Factors Influencing the Output of Rural Cataract Surgical Facilities in China: The SHARP Study

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Purpose. To identify factors associated prospectively with increased cataract surgical rate (CSR) in rural Chinese hospitals.

Methods. Annual cataract surgical output was obtained at baseline and 24 months later from operating room records at 42 rural, county-level hospitals. Total local CSR (cases/million population/y), and proportion of CSR from hospital and local competitors were calculated from government records. Hospital administrators completed questionnaires providing demographic and professional information, and annual clinic and outreach screening volume. Independent cataract surgeons provided clinical information and videotapes of cases for grading by two masked experts using the Ophthalmology Surgical Competency Assessment Rubric (OSCAR). Uncorrected vision was recorded for 10 consecutive cataract cases at each facility, and 10 randomly-identified patients completed hospital satisfaction questionnaires. Total value of international nongovernmental development organization (INGDO) investment in the previous three years and demographic information on hospital catchment areas were obtained. Main outcome was 2-year percentage change in hospital CSR.

Results. Among the 42 hospitals (median catchment population 530,000, median hospital CSR 643), 78.6% (33/42) were receiving INGDO support. Median change in hospital CSR (interquartile range) was 33.3% (−6.25%, 72.3%). Predictors of greater increase in CSR included higher INGDO investment ($P = 0.02$, simple model), reducing patient dissatisfaction ($P = 0.03$, simple model), and more outreach patient screening ($P = 0.002$, simple and multiple model).

Conclusions. Outreach cataract screening was the strongest predictor of increased surgical output. Government and INGDO investment in screening may be most likely to enhance output of county hospitals, a major goal of China's Blindness Prevention Plan.

Keywords: cataract surgery, rural, China, productivity

Unoperated cataract is the leading cause of blindness globally[1] and in China.[2–4] Given the strong association of cataract with older age,[5] this figure is expected to increase with the aging of China's population.

When cataract is treated by skilled surgeons, good vision[6–9] and patient satisfaction[10,11] can be achieved in 90% of cases. However, relatively few patients requiring surgery in China receive it: the 2010 cataract surgical rate (CSR) of 915/million population/y is much lower than that in neighboring Vietnam (2000/million/y) and India (>5000/million/y),[12] both of which are economically less developed than China.[13] The estimated number of cataract operations performed annually in China (360,000) falls short of the number becoming blind each year from cataract (400,000),[14] and, thus, there is an urgent need to increase China's cataract surgical output.

Due to a shortage of health care resources, surgical coverage in rural areas is especially low, only 43.1% among those bilaterally blind from cataract in a recent national survey.[4] Increasing surgical output at rural facilities is of critical importance to reducing the burden of treatable blindness in China. The principal source of eye care for rural dwellers in China is the county-level facility, of which there are approximately 2400, each covering an average population of approximately 500,000. These facilities typically are the lowest-level, and, thus, most convenient, public hospitals to offer ophthalmic services, including cataract surgery, and, thus, a major goal of China's current Blindness Prevention Plan is to increase their surgical capacity.

While factors influencing cataract surgical output have been examined systematically for Africa,[15] a review of the PubMed

and Sinomed databases in March 2014 failed to identify any peer-reviewed publications providing this information for China. To gather such data, we carried out a prospective, multicenter, observational survey among rural, county-level hospitals, the Study of Hospital Administration and Relative Productivity (SHARP), in six provinces of rural China. The goal of the current report is to provide information on the baseline cataract surgical output of such facilities (secondary outcome), and to identify factors predictive of increases in this output over 2 years (main outcome).

Methods

This study was done between July 2010 and March 2014. The protocol was approved in full by the Ethics Committee of the Zhongshan Ophthalmic Center, Sun Yat-sen University (Guangzhou, China). Oral informed consent was obtained from all participating administrators, physicians, and patients. The principles of the Declaration of Helsinki were followed throughout.

Participant Hospitals and Cataract Surgical Output Data

Hospitals were identified from lists provided by Orbis International, Helen Keller International, and Fred Hollows Foundation of rural, county-level hospitals with whom they had current or recent collaborations. Baseline data were obtained from 19 hospitals in Guangdong in 2009 and the remaining 23 hospitals in six provinces (including Guangdong) in 2011. Annual cataract surgical volume was recorded at the time of ascertainment of baseline data, and then 24 months later. These data were obtained in all cases directly from operating room records at the participating hospitals.

Basic Hospital and Administration Information

Hospital directors (4/42 = 9.52%) or heads of ophthalmology departments (38/42 = 94.5%) at each institution completed questionnaires, including the following information:

1. Hospital overview: population of the catchment area (typically in this case a county), breakdown of cataract surgery at the institution between physicians employed there and outside surgeons, annual outpatient clinical volume of the ophthalmology department, and frequency and patient volume of outreach screenings.
2. Hospital administration characteristics: demographic data on hospital director, and level of hospital support for the ophthalmology department (five questions directed to the head of the ophthalmology department, each graded on a 5-point Likert scale from "1, strongly disagree" to "5, strongly agree," for a maximum total score of 25).
3. International nongovernmental development organization (INGDO) support: participation in INGDO programs, total length of program, specific type, and amount of support provided.
4. Cataract surgical cost: availability of free cataract surgery, proportion of all cataract surgery offered free, cost of routine surgery, certification of facility to accept rural health insurance for cataract surgery, and reimbursement rate for such surgery.

Additionally, per capita gross domestic product (GDP) and total annual cataract surgical output for the hospital catchment area, and number of institutions in the catchment area capable of providing cataract surgical services were obtained from local health bureau records.

Surgeon Demographic Information and Skill Assessment

All of the eye surgeons who were capable of independent cataract surgery at baseline were asked to complete the surgeon questionnaire, which included data on age, sex, medical licensure status, annual independent cataract surgical volume at baseline, years performing independent cataract surgery, measurements routinely used in computing IOL power, and method(s) of cataract surgery regularly performed independently. Additionally, participants self-rated their own ability to carry out three basic examination techniques (indirect ophthalmoscopy, slit-lamp examination with a 90-diopter [D] lens, gonioscopy) on a 0 ("have never performed") to 4 ("have taught others") scale. The maximum score on this subtest was 12.

A single Manual Small Incision cataract surgery (MSICS) procedure was selected and recorded by each surgeon using a tripod-mounted digital recorder placed next to the operating microscope. Videos were graded as previously described (Wang LH, et al., unpublished observations, 2015) by two independent expert trainers for each of 12 specific steps of surgery and 7 global assessments using a slightly-modified version of the Ophthalmology Surgical Competency Assessment Rubric: Small Incision Cataract Surgery (OSCAR: SICS) developed by the International Council of Ophthalmology (ICO).[16] Grades for each step ranged from 2 (poor performance) to 5 (good performance), with a score of 0 if the step was performed by trainers. The subscore ranged from 0 to 35 for the global portion, 0 to 60 for the task-specific portion, and 0 to 95 points for the total score.

Surgical Outcomes

We assessed postoperative, uncorrected visual acuity at the time of discharge from hospital ($\leq$3 days postoperatively) for 10 consecutive cataract surgical patients at each facility. Early postoperative assessment of visual acuity recently has been validated as a reliable indicator of surgical quality in a multicountry study involving over 3000 patients at 40 centers.[17]

Patient Satisfaction

A widely-used patient satisfaction questionnaire, the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS),[18] previously validated in Chinese,[19] was administered by study personnel to 10 patients having recently undergone cataract surgery selected at random from the ophthalmology department clinic at each facility. This questionnaire includes 6 subsections (Communication with Nurses, Communication with Doctors, Responsiveness of Hospital Staff, Pain Management, Communication About Medicines, and Discharge Information), each containing two to three questions, and 4 individual items (Cleanliness of Hospital Environment, Quietness of Hospital Environment, Overall Hospital Rating, and Willingness to Recommend the Hospital). Patients could select a high, intermediate or low rating in response to each question.[18]

Statistical Methods

The CSR (measured in cases per million population per year) for each hospital was calculated by dividing each hospital's annual total cataract surgical volume from surgical records (see

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Participant Hospitals above) by the catchment area population. The local area CSR was calculated by dividing total annual cataract surgical volume for the catchment area, as obtained from the local health bureau, by the area population. The proportion of local cataract surgical output coming from competitor organizations (any other hospital in the catchment area capable of providing cataract surgical service) was calculated by subtracting the hospital CSR from the total local CSR and dividing by the total local CSR. The principal study outcome was the 2-year percentage change in CSR for each hospital.

Baseline hospital, patient, and surgeon characteristics were described as mean (SD) for continuous variables with normal distribution, as median (interquartile range [IQR]) for continuous variables with non-normal distribution, and frequency (percentage) for categorical variables. For video-based OSCAR Cataract Surgical Quality Score, the inter-rater agreement for each item was calculated using the unweighted κ statistic, with a score of >0.8 indicating excellent agreement.[20,21] The postoperative uncorrected visual acuity at hospital discharge[17] was categorized into three levels: good (≥6/18), medium (>6/60 and <6/18), and poor (≤6/60) according to World Health Organization (WHO) criteria.[22] The percentage of patients at each outcome level was calculated for each hospital, and the mean and median (IQR) were reported. Postoperative patient satisfaction on the HCAHPS questionnaire was reported as the mean proportion of high, intermediate, and low scores for each hospital for each subsection (or each item for the four individual items).

Simple linear regression models were used to investigate the effects of the above-described baseline hospital, surgeon, and patient characteristics/scores on baseline CSR and 2-year change in CSR for hospitals. The normality of the distributions of these two outcomes was assessed using histograms, Q-Q plots, and the Shapiro-Wilk test. Natural log transformation was done for hospitals' baseline CSR due to lack of normality. The linearity of the association between outcome and potential predictors was checked using Lowess plots. Natural log and square root transformations were made for the amount of INGDO support and years of experience of surgeons respectively to improve linearity. All variables with $P < 0.05$ in simple regression models of the primary and secondary outcome were included in multiple regression analysis.

Piecewise regression was used due to nonlinearity in the relationship between the outcomes and two potential predictor variables (the amount of support from INDGO and eye exam skill score) by dividing the variable into two pieces with different intercepts and slopes. All analyses were performed using Stata 12.0 software (StataCorp, College Station, TX, USA).

Results

A total of 42 hospitals from 6 provinces was included in the study. The median size of patient catchment area was 530,000 (IQR, 380,000–850,000), median CSR for areas surrounding the hospitals was 643 (IQR, 356–1005) cases per million per year, and facilities performed a median of 191 cataract surgeries and examined 9484 outpatients per year (Table 1). Over 90% (39/42 = 92.9%) of facilities performed some outreach screening, with 6 facilities screening more than 5000 patients annually. Over 90% of facilities (38/42 = 90.5%) offered some free surgery, with a median of 30% (IQR, 0%–83%) of free cases. Three-quarters (33/42 = 78.6%) of facilities were receiving INGDO financial support, at a median level of USD 59,700 over the last three years. All facilities accepted rural health insurance, which reimbursed on average 67% of the cost of cataract surgery, the median prereimbursement fee (IQR) for which was USD 119 (USD 48–263). Table 1 also gives demographic and professional information on hospital leadership and per capita GDP in the catchment areas of the participating hospitals.

A total of 75 (100%) surgeons capable of performing independent cataract surgery (mean age, 36.9 ± 6.8 years; 72% male) provided demographic and clinical information (Table 2). These doctors had been performing independent surgery for a median of 5 years, carrying out 100 (IQR, 30–200) cases per year. Virtually all of them (74/75 = 98.7%) could perform small incision cataract surgery, while 14.7% (11/75) could perform phacoemulsification. Over 90% (68/75 = 90.9%) reported using A-scan and keratometry to calculate the power of intraocular lenses. Quality of surgery appeared to be generally good: the mean OSCAR score based on a submitted videotape was 80.3 ± 7.93 (of 95 points), and uncorrected visual acuity on postoperative day 1 was ≥6/18 in 76.3% of subjects (10 consecutive patients for each hospital, 420 in total, 57.1% small incision, 2.86% phacoemulsification, 38.8% extracapsular, 1.19% missing data). The unweighted κ score for the two video graders using the OSCAR system was excellent at 0.89.

Satisfaction on the HCAHPS questionnaire among 10 previously-operated cataract surgical patients selected at random in the outpatient clinic at each facility was generally high: 75.0% gave a high score on Overall Hospital Ranking and 69.4% gave the same for Recommend the Hospital. The proportions of low scores in these two areas were 3.39% and 2.99%, respectively (Table 3).

The Figure shows the 2-year percentage change in CSR at the 42 participating hospitals in rank order. The median (IQR) change was 33.3% (–6.25, 72.3%), and the range was –68.5% to 225.5%.

In simple regression models, predictors of higher baseline CSR at the 42 hospitals included higher per capita GDP ($P = 0.01$), more financial support from INGDOs ($P = 0.04$), and high scores for Recommending the Hospital ($P = 0.02$) and Average Patient Satisfaction ($P = 0.01$). Having a higher proportion of local CSR performed by competitor institutions was associated with lower baseline hospital CSR ($P = 0.001$, Table 4). In multiple models, per capita GDP ($P = 0.007$), competitor share of CSR ($P = 0.001$), and high patient satisfaction ($P = 0.01$) remained significant.

Using similar models, predictors of greater 2-year percentage improvement in the CSR in the simple regression included carrying out more outreach screening (75% greater increase in CSR among hospitals screening >5000 persons annually, $P = 0.006$) and INGDO support (85% greater increase in CSR per USD 1000 in INGDO investment, $P = 0.02$), while receiving the lowest Average Patient Satisfaction scores was associated with greater percentage decline in CSR (5.5% decline per 1% increase in patients giving the lowest score, $P = 0.03$). In multiple models, only performing a larger volume of patient outreach screening was associated with greater percentage improvement in CSR ($P = 0.002$, Table 5). Neither postoperative visual acuity nor cost of surgery was significantly associated with baseline CSR or change in CSR.

Discussion

Annual surgical output generally increased at these facilities, at a median rate of 33% over 2 years. Our findings indicated that all factors predicting our main outcome, 2-year percentage change in CSR, were under the direct control of hospitals and the organizations supporting them. These included INGDO investment, cataract screening outreach, and patient satisfaction. As the sole significant factor in multiple regression

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Table 1. Baseline Hospital Characteristics: Demography, Clinical Output, Administration, Support, Surgical Cost, Surgical Support

Item	Result
Clinical characteristics	
No. hospitals	42
Per Capita GDP at baseline, USD, *n* (%)	
≤2000	16 (38.1)
2000–3000	11 (26.2)
>3000	15 (35.7)
Province, *n* (%)	
Guangdong	25 (59.5)
Jiangxi	6 (14.3)
Sichuan	3 (7.14)
Yunnan	2 (4.76)
Gansu	3 (7.14)
Inner Mongolia	3 (7.14)
Catchment area population, million, median (IQR)	0.53 (0.38–0.85)
Cataract surgical rate for area, million/y, median (IQR)	643 (356–1005)
No. institutions in catchment area capable of independent cataract surgery, median (IQR), (range)	1 (1–3), (1–10)
Baseline independent annual cataract operations, median (IQR)	191 (122–300)
Baseline annual cataract operations, outside surgeon, median (IQR)	0 (0–50)
Surgeons per hospital capable of performing independent cataract surgery, *n* (%)	
1	23 (54.8)
>1 (2–5)	19 (45.2)
Annual outpatient clinical visits, eye department, median (IQR)	9484 (5800–16141)
Hospital performs outreach cataract screening, *n* (%)	
Yes	39 (92.9)
No	3 (7.14)
Annual patients seen in outreach screening, *n* (%)	
≤5000	33 (84.6)
>5000	6 (15.4)
Missing	3 (7.14)
Hospital administration characteristics	
Hospital director in charge of eye department	
Age, y, mean (SD)	47.7 (5.14)
Male sex, *n* (%)	37 (88.1)
Clinical specialty, *n* (%)	
Internist	11 (26.2)
Surgeon	19 (45.2)
Ophthalmologist	3 (7.14)
Other	9 (21.4)
Time at current hospital, y, *n* (%)	
≤4	10 (23.8)
5–14	11 (26.2)
≥15	21 (50.0)
Total time as hospital director, y, median (IQR)	7 (2.5–12)
Native of province, *n* (%)	37 (88.1)
Native of county, *n* (%)	32 (76.2)
Score for administration support for eye department, mean (SD), (range)	18.1 (4.57), (8–25)
International nongovernmental development organization, INDGO, support	
INDGO program, *n* (%)	
Yes	33 (78.6)
No	9 (21.4)
Total support amount, thousand USD, during past 3 y, median (IQR)	58.7 (3.97–58.7)
Surgery cost	
Free cataract surgery offered, *n* (%)	
Yes	38 (90.5)
No	4 (9.52)
% of surgeries offered for free, median (IQR)	30 (0–83)
Baseline surgical cost, USD, median (IQR)	119 (48–263)
Accept rural health insurance, *n* (%)	
Yes	42 (100)
No	0 (0.0)
% Reimbursement rate, median (IQR)	67.0 (49.5–67.0)

Table 2. Baseline Surgeon Characteristics and Surgical Quality

Item	Result
Surgeon characteristics	
No. surgeons capable of performing independent cataract surgery	75
Age, y, mean (SD)	36.9 (6.88)
Male sex, *n* (%)	54 (72.0)
Has medical license, *n* (%)	
Yes	73 (98.7)
No	1 (1.35)
Missing	1 (1.33)
Total annual independent cataract surgeries, median (IQR)	100 (30–200)
Years performing independent surgery, median (IQR)	5 (2–10)
Self-rated eye exam skill score, mean (SD), (range)	7.30 (3.23), (0–12)
Cataract surgical method used (>1 answer possible), *n* (%)	
ECCE	20 (26.7)
SICS	74 (98.7)
Phaco	11 (14.7)
Surgery quality measures	
Measurements used in computing IOL power, *n* (%)	
A-scan only	7 (9.33)
Keratometry only	0 (0.00)
A-scan + keratometry	68 (90.7)
Average power IOL	0 (0.0)
OSCAR Cataract Surgical Quality Score from video, mean (SD)	80.3 (7.93)
Postoperative uncorrected visual acuity (10 cases)	
Good (% ≥ 6/18), mean, median (IQR)	76.3, 80 (60–100)
Intermediate (% > 6/60 and < 6/18), mean, median (IQR)	18.3, 10 (0–30)
Poor (% ≤ 6/60), mean, median (IQR)	5.23, 0 (0–10)

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Table 3. Postoperative Patient Satisfaction Using HCAHPS Questionnaire (10 Randomly-Selected, Previously-Operated Cataract Patients Identified in the Ophthalmology Clinic)

Item	High Score %	Intermediate Score %	Low Score %
Communication with nurses	78.5	20.7	0.74
Communication with doctors	86.7	12.6	0.73
Responsiveness of hospital staff	85.6	13.2	1.18
Pain management	74.8	18.8	6.49
Communication about medicines	44.7	12.1	43.2
Cleanliness of hospital environment	77.0	21.5	1.46
Quietness of hospital environment	79.5	19.3	1.22
Discharge information	78.9	0	21.1
Overall hospital ranking	75.0	21.6	3.39
Recommend the hospital	69.4	27.6	2.99
Average (overall satisfaction)	75.0	18.6	8.24

models, outpatient screening was particularly important in increasing surgical output. This was in contradistinction to baseline CSR, where factors beyond the control of hospitals, such as local GDP and the surgical activity of competitors, also were of importance. Our results highlight the value of increasing demand for surgical services, and not just the capacity to supply them, in this setting.

Our review of PubMed and SinoMed databases in March 2014 identified few studies in the published literature investigating factors that might influence cataract surgical output of rural hospitals, particularly in prospective fashion. Courtright et al.[15] found higher ratios of nurses to doctors and surgical kits to surgeons predictive of higher surgical volume in a cross-sectional study of hospitals in east Africa. (Though we attempted to measure these variables, data obtained from different sources were contradictory and ultimately were not used.) Our review disclosed no other prospective, multicenter studies reporting on predictors of cataract surgical output in developing areas.

Our principal result concerning the importance of outreach screening is consistent with previous reports from rural China that outreach screening can increase CSR in rural areas.[23] This appears at least in part to be due to the effect of screening on increasing access to service among women, those with lower educational levels, and the poor.[24] Though outreach screening for cataract has been implemented by many rural facilities in China (including 90% of the current sample), higher-volume screening appeared to be particularly important in our models (>5000 screenings per year, Table 5), which requires a substantial investment on the part of hospitals. Finding cost-effective and sustainable models for this remains a challenge.

Our finding of the importance of patient satisfaction in the acceptance of surgical service also is consistent with previous work from rural China.[25] Increasing patient satisfaction has been shown in other studies in the region to reduce complaints against medical institutions and to improve provider morale.[26] However, focus groups performed in conjunction with the current study revealed that hospital administrators and doctors did not identify patient satisfaction as important in increasing cataract surgical volume.[27] These results highlight the need for educational programs targeting these stakeholders and emphasizing the importance of patient satisfaction.

Our findings on the impact of INGDO investment on increasing CSR is consistent with previous findings on the importance of INGDO support for cataract surgery in rural China[28] and elsewhere.[29,30] As government investment in the eye care sector continues to grow rapidly in China,[31] it may be expected that the investment necessary to support high-volume outreach screening programs and high-quality patient service will increasingly come from the government. Advocacy is needed, based on results such as those of the current study, aimed at directing government investments to the areas most likely to yield increases in surgical output. While the current Chinese National Prevention of Blindness Plan identifies increasing CSR as a key goal, the importance of increasing cataract outreach screening is not mentioned.[32]

Our failure to observe an association between surgical quality and increases in output was surprising, as high quality surgery often has been seen as the key to driving increases in patient demand.[33] This may partly have been due to the generally high quality of surgery reflected in observed outcomes and the videos submitted for grading. The propor-

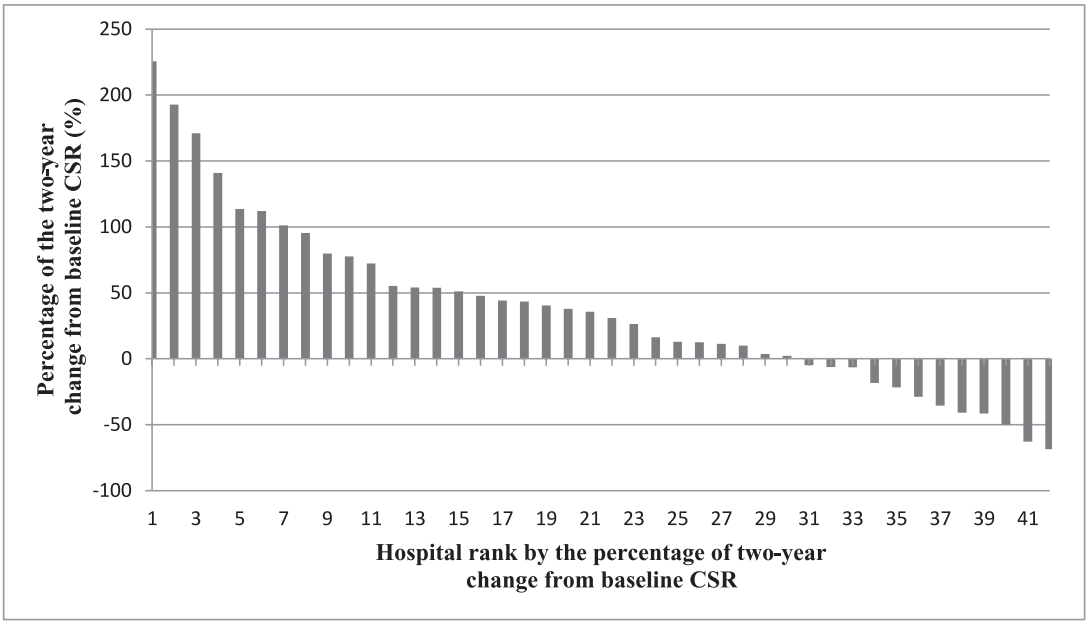

Figure. Percentage 2-year change from baseline CSR for participating hospitals, ranked by percentage change.

Table 4. Linear Model of Potential Predictors of Log Transformed Baseline CSR for Participating Hospitals

	Simple Regression		Multiple Regression*	
	β (95% CI)	*P* Value	β (95% CI)	*P* Value
Baseline per capita GDP				
≤2000	Reference		Reference	
2000–3000	−0.05 (−0.60, 0.49)	0.85	0.31 (−0.15, 0.78)	0.18
>3000	0.66 (0.16, 1.16)†	0.01†	0.60 (0.18, 1.03)†	0.007†
Proportion of local annual surgical volume carried out by competitor institutions	−0.01 (−0.02, −0.005)†	0.001†	−0.01 (−0.02, −0.005)†	0.001†
Annual number of baseline outreach screenees				
≤5000	Reference			
>5000	−0.28 (−0.97, 0.41)	0.41		
Annual baseline eye clinic volume (thousand persons)	−0.01 (−0.05, 0.03)	0.51		
Hospital director (y at hospital)				
≤4	Reference			
5–14	0.06 (−0.61, 0.73)	0.86		
≥15	−0.15 (−0.74, 0.45)	0.62		
Hospital director is local to county	0.28 (−0.27, 0.83)	0.31		
Administration support score	−0.008 (−0.06, 0.04)	0.76		
Amount of support from INDGO during past 3 y (thousand USD, Natural log transformed)	0.13 (0.006, 0.25)†	0.04†	0.05 (−0.05, 0.16)	0.31
Baseline surgery cost (thousand USD)	0.09 (−1.37, 1.55)	0.90		
Baseline proportion of free surgeries	−0.001 (−0.007, 0.005)	0.72		
Number of independent cataract surgeons at baseline				
1	Reference			
>1	0.27 (−0.20, 0.74)	0.25		
Mean age of surgeons	−0.01 (−0.05, 0.03)	0.59		
Mean y of experience of surgeons (square root transformed)	−0.15 (−0.36, 0.06)	0.15		
Eye exam skill score	0.01 (−0.07, 0.10)	0.73		
Mean OSCAR score	0.008 (−0.02, 0.04)	0.63		
Postoperative uncorrected visual acuity (10 cases) Proportion of bad postvision results				
0	Reference			
0–11	−0.31 (−0.95, 0.34)	0.35		
>11	0.18 (−0.51, 0.87)	0.60		
Postvision acuity (logMAR)	−0.09 (−1.81, 1.63)	0.91		
Overall hospital ranking: high score	0.008 (−0.006, 0.02)	0.26		
Overall hospital ranking: low score				
0	Reference			
>0	−0.20 (−0.74, 0.33)	0.45		
Recommending the hospital: high score	0.01 (0.002, 0.02)†	0.02†		
Recommending the hospital: low score				
0	Reference			
>0	−0.40 (−0.98, 0.18)	0.17		
Average patient hospital satisfaction score: high score	0.03 (0.008, 0.06)†	0.01†	0.03 (0.006, 0.05)†	0.01†
Average patient hospital satisfaction score: low score	−0.02 (−0.08, 0.04)	0.43		

CI, confidence interval.

* All variables in the simple regression with $P < 0.05$ were included in multiple regression except strongly recommending the hospital due to high correlation (0.66) with average patient hospital satisfaction high score.

† Factors significant at the $P < 0.05$ level.

tion of patients with uncorrected vision >6/18 in the immediate postoperative period (76%) was substantially higher than previously reported using a similar technique among 19 rural county-level facilities in China (47%).[17] This raises some concerns over the reliability of the surgical outcome data provided, which was what prompted us initially to carry out video grading of cases as well. Though the small number of video cases available and uncertainty over their representative nature is a potential limitation, it also may be that patient acceptance of cataract surgical services is less sensitive to surgical outcome quality than previously believed, particularly when surgery widely achieves a certain quality level. There are few actual data to support the hypothesis that better surgical quality is associated prospectively with higher rates of patient uptake; Courtright et al.[15] did not examine outcome as a potential determinant of output.

Another surprising finding was the failure to observe an association between cost of surgery and growth in surgical output, in view of a recent randomized trial in rural China showing a significant increase in surgical uptake associated

Table 5. Linear Model of Potential Predictors of the Percentage of the Two-Year Change From Participating Hospitals' Baseline CSR

	Simple Regression		Multiple Regression*	
	β (95% CI)	*P* Value	*β* (95% CI)	*P* Value
Baseline Per Capita GDP				
≤2000	Reference			
2000–3000	−42.7 (−94.0, 8.55)	0.10		
>3000	−43.3 (−90.3, 3.78)	0.07		
Proportion of local annual surgical volume carried out by competitor institutions	0.02 (−0.67, 0.71)	0.95		
Annual number of baseline outreach screenees				
≤5000	Reference		Reference	
>5000	74.8 (22.7, 126.9)†	0.006†	86.4 (34.0, 138.8)†	0.002†
Annual baseline eye clinic volume (thousand persons)	2.81 (−0.44, 6.05)	0.09		
Hospital director (y at hospital)				
≤4	Reference			
5–14	−11.2 (−71.3, 48.9)	0.71		
≥15	−13.6 (−66.5, 39.2)	0.61		
Hospital director is local to county	−43.8 (−91.1, 3.57)	0.07		
Administration support score	4.08 (−0.38, 8.55)	0.07		
Amount of support from INDGO during past 3 years, Natural log transformed, per thousand USD, piecewise regression				
≤USD 4000	−11.1 (−32.9, 10.6)	0.31	−7.32 (−26.0, 11.4)	0.43
>USD 4000	84.5 (11.5, 157.5)†	0.02†	46.8 (−18.5, 112.1)	0.15
Baseline surgery cost, thousand USD	12.1 (−117.6, 141.8)	0.85		
Baseline proportion of free surgeries	0.06 (−0.46, 0.58)	0.82		
Number of independent cataract surgeons at baseline				
1	Reference			
>1	18.0 (−23.8, 59.8)	0.39		
Mean age of surgeons	1.59 (−2.01, 5.18)	0.38		
Mean y of experience of surgeons, square root transformed	0.78 (−2.77, 4.32)	0.66		
Eye exam skill score, piecewise regression				
≤6	17.3 (−0.81, 35.5)	0.06		
>6	−6.59 (−22.6, 9.40)	0.40		
Mean OSCAR score	1.09 (−1.47, 3.64)	0.40		
Postoperative uncorrected visual acuity, 10 cases				
Proportion of bad postvision results				
0	Reference			
0–11	−6.77 (−62.4, 48.8)	0.81		
>11	−24.5 (−83.6, 34.7)	0.41		
Postvision acuity, logMAR	66.0 (78.5, 210.6)	0.36		
Overall hospital ranking: high score	−0.12 (−1.45, 1.21)	0.86		
Overall hospital ranking: low score				
0	Reference			
>0	−19.7 (−66.2, 26.8)	0.40		
Recommend the Hospital: high score‡	−0.85 (−1.84, 0.14)	0.09		
Recommend the Hospital: low score‡				
0	Reference			
>0	−1.13 (−52.7, 50.4)	0.97		
Average patient hospital satisfaction score: high score‡	−2.14 (−4.43, 0.16)	0.07		
Average patient hospital satisfaction score: low score‡	−5.54 (−10.4, −0.71)†	0.03†	−1.34 (−5.96, 3.28)	0.56

* All variables in the simple regression with $P < 0.05$ were included in the multiple regression.

† Items significant at the $P < 0.05$ level.

‡The β value for these variables indicates the difference in 2-year percent change for a 1% increase in patients giving the highest or lowest score on these sections of the satisfaction survey.

with free surgery.[34] Our negative finding is consistent though with a previous population-based study,[25] and the effect of offering free surgery appears to be limited: refusal rates in the above-cited trial[34] remained >70%. It may also be that the cost of cataract surgery is sufficiently heavily subsidized by the government rural health insurance scheme (the New Rural Cooperative Medical System, NCMS) to reduce the impact of surgical cost on uptake. All of the hospitals in the current

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survey participated in NCMS, as is typical of rural government facilities in China, and the median reimbursement rate was 67%, leaving a median out-of-pocket expense of USD 39. This is considerably less than the mean amount rural dwellers were willing to pay for surgery, USD 55, at a time several years ago when income levels in rural China were substantially lower than they are now.[35]

Strengths of the current study include its prospective design and enrollment of a number of hospitals from many regions in China. The data collected covered most of the major factors that have been posited as important in driving demand for cataract surgical service, and validated instruments and protocols, and objective techniques, such as grading of surgical videos, were used wherever possible. All of these tend to increase confidence in the validity of these findings. Weaknesses also must be acknowledged. A majority of the participating hospitals had recent or current collaborations with INGDOs, and over half of hospitals were from a relatively high-income province, Guangdong. These hospitals were not identified using a randomized sampling strategy, and, thus, care must be taken in applying these results to the over 2000 county hospitals currently existing in China. Importantly, there is evidence that participating hospitals are not atypical with regard to their increase in output, our main outcome of interest: the median 2-year increase in CSR of 33% which we observed is similar to the increase reported in CSR for the entire country, from 676 in 2008[36] to 900 in 2010[32] (33%).

Uncertainty about the reliability of surgical outcome data provided by hospitals has been highlighted above. Using surgeon's self-rating to evaluate specialized skills may have suffered from similar problems. Finally, though we collected patient-level factors, such as per capita GDP and satisfaction with hospital care, it was not practical for us to record exhaustive information on those patients actually presenting to these eye departments for care. Such information might have improved our models, though as such patient factors generally were not under the control of facilities, these data would not generally have led to strategies for facilities to improve volume, which was our principal study aim. Many of the above limitations are inherent in the need to accomplish this survey within a relatively modest budget.

Despite those limitations, our study is the first prospective, multicenter survey of which we are aware in China or elsewhere to evaluate factors potentially contributing to increasing rural cataract surgical capacity over time. Our conclusions provided a potential guide for government investment to produce increases in surgery, focused on the areas of high-volume outreach screening and improved patient service.

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