract operation (source: Department of Health).
†Proportions from the National Cataract Audit II (1997).[3]

Table 3 Change in the population pool of vision impairing cataract, over a 5 year period to year 2001. The level of cataract surgery during the period is assumed to follow current practice (including the yearly increases observed in 1994–5 and 1995–6). The proportion of operations performed on people aged 65 and older and on those with visual acuity of < 6/12 are also assumed to follow current practice

	Pool of unoperated cataract:				*Operations performed over the 5 year period:*	
Age group	*At start of the 5 year period*	*At end of the 5 year period*	*Change (%)*	*Cases expected to die without the benefit of surgery*	*On all cataract cases, aged 65 and older*	*On <6/12 vision cases, aged 65 and older*
65+	2 356 546	2 556 477	+199 931 (8.48%)	732 836	764 330	560 571

Table 4 Change in the population pool of vision impairing cataract, over a 5 year period to year 2001, under various assumptions concerning the level and pattern of cataract surgery. The population pool of unoperated cataract at start of the 5 year period = 2 356 546

	Vision impairing cataract:			
Assumptions	*Size of pool by year 2001, and % change*	*Number expected to die without sight restoring surgery*	*Total number of operations on people aged 65 and older*	*Comments on cataract backlog by the year 2001*
1 Current practice unchanged over the 5 year period (as in Table 3)	2 556 477 (+8.48%)	732 836	764 330	Marked worsening of the cataract backlog
To prevent the backlog worsening:				
2 No additional operations, but all surgery in the age group 65 and older directed to people with impaired vision (<6/12)	2 435 579 (+3.35%)	693 269	764 330	Substantial improvement on (1) above, but the backlog still increasing
3 476 500 additional operations allocated to the cases aged 65 and older	2 356 549 (0.00%)	657 546	1 240 830	Backlog virtually unchanged—ie, no worsening
4 346 000 additional operations all directed to people with visual acuity <6/12	2 356 575 (0.00%)	660 255	1 110 330	Backlog virtually unchanged—ie, no worsening
5 All operations in age group 65+ directed to people with visual acuity <6/12 and 136 600 additional operations similarly directed	2 356 658 (0.00%)	664 614	900 930	Backlog virtually unchanged—ie, no worsening

While Table 3 is based on levels of surgery according to current practice, in Table 4 various assumptions are made concerning level and pattern of cataract surgery. The impacts of these changes on the cataract pool and the magnitude of the backlog expected by the year 2001 are reported.

Some control of the pool from increasing can also be achieved without additional operations but with targeting of all the operations that would be expected in the age group 65 and older, to those within that age group who have visual acuity of <6/12. This would result in a smaller increase (about +3.35%) in the backlog over the 5 year period, compared with the 8.48% increase expected without a targeting strategy.

In order to keep the backlog of cataract cases from escalating beyond its current level, 476 500 additional operations are required for the 65 year and older cases over the 5 year period. All of these additional operations are assumed to be allocated to various visual acuity groups according to current practice—that is, with no positive discrimination towards those with visual acuity of <6/12.

If the additional operations are targeted—that is, directed towards cases with visual acuity of <6/12, 346 000 will be needed to stop the backlog from increasing.

The combined strategies of targeting the committed operations and the additional operations would prevent the increase in the backlog with 136 000 additional operations over the 5 year period. In total, this would be 900 930 operations on eyes with visual acuity of <6/12.

As can be seen in Table 4, even the combined strategy will have the effect of only a small reduction in the number of cases expected to die within the 5 year period without having surgery.

Discussion

The model was constructed to simulate, as closely as possible, the dynamics of vision impairing cataract in the elderly population of England and Wales. The results (outputs) from the model, however, should not be regarded as absolutely accurate. There may be some degree of uncertainty and imprecision in the reported output figures. These, we believe, are small in relation to the magnitude of the output figures. The inaccuracies may arise because the model outputs depend importantly upon the extent to which the input prevalence data approximate the true averages for the population, the validity of the much used mathematical model for deriving incidence, and the inherent sampling errors in the input prevalence data.

One of the main assumptions made in this work is that the underlying *incidence* of vision impairing cataract in the population will not be reduced by preventive measures during the 5 year period, since there is insufficient information about the aetiology of cataract to allow useful proposals for prevention. The incidence determines the number of new cases that arise in the population in a given time and this, in turn, is the major contributor to the magnitude of the pool of vision impairing cataract at any given time. Clearly, if the number of new cases were balanced by the number of cataract operations, the pool would not increase. Indeed, this measure combined with the mortality expected in the affected age groups would lead to a rapid diminution of the pool over a short period of time. Our study has established that a substantial backlog exists, which will escalate to over 2.5 million affected individuals by the end of the century if the status quo in service provision remains unaltered. The status quo includes a modest yearly increase in cataract operations, based upon the observed figures between 1994 and 1996.

Given the stability of the population age structure, we have no reason to believe that the large backlog has come upon us suddenly. Associated with this, are the large numbers with poor vision, dying without having the benefit of sight restoring cataract surgery.

The perspective of our work has not been just that the health service should keep up with the number of new cases occurring, but to consider options to prevent the growth of the pool of unoperated cataract cases. The government could decide that we can tolerate a seriously increasing pool and a marked worsening of the cataract backlog. At the other extreme, it could opt for 476 500 additional operations along the lines of current allocation practice. This would prevent the backlog from worsening. Even if this additional number of cataract surgery was affordable in the budgetary sense, it would still have to be ascertained if it is achievable given the present staffing resources.

The adoption of a policy of targeting operations to those with poor visual acuity (<6/12) would mean that those with cataract but with good vision could have some diminished vision for a period, but would be eligible for the surgery if their visual acuity falls below the level of 6/12. Targeting of this type for the committed resources together with resources for an additional 136 000 targeted operations would ensure no worsening of the cataract backlog. The government may wish to opt for a combination of 346 000 additional operations over a 5 year period targeted, and 764 000 untargeted, thereby controlling the pool and for the present avoiding the controversy which is likely to arise out of a totally targeted strategy.

There is sufficient capacity within the NHS to accommodate the additional operations if resources were made available. We estimate that current cataract surgical practice is operating at 5/8 of capacity—that is, at about 38% below capacity, which could be expected given the theatre time and staffing resources allocated at present. Bringing the rate to 7/8 of full capacity would result in about 70 000 additional operations per year.

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Contributors: DCM and AR did the basic data collection, analysis, and modelling; PD was a member of the modelling team, and calculation of surgery allocations by vision; GV supervised the clinical researcher; SF provided the public health input; and AM provided background medical research assistance.

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