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Cataract surgery workload estimates in Theni district, India

Sachin Gupta [1], Ashok Vardhan,[2] Viraj Ambalam,[3] Vinothkumar Rajendran [3], Sanil Joseph [3], Thulasiraj D Ravilla [3]

[1]Cornell University SC Johnson College of Business, Ithaca, New York, USA
[2]Aravind Eye Hospital, Tirupati, Andhra Pradesh, India
[3]LAICO, Madurai, India

Correspondence to
Mr Thulasiraj D Ravilla, LAICO, Madurai, India;
thulsi@aravind.org

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ABSTRACT

Background/aims To estimate the annual cataract surgery workload in Theni district, Tamil Nadu, India based on current utilisation of cataract services, prevalence of blindness and vision impairment (VI), and cataract burden-reduction goals.

Methods We conducted a population-based longitudinal study between January 2016 and April 2018. We recruited 24 327 participants based on a random cluster sampling method; 7127 participants were ≥40 years. During the year following initial enrolment, we tracked utilisation of eye care services; and at the end of the 1-year period, we conducted a detailed eye examination of participants age ≥40.

Results In the sample age ≥40 years, 13.0% had a visually significant cataract, and 17.8% had prior cataract surgery in at least one eye. The prevalence of cataract blindness based on presenting visual acuity in the better eye (PVA_{BE})<3/60 was 0.34% and VI (PVA_{BE}<6/12) was 9.92%. 3.10% of the study population had obtained cataract surgery during 1 year, resulting in a cataract surgical rate of 9085. We estimated the effective cataract surgical coverage (eCSC) to be 54.5% and the CSC to be 75.7%, implying a sizeable quality gap. Prevalence, utilisation and coverage varied by age and gender. We estimated that a goal of eliminating the backlog of VI (PVA_{BE}<6/12) in 5 years would increase the annual cataract surgery workload by 11.5% from the current level.

Conclusions Our estimates of cataract surgery workloads under different scenarios can provide a useful input into planning of eye health services in Theni district.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Current planning for eye care is often done using the data from population-based surveys that essentially report prevalence of blindness and visual impairment due to various causes.

WHAT THIS STUDY ADDS

⇒ This study estimates the eye care needs in the community considering the current utilisation pattern, the prevalence of blindness and visual impairment as well as the guidelines for intervention threshold.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ For the first time, this study will establish the annual eye care needs for a population.
⇒ We hope this will help planners establish the required capacity and influence policies for generating necessary human resources and infrastructural needs.

INTRODUCTION

Although India has achieved significant reduction in the burden of blindness in recent decades, untreated cataract remains a major challenge.[1–5] A key question is how to develop sustainable strategies to eliminate blindness and vision impairment (VI) due to cataract, in the face of limited resources. Integral to this planning question is the need to estimate the surgical workload. That is, how many cataract surgeries need to be performed, and how many patients need to be operated on, per planning period or annually? The purpose of this paper is to provide an approach and answer to this question in the context of Theni district in Tamil Nadu state, India.

Past studies have typically approached this question by starting with estimates of prevalence of cataract-caused VI and blindness in a population, often based on Rapid Assessment of Avoidable Blindness studies (https://www.raab.world/). Additionally, some studies derive annual incidence estimates based on the prevalence using a statistical model.[6–8] Thereafter, assumptions are made to arrive at service delivery goals by the policymaker. For instance, some studies assume that only incident cataracts will be addressed each year without any conscious attempt to address the cataract backlog[6]; others assume that some part of the backlog based on a VI threshold will also be explicitly addressed.[9 10] In a few instances, as an input into the goal setting, studies have also considered patients' felt needs, such as reported satisfaction with their vision, or whether individuals considered their eyesight bad enough to merit surgery.[11 12] These assumptions then lead to a target cataract surgical rate (CSR), or the number of cataract surgeries that need to be performed each year per million population. However, in reality, targets that will eliminate cataract as a cause of blindness or VI at national or subnational level are seldom set.

These approaches adopt a largely supply-centric view to determine the surgical workload; they assume that capacity that is created with a goal of reducing, for instance, cataract blindness, will in fact be directed to patients who are cataract blind. Clearly, this may not occur, since realised patient demand depends on patients choosing to seek care for their vision-limiting diseases. For instance, there is rising demand for cataract surgery at lower VI

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thresholds in India[13] and many other countries.[14–17] This implies that it is necessary to consider the utilisation of cataract surgical services in determining the workload.

The objective of the current study is to estimate the annual cataract surgery workload in Theni district, Tamil Nadu, India based on current utilisation of cataract services, prevalence of blindness and VI, and cataract burden-reduction goals.

MATERIALS AND METHODS

Study design

We conducted a population-based longitudinal study between January 2016 and April 2018 in the Theni district of Tamil Nadu, India. Theni district has a population of 1.2 million which is a mix of urban (55%) and rural (45%). The study was conducted in three phases, (1) household-level enumeration and enrolment, (2) preliminary eye examination at households 1-year post-enrolment and (3) detailed eye examination at central cluster locations. During the year following initial enrolment, we tracked utilisation of eye care services. At the end of the 1-year period, we also asked participants about their eye care utilisation in the past year and conducted a detailed eye examination of participants age ≥40. Details of the study design are described in our other publication.[18]

Study participants

We recruited participants from the entire Theni district of 1.2 million population. The sample size was calculated assuming a 2.0% prevalence of blindness among people aged ≥40 years[19] and an error bound (precision) of 20% at 95% confidence level. A random cluster sampling method with probability proportional to size was used. Sampling was done at the household level from selected clusters, covering all age groups. With each cluster population ranging from 800 to 1000, a total of 34 clusters (17 rural+17 urban) were randomly selected from a sample frame of 1454 clusters (urban – 787, rural – 667) which were provided by the Theni District Collector based on population data.

Definitions of vision categories, prevalence, utilisation and coverage

Following the definitions used in the Indian National Blindness and VI Survey,[3] we used presenting visual acuity in the better eye (PVA_{BE}) thresholds as follows: blindness (PVA_{BE}<3/60), severe VI (PVA_{BE}≥3/60 to <6/60), moderate VI (PVA_{BE}≥6/60 to <6/18), mild VI (PVA_{BE}≥6/18 to <6/12) and VI (PVA_{BE}<6/12). Visually significant (VS) cataract in an eye was defined as any of the following diagnoses—cataract or lens changes, early cataract, immature cataract, mature cataract, nuclear or brown cataract, posterior subcapsular cataract, traumatic cataract and hypermature or Morgagnian cataract—and best-corrected visual acuity (BCVA)<6/12 in that eye. Prior cataract surgery was identified based on diagnoses of aphakia or pseudophakia. Total prevalence (persons) was defined as the unique number of persons with either a VS cataract or previously operated cataract in either eye. Utilisation was defined as cataract surgery in either eye performed during the 12-month period after enrolment and was tracked using three approaches. First, subjects were asked to carry an eye-health diary and present it to eye-health providers during the study period. Second, Aravind hospitals and outreach camps live-tracked utilisation by subjects from the study clusters. Third, we conducted retrospective tracking based on self-reporting by subjects via a survey. Details of these approaches are provided in our other publication.[18]

Effective cataract surgical coverage (eCSC) was defined as the proportion of adults aged 40 years and older who are in need of cataract surgery, who have received this surgery, and have a resultant good-quality distance visual acuity outcome.[20 21] Cataract surgery coverage (CSC) was defined as the proportion of adults aged 40 years and older who are in need of cataract surgery, who have received this surgery, regardless of visual outcome.[22] Both metrics measure the effectiveness of past cataract intervention programmes in providing services. CSR is defined as the number of cataract surgeries performed in a year per million population,[23] and is a flow measure of the quantity of cataract services. We define the quality gap[21] as 1−(eCSC/CSC), which expresses the difference between the two measures relative to the CSC and is interpretable as the proportion of cataract surgeries performed in a year that failed to reach the good-quality distance visual acuity threshold.

Statistical analyses

We performed descriptive analyses of the data using SAS V.9.4. All reported p values are two sided.

RESULTS

Study population

We recruited 24 327 participants of all ages, of which 7127 participants were of age ≥40 years.

Prevalence of blindness and VI

Of the 7127 study participants, PVA_{BE} was available for 7109 participants. The percentage of all causes blind (PVA_{BE}<3/60) in our sample is 0.53% (95% CI 0.37% to 0.70%, n=38/7109), severely visually impaired (PVA_{BE}≥3/60 to <6/60) is 0.44% (95% CI 28% to 0.59%, n=31/7109), moderately visually impaired (PVA_{BE}≥6/60 to <6/18) is 16.7% (95% CI 15.83% to 17.56%, n=1187/7109), mildly visually impaired (PVA_{BE}≥6/18 to <6/12) is 6.2% (95% CI 5.64% to 6.76%, n=441/7109) and not visually impaired (PVA_{BE}≥6/12) is 76.13% (95% CI 75.14% to 77.12%, n=5412/7109).

Age-specific and gender-specific prevalence of any VS cataract

Of the 7127 study participants, BCVA measures for both eyes were available for 7087 participants. We identified VS cataract in 13.0% (95% CI 12.2% to 13.8%, n=923/7087) of the participants (table 1). The age-specific prevalence was 2.8% (72/2601) for age 40–49 years, 10.3% (205/1985) in the 50–59 group, 21.8% (343/1571) in the 60–69 group, 31.8% (237/746) in the 70–79 group and 35.9% (66/184) in the 80 and over group (p<0.0001). The prevalence of VS cataract among males was 12.2% (366/2989) and among females was 13.6% (557/4098) (p<0.0001).

Age-specific and gender-specific prevalence of any prior cataract surgery and total prevalence

The overall prevalence of any prior cataract surgery was 17.8% (95% CI 16.9% to 18.7%, n=1262/7087) (table 1). The age-specific prevalence was 3.1% (81/2601) for age 40–49 years, 11.5% (229/1985) in the 50–59 group, 28.8% (453/1571) in the 60–69 group, 51.9% (387/746) in the 70–79 group and 60.9% (112/184) in the≥80 group (p<0.0001). The prevalence of any prior cataract surgery among males was 16.8% (501/2989) and among females was 18.6% (761/4098) (p=0.049).

Table 1 Prevalence (persons) of any visually significant (VS) cataract*, any prior cataract surgery† and total prevalence‡, by age and gender, in Theni population (n=7127)

Age, years	Sample size	Sample size with complete data§	Prevalence of any VS cataract		Prevalence of any prior cataract surgery		Total prevalence	
			n persons	% (95% CI)	n persons	% (95% CI)	n persons	% (95% CI)
40–49	2602	2601	72	2.8 (2.1 to 3.4)	81	3.1 (2.4 to 3.8)	133	5.1 (4.3 to 6.0)
50–59	1999	1985	205	10.3 (9.0 to 11.7)	229	11.5 (10.1 to 12.9)	384	19.3 (17.6 to 21.1)
60–69	1584	1571	343	21.8 (19.8 to 23.9)	453	28.8 (26.6 to 31.1)	705	44.9 (42.4 to 47.3)
70–79	755	746	237	31.8 (28.4 to 35.1)	387	51.9 (48.3 to 55.5)	575	77.1 (74.1 to 80.1)
≥80	187	184	66	35.9 (28.9 to 42.8)	112	60.9 (53.8 to 67.9)	160	87.0 (82.1 to 91.8)
Gender								
Male	3004	2989	366	12.2 (11.1 to 13.4)	501	16.8 (15.4 to 18.1)	768	25.7 (24.1 to 27.3)
Female	4123	4098	557	13.6 (12.5 to 14.6)	761	18.6 (17.4 to 19.8)	1189	29.0 (27.6 to 30.4)
Total	7127	7087	923	13.0 (12.2 to 13.8)	1262	17.8 (16.9 to 18.7)	1957	27.6 (26.6 to 28.7)

*VS cataract in an eye is defined as any of the following diagnoses—cataract or lens changes, early cataract, immature cataract, mature cataract, nuclear or brown cataract, traumatic cataract and hypermature or Morgagnian cataract— and best-corrected visual acuity (BCVA)<6/12 in that eye.
†Any prior cataract surgery is defined as any of the following diagnoses: aphakia, pseudophakia.
‡Total prevalence (persons) is defined as the unique number of persons with either a present VS cataract or previously operated cataract in either eye. Example calculation for the total sample is as follows. Total prevalence (persons)=[VS cataract in LE (641)+VS cataract in RE (654)+Previously operated cataract in LE (1008)+Previously operated cataract in RE (1087)]−[VS cataract in both eyes (372)+Previously operated cataract in both eyes (833)+VS cataract in LE and previously operated cataract in RE (135)+Previously operated cataract in LE and VS cataract in RE (93)]=1957.
§BCVA measurements were missing in at least one eye for 40 participants.
BCVA, best corrected visual acuity; LE, left eye; RE, right eye.

Summing the prevalence of any VS cataract and any prior cataract surgery and accounting for duplication results in the total prevalence (table 1) of 27.6% (95% CI 26.6% to 28.7%, n=1957/7087). Age-specific and gender-specific total prevalence are obtained similarly.

VI and blindness in persons with VS cataract

In table 2, we show the prevalence of VI and blindness among persons with VS cataract (see table 1), based on PVA_{BE}. We had complete data for 7075 of 7127 participants. The percentage cataract-blind in our sample is 0.34% (95% CI 0.20% to 0.47%, n=24/7075), severely visually impaired is 0.30% (95% CI 0.17% to 0.42%, n=21/7075), moderately visually impaired is 7.77% (95% CI 7.15% to 8.40%, n=550/7075), mildly visually impaired is 1.51% (95% CI 1.23% to 1.80%, n=107/7075), and not visually impaired is 3.04% (95% CI 2.64% to 3.44%, n=215/7075). We also show the prevalence of blindness and visual impairment by age and gender.

Cataract surgical coverage

Table 3 (detailed definitions of eCSC and CSC are provided) shows that the eCSC was 54.5% (95% CI 53.5% to 55.5%) and the CSC was 75.7% (95% CI 74.6% to 76.7%) in Theni district. 28% of surgeries failed to reach the quality threshold of PVA≥6/12 in the operated eye. Age-specific and gender-specific findings are also shown for both measures.

Cataract surgery utilisation and CSR

In table 4, we show the cataract surgery utilisation rate, which is the number of participants by age and gender who underwent cataract surgery during the past 12 months as a fraction of the number of participants age ≥40 years. A total of 221 participants reported receiving cataract surgery.

To obtain an estimate of the CSR we rely on the full study sample size of 24 327, regardless of age. This leads to an estimate of 9085 cataract surgeries per million population in Theni

Table 2 Presenting visual acuity in better eye in patients with any visually significant cataract, by age and gender, in Theni population (n=923)*

Age, years	Sample size	Sample size with complete data	Presenting visual acuity in better eye % (n)				
			No VI	Mild VI	Moderate VI	Severe VI	Blindness
			≥6/12	≥6/18 to <6/12	≥6/60 to <6/18	≥3/60 to <6/60	<3/60
40–49	2602	2601	1.23 (32)	0.27 (7)	1.11 (29)	0.08 (2)	0.08 (2)
50–59	1999	1983	2.77 (55)	1.51 (30)	5.65 (112)	0.20 (4)	0.10 (2)
60–69	1584	1569	5.10 (80)	2.55 (40)	13.26 (208)	0.32 (5)	0.51 (8)
70–79	755	744	4.44 (33)	3.36 (25)	21.64 (161)	1.08 (8)	1.08 (8)
80 and over	187	184	8.15 (15)	2.72 (5)	21.74 (40)	1.09 (2)	2.17 (4)
Gender							
Male	3004	2981	3.52 (105)	1.44 (43)	6.81 (203)	0.20 (6)	0.23 (7)
Female	4123	4094	2.69 (110)	1.56 (64)	8.48 (347)	0.37 (15)	0.42 (17)
Total	7127	7075	3.04 (215)	1.51 (107)	7.77 (550)	0.30 (21)	0.34 (24)

*Of the 923 participants, 6 had missing data on PVA_{BE}. Therefore, the number of participants in parentheses in the last row of the table sums to 917.
PVA_{BE}, presenting visual acuity in the better eye; VI, visual impairment.

Table 3 Effective cataract surgical coverage (eCSC) and CSC persons, by age and gender, in Theni population (n=7127)

Age, years	Sample size	Sample size with complete data	No of persons (n)					eCSC*	CSC†	Quality gap (1−eCSC/CSC)
			a	b	c	d	e			
40–49	2602	2601	14	24	20	31	19	54.3	72.9	0.26
50–59	1999	1983	28	111	50	128	66	57.0	73.0	0.22
60–69	1584	1569	49	240	91	301	111	57.5	77.9	0.26
70–79	755	744	20	204	49	288	110	50.1	75.4	0.34
80 and over	187	184	10	64	18	85	35	53.6	74.6	0.28
Gender										
Male	3004	2981	58	244	99	313	112	57.6	78.6	0.27
Female	4123	4094	63	399	129	520	229	52.6	73.9	0.29
Total	7127	7075	**121**	**643**	**228**	**833**	**341**	**54.5**	**75.7**	**0.28**

a: Individuals with unilateral operated cataract attaining PVA≥6/12 in the operated eye, who have BCVA<6/12 in the other eye.
b: Individuals with bilateral operated cataract attaining PVA≥6/12 in at least one eye.
c: Individuals with unilateral operated cataract (regardless of VA in the operated eye) and BCVA<6/12 in the other eye.
d: Individuals with bilateral operated cataract, regardless of VA in the operated eyes.
e: Individuals with BCVA<6/12 in both eyes with cataract as the main cause of vision impairment or blindness in one or both eyes.
*ECSC is defined as [(a+b)/(c+d+ e)]×100.
†CSC is defined as [(c+d)/(c+d+ e)]×100.
BCVA, best-corrected visual acuity; PVA, presenting visual acuity.

district in 12 months, computed as 221/24 327×1M. Further, we obtain a CSR of 7991 surgeries for males based on the study sample of 11 889 males, and 10 130 for females based on the study sample of 12 438 females. Notably, the CSR for the female population is much higher than for the male population.

DISCUSSION

Several factors influence the demand for cataract surgery; these include the dynamics of age in the population, the visual acuity threshold used as an indication for surgery, and the proportion of those eligible for surgery who express the demand.[5] Globally, the share of the population aged 65 years or over is expected to increase from 9.3% in 2020 to around 16.0% in 2050.[24] Growing supply of safe, effective and reliable cataract surgery, increasing literacy and need for better vision in this digital era, have all fueled patient demand.[5 16] The focus of the current study is to assess the cataract surgery workload in Theni district, accounting for patient demand.

To make the evidence more comprehensive, in our study, we defined the age-based inclusion criterion to be 40+ instead of the more commonly used 50+. To begin, it is useful to compare our estimated prevalence of blindness and VI (in general, not only cataract caused) in Theni district with corresponding statistics for India based on PVA_{BE} available in Vashist *et al*.[3] Since national statistics are available only for the population ≥50 years,[3] for the same subpopulation (i.e., ≥50 years) we estimate prevalence of blindness (<3/60) in Theni to be 0.49% (India 1.99%), severe VI (≥3/60 to <6/60) to be 0.43% (India 1.96%), moderate VI (≥6/60 to <6/18) to be 11.65% (India 9.81%), mild VI (≥6/18 to <6/12) to be 2.23% (India 12.92%) and VI (<6/12) to be 14.80% (India 26.68%). Thus, prevalence of VI, severe VI and blindness is lower in Theni than nationally. In fact, blindness prevalence in Theni is lower than all 31 districts of India that were surveyed in Vashist *et al*.[3]

Consistent with recent studies,[25] our definition of prevalence of VS cataract is based not only on a cataract diagnosis but also a BCVA<6/12. Accordingly, our estimates of total prevalence should be compared with findings from other studies that may have used different inclusion criteria for age and different VA thresholds for vision categories with care. Murthy *et al*.[26] report the prevalence of cataract blindness in the 50+ population in India to be 5.3%, based on <6/60 vision, and also report a declining trend since the 1970s. The analogous cataract blindness estimate (PVA_{BE}<6/60) based on our data for the 50+ Theni population is considerably smaller at 0.92%.

Our definition of eCSC (table 3) is based on recent guidelines provided by a WHO expert group[20] whereby the population in need of cataract surgery is defined as individuals with BCVA<6/12 with cataract as the main cause of VI. This threshold was selected because it is consistent with the International Classification of Diseases (11th revision) definition of VI. Notably, this threshold is better than lower thresholds of 6/18 or 6/60 that have previously been used.[21] Furthermore, the threshold for defining a good quality outcome now provided by the WHO is PVA≥6/12, which is also higher than the previous standard of 6/18.[21] A consequence of these changes is that our estimates of eCSC and CSC are among the first under the new thresholds and hence not readily comparable with past reported values.

Our estimate of CSC of 75.7 (table 3) says that about three-fourths of persons in Theni in need of cataract surgery have received it; however, the estimate of eCSC of 54.5 implies

Table 4 Cataract surgery utilisation in 12 months and estimated cataract surgical rate (CSR)* by age and gender in Theni population

Age, years (n)	Utilisation % (95% CI)	No of persons (n)	Estimated cataract surgical rate
40–49 (n=2602)	0.85 (0.49 to 1.20)	22	
50–59 (n=1999)	3.10 (2.34 to 3.86)	62	
60–69 (n=1584)	5.30 (4.20 to 6.41)	84	
70–79 (n=755)	5.96 (4.27 to 7.65)	45	
80 and over (n=187)	4.28 (1.38 to 7.18)	8	
Gender (n)			
Male (n=3004)	3.16 (2.54 to 3.79)	95	7991
Female (n=4123)	3.06 (2.53 to 3.58)	126	10 130
Total (n=7127)	3.10 (2.70 to 3.50)	221	9085

*The CSR reflects the number of surgeries performed in 1 year per million population. Our study sample size was 24 327 (male 11 889, female 12 438). We calculated the CSR as follows: CSR=(number of surgeries reported in study in 12 months×1 000 000)/study sample size. Example calculation: overall CSR=(221×1 000 000)/24 327=9085.

that only slightly more than half of persons in need of cataract surgery have received it and achieved the desired visual outcome of PVA≥6/12. Hence, roughly 28% of cataract surgeries performed failed to reach the quality threshold, due to surgery or refractive error correction. Importantly, when we measure CSC based on a threshold of BCVA≥6/12 instead of PVA≥6/12 (as reported in table 3), the quality gap shrinks from 28% to approximately 6%. This indicates that most of the quality gap is due to uncorrected refractive error. The quality gap in cataract services[21] is also found to occur across age and gender groups, with the largest gap in the 70–79 age group at 34%. The visual outcome in older patients is poorer because of more corneal astigmatism and because manual small incision cataract surgery is the commonly performed surgical technique which inherently induces astigmatism. Additionally, we also find a gender gap, with both eCSC and CSC being five points higher for males than females, consistent with the findings of other population-based studies in developing countries. For instance, Lewallen *et al*.[27] report that in 21 of 23 surveys, the CSC was higher among men than women.

While the prevalence of cataract is highest in the 80+ subpopulation (table 1), which is unsurprising, both the CSC (table 3) and the utilisation (table 4) are lower in this group relative to the 60–69 and 70–79 subpopulations. Notably, this difference suggests lower priority for cataract surgery by patients in the 80+ age group due to old age or associated systemic comorbidities.

Our estimate of the CSR in Theni at 9085 surgeries per million population (table 4) is considerably higher than the nationwide estimate of 5000[4] for India and in fact is closer to the CSRs of developed countries such as the USA, France, Netherlands, Spain and Sweden.[28] This could be attributable to the fact that in Theni district there is an extensive network of eye care services creating easy access—no one needs to travel for more than five miles to get to an eye care service. The services are also affordable with options for free and subsidised care.

Notably, the CSR for the female population at 10 130 is over 20% higher than the CSR of 7991 for the male population (table 4). This is a positive development in the direction of correcting the gender inequity in eye care in this district that the CSC indicates.

Workload assessment

Our broad approach to assess the cataract surgery workload in Theni district in a 1-year period is to consider four alternative hypothetical scenarios based on specific goals of reducing the prevalence of cataract-caused blindness or visual impairment (table 5). Across the four scenarios we held constant the 12-month current utilisation rate (percentage of the population that underwent cataract surgery in 12 months of the study, table 5 column A) of 3.10% that we measured in the study (table 4). Achievement of the goals would require additional utilisation which would also contribute to the cataract surgical workload (table 5, column B). Importantly, some individuals who contribute to the achievement of the goal and hence are counted in the additional utilisation are already included in the current utilisation. For instance, of the study sample of 7167, 1.63% had obtained cataract surgery in the 12-month period post-enrolment and had PVA≤6/12; these are considered duplication between the current utilisation and additional utilisation in scenario 4. Therefore, we correct for this duplication (table 5, column C) to obtain the net utilisation (table 5, column D). Note that correcting this duplication is possible in our study because we collected the preoperative vision of participants who utilised cataract services during the 1-year period after enrolment. More broadly, computation of columns A–D is possible in our study because we collected utilisation data. This aspect is an important distinction relative to previous workload assessment studies.

We translate the prevalence-reduction goals in each scenario into an estimate of the number of persons who would need to undergo cataract surgery by applying the net utilisation rates to the population of Theni district (table 5, column E). For simplification, in the current analysis, we assume that only one eye per person will be operated on. Since we have defined prevalence of blindness and VI based on PVA_{BE}, this assumption implies that each surgery will reduce prevalence by one person.

Table 5 12-month workload estimates for cataract surgery in Theni population (≥40 years) in hypothetical scenarios based on goals of reducing cataract burden

Scenario	Goal	Current utilisation % (A)	Additional utilisation to achieve goal % (B)	Overlap between current and additional utilisation % (C)	Net utilisation % (D=A+B−C)	Number of persons to be treated (E=D×population of 540 078)	Estimated CSR based on 2021 projected population of 1.319 million (F)
1	Meet current demand	3.10	0	0	3.1	16 742	12 689
2	Meet current demand and eliminate present burden of PVA_{BE}<3/60	3.10	0.34	0.20	3.24	17 517	13 276
3	Meet current demand and eliminate present burden of PVA_{BE}<6/60	3.10	0.64	0.41	3.33	18 001	13 643
4	Meet current demand and eliminate 1/5th of present burden of PVA_{BE}<6/12	3.10	1.98	1.63	3.46	18 667	14 148

Column A: Based on last row of table 4.
Column B: Based on last row of table 2. In particular, the 1.98 in scenario four is obtained as 1/5×(1.51+7.77+0.30+0.34).
Column C: Of the 221 study participants who obtained cataract surgery in the last 12 months (table 4), data on PVA_{BE} was available for 149. Of these, 14 (0.20% of 7127) had PVA<3/60, 29 (0.41% of 7127) had PVA<6/60, and 116 (1.63% of 7127) had PVA<6/12, where 7127 is the study sample size.
Column D: Since participants in column C are included in both columns A and B, we remove the duplication by subtracting.
Column E: Theni district population (≥40 years) is projected to grow to 540 078 in 2021 from the 2011 level of 425 376. This is done by applying the 10-year growth rate of 26.96% of Tamil Nadu population (≥40 years) obtained from https://main.mohfw.gov.in/sites/default/files/PopulationProjectionReport2011-2036-upload_compressed_0.pdf.
Column F: Theni district population for 2021 based on 10-year Tamil Nadu population growth rate of 5.9% applied to 2011 population of 1 245 899.
PVA_{BE}, presenting visual acuity in the better eye.

Scenario one provides the baseline or status quo wherein we assume that the current utilisation rate continues to occur, resulting in the need to perform cataract surgery on 16 742 persons. In scenario 2, in addition to current utilisation, a goal of eliminating cataract-caused blindness (PVA_{BE}<3/60) is specified, resulting in additional utilisation of 0.34%. Since some persons with PVA_{BE}<3/60 are already included in the current utilisation, we correct for this duplication, resulting in a net need to perform surgeries on 17 517 persons, 4.6% higher than scenario 1. In scenario 3, a goal of eliminating severe visual impairment (PVA_{BE}<6/60) is specified, resulting in a need to perform surgeries on 18 001 persons, 7.5% higher than Scenario 1. Finally, in scenario 4, we assume an annual goal of eliminating one-fifth of prevalent burden of mild or worse VI (PVA_{BE}<6/12), resulting in a need to perform surgeries on 18 667 persons, which is 11.5% above scenario 1. In column F of table 5, we translate these workload estimates into target CSRs using the estimated 2021 Theni district population of 1.319 million. We find that the target CSR ranges from 12 689 in scenario 1 to 14 148 in scenario 4. We hope these estimates can help inform district-level planning of eye care services.

A strength of our study is the use of a random cluster sampling strategy, covering both rural and urban populations of Theni district. The large sample size in the study also permitted robust analysis of age and gender subgroups. A limitation of our study is that we could not track eye care utilisation by participants who accessed and availed services by providers other than Aravind. However, we do not consider this a significant drawback since Aravind is estimated to provide more than 80% of all eye care in Theni district. When using our estimates of CSR (table 4), readers should note that they are based on utilisation rates measured in Theni district during the study period (January 2016–April 2018). We acknowledge that our proposed longitudinal methodology to measure cataract surgery utilisation could be expensive and time-consuming to execute at the national level. An alternative approach would be to measure utilisation via recall along with clinical parameters in a cross-sectional study, while recognising the inherent limitations of a recall-based measure. Finally, while in the current analysis, we assumed that only eye per person will be operated on in obtaining the workload estimates, accounting for individuals choosing to obtain bilateral cataract surgery will be important in future work.

Twitter Sanil Joseph @saniljoseph

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ORCID iDs
Sachin Gupta http://orcid.org/0000-0001-9459-5233
Vinothkumar Rajendran http://orcid.org/0000-0001-9161-5198
Sanil Joseph http://orcid.org/0000-0002-8467-5544
Thulasiraj D Ravilla http://orcid.org/0000-0002-1935-7443

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