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Place of service and the volume-outcome relationship: evidence from eye surgeries

Anthony Yu

Surgeries have increasingly moved into the outpatient setting, yet training in the non-hospital setting is rare. Using Medicare claims from 1999 through 2013 on 4,117,141 cataract surgeries, 153,148 retina surgeries, and 91,276 glaucoma surgeries, this research studied whether the relationship between surgeon volume and adverse patient outcomes differed by facility type for eye surgeries. Regression analyses demonstrated a strong association between surgeon volume and patient outcomes for all three types of surgeries. Moving from the lowest to a higher surgeon-volume quintile corresponded with a 9–27% decrease in the odds of complications. However, these volume-outcome relationships did not statistically differ based on whether a procedure was rendered in a hospital versus an ambulatory surgery center or rendered in a high-volume versus a low-volume facility, underscoring the importance of case turnover for quality.

Volume-outcome relationships have been documented for a variety of surgical procedures, and these relationships have influenced health policy[1–3]. Depending on this relationship, policies regulating the number of physicians or imposing minimum thresholds for the number of surgeries per physician could affect patient quality. However, few studies explore the volume-outcome relationship for different types of facilities, such as hospitals and ambulatory surgery centers (ASCs). A qualitative study concluded that ASCs offered residents more procedural practice due to faster case turnover, allowing the doctor to move more quickly down the learning curve[4]. While case turnover is likely to be higher at ASCs, cases at ASCs may not impart the same learning experience as they might at a hospital. Therefore, understanding whether the volume-outcome relationship differs by setting is critical for policy.

In ophthalmology, most studies focused on the volume-outcome relationship for cataract surgeries due to higher volume, with limited attention to other surgeries and sites of service[5–7]. To address this gap in the literature, I used administrative claims from Medicare between 1998 and 2013 to study the volume-outcome relationship by place of service for eye surgeries. I make several contributions. First, I studied this relationship using a comprehensive dataset leveraging over four million procedures in the United States. Other studies involved fewer procedures over a shorter period and a narrower geography. The large number of records allowed me to study several types of eye surgeries, besides cataract surgeries. I document strong associations between surgeon volume and adverse outcomes for cataract surgery, retinal surgery (e.g., vitrectomy), and traditional glaucoma surgery (e.g., trabeculectomy). However, I did not find conclusive evidence of differences in the volume-outcome relationship across facility type, such as an ASC versus hospital outpatient department, or a high volume versus low volume facility. All else equal, the volume-outcome gradient was not steeper in ASCs compared to hospitals, and if the surgeon had more experienced colleagues in the same facility.

Methods

Data

I used a 20 percent random sample of Traditional Medicare claims data from 1998 through 2013. Traditional Medicare is a public health insurance program in the United States provided to older adults (aged 65 and over) and the disabled. Unlike aggregated data, Medicare claims data allow researchers to track patients across multiple providers and facilities. The Carrier file, which is a 20% random sample of claims submitted by practitioners, was used to identify surgery dates, service settings (ASC vs. hospital), whether a physician-in-training was present, patient medical history, and post-operative adverse events[8]. To obtain surgeon demographics, I used the Medicare Data on Provider Practice and Specialty (MD-PPAS) from 2008 through 2013[9]. For patient demographics and Medicare Advantage (MA) enrollment trends, I incorporated data from the beneficiary summary file, CMS enrollment reports, and Decennial Census[10–12]. Finally, to identify hospital stays and related variables, I relied on MEDPAR and outpatient hospital claim files.

Economics, Sociology, and Statistics Department, RAND Corporation, Arlington 22202, USA. email: ayu@rand.org

I focused on three types of surgery: cataract surgery, retinal detachment surgery, and traditional glaucoma surgery. During this time period, these were the most common eye surgeries also rendered at ASCs. Cataract surgeries included both extracapsular and intracapsular cataract extractions, though in the data, well over 99 percent were extracapsular. Following the National Eye Institute, I defined retinal detachment surgeries to include vitrectomy, scleral buckle, and pneumatic retinopexy[13]. Finally, I examined "traditional" glaucoma surgeries, including *ab externo* trabeculectomy[14]. *Ab interno* trabeculectomy or minimally invasive glaucoma surgery (MIGS) has grown in popularity but was not performed regularly until the late 2010s. Future research could study the volume-outcome relationship for these procedures. Supplemental Table S1 describes the exact CPT procedure codes used to identify surgeries and the number of procedures in the analysis sample.

Surgeon volume was constructed as the number of surgeries of that type completed by the rendering physician in the last 365 days according to the Medicare claims. Physicians were identified by National Provider Identifiers (NPI). NPIs were implemented in 2007 to replace the Unique Physician Identification Numbers (UPIN). For data prior to 2007, I mapped UPINs to NPIs using a crosswalk provided by the National Bureau of Economic Research, with over a 95 percent match. Since the data is a 20 percent random sample, the volume was multiplied by five.

The main outcome was a binary indicator of a post-operative adverse outcome in the 30 days following surgery, which I defined separately for each kind of surgery. I constructed this composite outcome by identifying adverse events using ICD-9 diagnosis codes used in prior studies[15–18]. There were a few adverse events that could be from all three surgeries: endophthalmitis, vitreous hemorrhage, and retinal edemas. Adverse events specific to cataract surgery included cataract fragments and posterior capsule opacification. Since some diagnoses are age-related, I required that the patient's claims in the prior year did not have that diagnosis code. Supplemental Table S2 describes the ICD-9 diagnosis codes used to flag adverse events of each surgery type.

Sample selection

My analysis sample included data from January 1, 1999, through September 30, 2013, for beneficiaries aged 66 and over. These restrictions ensured that I observed at least one year of medical history for each patient and also ensured that I observed a full year of claims for each surgeon to construct volume. Second, I focused on ASC and hospital settings. Over 85 percent of these procedures were conducted in these two settings. Finally, I included only procedures where I could identify the specific facility based on the Medicare provider number (hospitals) or tax identification number (ASCs). This final step deleted another eight percent of the sample and left 4.4 million surgeries in this study. Supplemental Figure S1 illustrates how varied sources were linked to construct the analysis datasets.

By surgery type, I ranked rendered services based on the volume of the patient's surgeon in the last 365 days prior to surgery and created five equally sized surgeon-volume quintiles (i.e., procedure-weighted surgeon-volume quintiles or surgeon-volume quintiles). The surgeon-volume quintiles were 0–105, 106–200, 201–315, 316–520, and 521–1360 surgeries for cataracts. For retinal detachment surgeries, surgeon-volume quintiles were 0–25, 26–45, 46–65, 66–100, and 101–275 surgeries in the last year. Finally, surgeon-volume quintiles were 0–5, 6–20, 21–40, 41–70, and 71–180 surgeries for traditional glaucoma surgeries.

Statistical analysis

I calculated the raw volume-outcome relationship by calculating odds ratio of an adverse outcome within 30 days of the procedure for each surgeon-volume quintile relative to the first quintile. Then, to adjust for potential confounders, I estimated logistic regressions of an adverse outcome on indicators for surgeon-volume quintile. These regressions included indicators being rendered in an ASC, indicators for in a high-volume facility (i.e., above-median facility volume ranked by episode), observable patient characteristics (race, gender, age, Medicaid, and Elixhauser comorbidity score), Census division fixed effects, calendar year fixed effects, state Medicare Advantage (MA) penetration rates, physician age, physician age-squared, physician gender, whether a resident was present, and indicators for same-day non-focal procedures[19]. Census division fixed effects adjusted for regional differences in complication rates. Year fixed effects adjusted for differences over time. MA are Medicare plans run by private insurance companies and older adults have the option to choose these plans over Traditional Medicare. Therefore, MA penetration rates controlled for the growth of private plans, which may be negatively correlated with Traditional Medicare volume. Standard errors were clustered by physician NPI. To study heterogeneity by facility, I estimated separate coefficients by place of service. All regression-adjusted volume-outcome relationships are expressed as odds ratios with 95 percent confidence intervals. All analyses were conducted using Stata, version 17.0.

This study was reviewed and approved by Institutional Review Board (IRB) of the National Bureau of Economic Research (Approval Number: 19_475). The study was determined to fall under Exemption #4 as detailed at 45 CFR 46.104(d)(4) publicly available identifiable private information, the identity of the subjects cannot be readily ascertained, and the investigator will neither contact the subjects nor re-identify subjects, use of identifiable health information when that use is regulated by HIPAA, or Analysis of data on behalf of a federal agency. All methods were performed under the relevant guidelines and regulations.

Results

This study examined over 4.3 million procedures between 1999Q1 and 2013Q3, of which 4,117,141 were cataract surgeries, 153,148 were surgeries for retinal detachment, and 91,276 were surgeries to correct glaucoma (Table 1). The average patient age ranged between 76 and 78. Patients were overwhelmingly white and mostly female. 12–15 percent were dually eligible for Medicaid and Medicare. During this time, most cataract procedures were performed in ASCs. For surgeries to correct retinal detachment or glaucoma, hospitals rendered 72 and 54 percent of procedures, respectively.

Variable	Cataract	Retina	Glaucoma
(a) Patient and facility characteristics			
Nonwhite	10%	13%	25%
Female	62%	52%	61%
Elixhauser score	3.08	3.64	3.15
Medicaid	12%	13%	15%
ASC	54%	28%	46%
Hospital (inpatient or outpatient)	46%	72%	54%
Age	76.71	75.54	78.04
	(6.31)	(6.63)	(6.68)
Facility Medicare FFS volume in last year	811	151	68
	(613)	(125)	(74)
ASC	997	163	67
	(626)	(135)	(70)
Hospital (inpatient or outpatient)	593	146	69
	(519)	(120)	(77)
(b) Surgeon characteristics			
Resident or fellow present	1%	1%	3%
Surgeon Medicare FFS volume in last year	335	65	40
	(280)	(48)	(38)
ASC	379	80	43
	(299)	(55)	(40)
Hospital (inpatient or outpatient)	285	59	38
	(247)	(43)	(36)
Surgeon age	51	48	49
	(9)	(8)	(8)
(c) Selected 30-day post-operative adverse events			
Endophthalmitis	0.12%	0.24%	0.16%
Retinal detachment	0.09%	0.79%	0.25%
Vitreous hemorrhage	0.06%	0.36%	0.12%
Retinal edema	0.74%	1.22%	0.57%
30-day composite	2.09%	5.28%	5.05%
30-day composite with hospitalization	0.03%	0.14%	0.13%
Total episodes	4,117,141	153,148	91,276
Total distinct patients	2,424,961	74,621	40,303

Table 1. Summary Statistics. This table reports means of patient, episode, surgeon, and complication variables. The sample includes episodes between 1999Q1 and 2013Q3 from the 20% Carrier file. Standard deviations are reported in parentheses for non-binary variables.

On average, cataract surgery patients used surgeons who completed 335 cataract surgeries in the last 365 days. Average surgeon volume was higher at ASCs compared to hospitals (379 vs. 285). The average surgeon volume for retinal detachment and glaucoma surgeries was smaller, at 65 and 40, respectively. Like cataract surgeries, average surgeon volume was higher at ASCs than at hospitals. The presence of a resident or fellow ranged between 1 to 3 percent, and the average surgeon age was approximately fifty.

Average facility volume was larger than surgeon volume. The average Medicare volume for a cataract surgery facility in the last year was 811. That is, on average, patients visited a facility where a total of 811 cataract surgeries was rendered in the last year. The average facility volume was higher at ASCs than hospitals (997 vs. 593). The average facility volume for retinal detachment and glaucoma surgeries was smaller, at 151 and 68, respectively; average facility volume was similar at ASCs compared to hospitals.

On average, 2.1 percent of cataracts, 5.3 percent of retina, and 5.1 percent of glaucoma surgeries resulted in some adverse outcome in the 30 days after the procedure. This statistic is a composite measure composed of indicators of several diagnoses, such as endophthalmitis, retinal edema, and tears (see Supplemental Table S2 for the full list of diagnosis codes used to identify each surgery type). The average rate of adverse events with hospitalization was substantially lower than those without, at 0.03 percent for cataracts and 0.1 percent for retina and glaucoma surgeries. The most common adverse outcome was retinal edema, with a likelihood ranging from 0.6 to 1.2 percent. See Supplemental Table S3 for 30-day complication rates by facility type, which was similar across facility types.

Association between volume and outcomes

Figure 1 summarizes the raw and regression-adjusted volume-outcome relationship for cataract surgeries, retinal detachment surgeries, and glaucoma surgeries. Focusing on cataract surgeries, moving from a surgeon in the first quintile of volume to the third quintile of volume would reduce exposure to adverse outcomes by 20 percent, with an odds ratio of 0.80 (95% CI 0.77–0.84). For surgeries to correct retinal detachment, the odds ratio of the third surgeon-volume quintile was 0.82 (95% CI 0.75–0.90). The third surgeon-volume quintile odds ratio was 0.84 (95% CI 0.75–0.94) for traditional glaucoma surgeries. For all three types of surgeries, the odds ratios for the third, fourth, and fifth surgeon-volume quintiles were not statistically significantly different from each other. Volume-outcome associations were less precise for complications that also result in hospitalization but were still visibly present for cataract and retina surgeries see Supplemental Figure S2).

Volume-outcome relationship by hospital versus ASC

Figure 2 presents odds ratios for volume quintiles by place of service (ASC vs. hospital). For surgeons who performed between 201 and 315 cataract surgeries on Medicare patients per year, relative to those who performed between 0 and 105 procedures, the odds ratio for an adverse outcome at an ASC was 0.85 (95% CI 0.80–0.92), and at a hospital was 0.76 (95% CI 0.71–0.80). For surgeries for retinal detachment, compared to surgeons who performed 0–25 procedures per year, surgeons who performed between 46 and 65 had odds ratios of 0.78 (95% CI 0.63–0.96) and 0.83 (95% CI 0.75–0.92) in ASC and hospital settings, respectively. Finally, for glaucoma surgeries, relative to surgeons who performed between 0 and 5 per year, surgeons who performed between 21 and 40 procedures had odds ratios of 0.83 (95% CI 0.71–0.97) and 0.85 (95% CI 0.73–0.99) at hospitals and ASCs, respectively. The differences between odds ratios were not statistically significantly different from each other by facility type. I found similar patterns for adverse events with hospitalizations (Supplemental Figure S3).

Volume-outcome relationship by facility volume

Finally, to test if more experienced colleagues were associated with faster learning, I estimated the volume-outcome relationship by above (high) or below-median (low) procedure-weighted facility volume. Figure 3 shows that cataract surgeons who performed between 201 and 315 surgeries on Medicare patients per year, when compared to those who performed between 0 and 105 procedures per year, had an odds ratio for an adverse outcome of 0.81 (95% CI 0.76–0.87) at high-volume facilities and 0.80 (95% CI 0.76–0.84) at low-volume facilities. For surgeries for retinal detachment with surgeons who performed between 46 and 65 services in the last year, relative to those who perfomed 0–25, odds ratios were 0.77 (95% CI 0.69–0.86) and 0.90 (95% CI 0.77–1.05) for low and high-volume facilities, respectively. For glaucoma surgeries, surgeons who performed between 21 and 40 procedures in the last year relative to those who performed 0–5 in the last year had odds ratios of 0.86 (95% CI 0.76–0.98) and 0.78 (95% CI 0.64–0.96) for low and high-volume facilities. We could not reject a similar volume-outcome association in low vs. high volume facilities when requiring that adverse events had hospitalizations (Supplemental Figure S4).

Discussion

The volume-outcome relationship has been widely studied for cataract surgeries, but less is known about how the effect differs across other eye surgeries and facility settings. This paper fills this gap by using Medicare claims between 1998 and 2013, containing over 4.3 million procedures, to study the volume-outcome relationship for common types of eye surgery: surgeries for cataracts, retinal detachment, and glaucoma. For all three kinds of surgery, I found that rates of adverse events decreased with surgeon volume. Improvements in quality diminished once surgeons completed enough procedures to be in the third quintile of Medicare volume, corresponding to 201–315 cataract surgeries, 46–65 retina surgeries, and 21–40 traditional glaucoma surgeries in the prior year. Compared to seeing a surgeon in the first quintile of surgeon volume, seeing a surgeon in the third quintile reduces exposure to adverse events by approximately 16–20 percent. These results were robust to changing the post-surgery window to detect adverse outcomes, but was noisier when also hospitalizations were required to qualify as adverse events. The noise is likely because very few eye surgeries resulted in an adverse outcome with a hospitalization. However, we could not reject a negative correlation.

Relative to the literature, the overall rate of complication in this study was mechanically higher because of the longer sampling window (30 vs. 14 days). However, the volume-outcome relationship estimated for cataract surgery is consistent with estimates from the literature. Bell et al. (2007) estimated odds ratios of 0.52 (95% CI 0.39–0.69) for mean annual cataract surgery volume on a 14-day complication rate[7]. Keay et al. also leveraged Medicare claims between 2003 and 2004 to estimate the volume-outcome relationship using post-operative endophthalmitis within 42 days as the outcome[20]. When comparing surgeons who do 51–200 procedures to those who do 201–500 procedures, their estimates imply an odds ratio of 0.79, similar to this study. There are studies that examined risk factors for endophthalmitis following glaucoma and retina surgeries using comparable data, but few study the volume-outcome relationship explicitly[21,22].

Although ASCs and hospitals had slightly different average complication rates, the association between volume and outcomes did not differ significantly across facility types. In particular, I could not reject that the marginal effect of increasing surgeon experience at a hospital was different from that in an ASC. The volume-outcome relationship also did not differ by whether the facility was high or low volume, indicating that having experienced colleagues was not a direct substitute for individual surgeon practice. Given an acceptable level of patient complication risk, these results suggest expanding or shifting some teaching to other types of facilities, such as ASCs or currently non-teaching hospitals, may not harm physician skill development.

However, there are several limitations to this study's findings. First, this paper narrowly focused on eye surgeries. Therefore, the findings of this study should be interpreted with caution to avoid over-generalization.

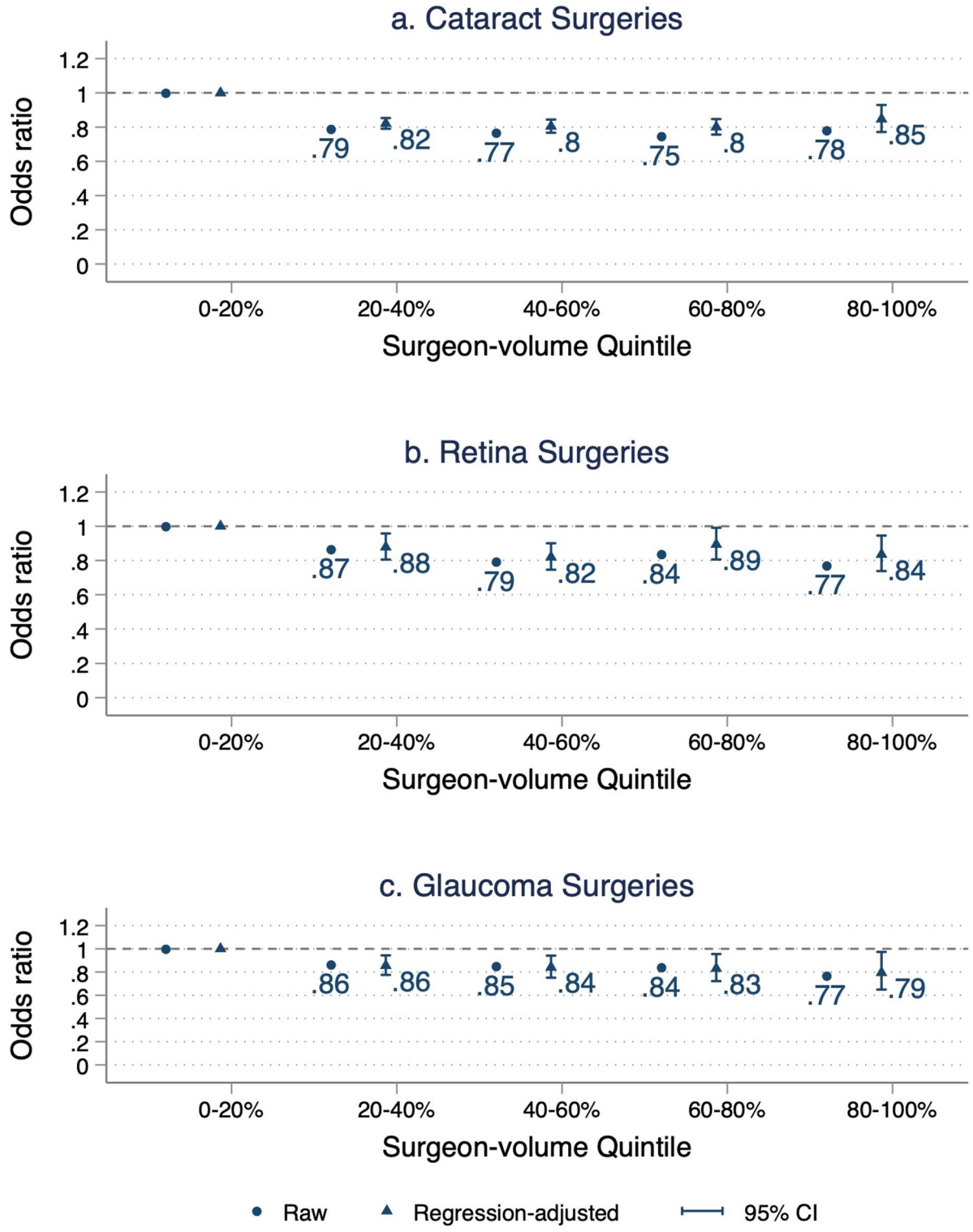

Fig. 1. Association of adverse events and surgeon volume. Each panel of the figure illustrates the volume-outcome relationship for a specific type of eye surgery, depicting the odds ratios of adverse outcomes across surgeon-volume quintiles. Panel a plots the relationship for cataract surgeries, panel b plots the relationship for retinal detachment surgeries, and panel c plots the relationship for traditional glaucoma surgeries. The outcome is a binary indicator for an adverse outcome within 30 days of the surgery. Regression-adjusted estimates also corresponding 95% confidence intervals. For cataract surgeries, volume quintiles were: 0–105, 106–200, 201–315, 316–520, and 521–1360 surgeries in the last year. For retinal detachment surgeries, volume quintiles were: 0–25, 26–45, 46–65, 66–100, and 101–275 surgeries. For traditional glaucoma surgeries, volume quintiles were: 0–5, 6–20, 21–40, 41–70, and 71–180 surgeries.

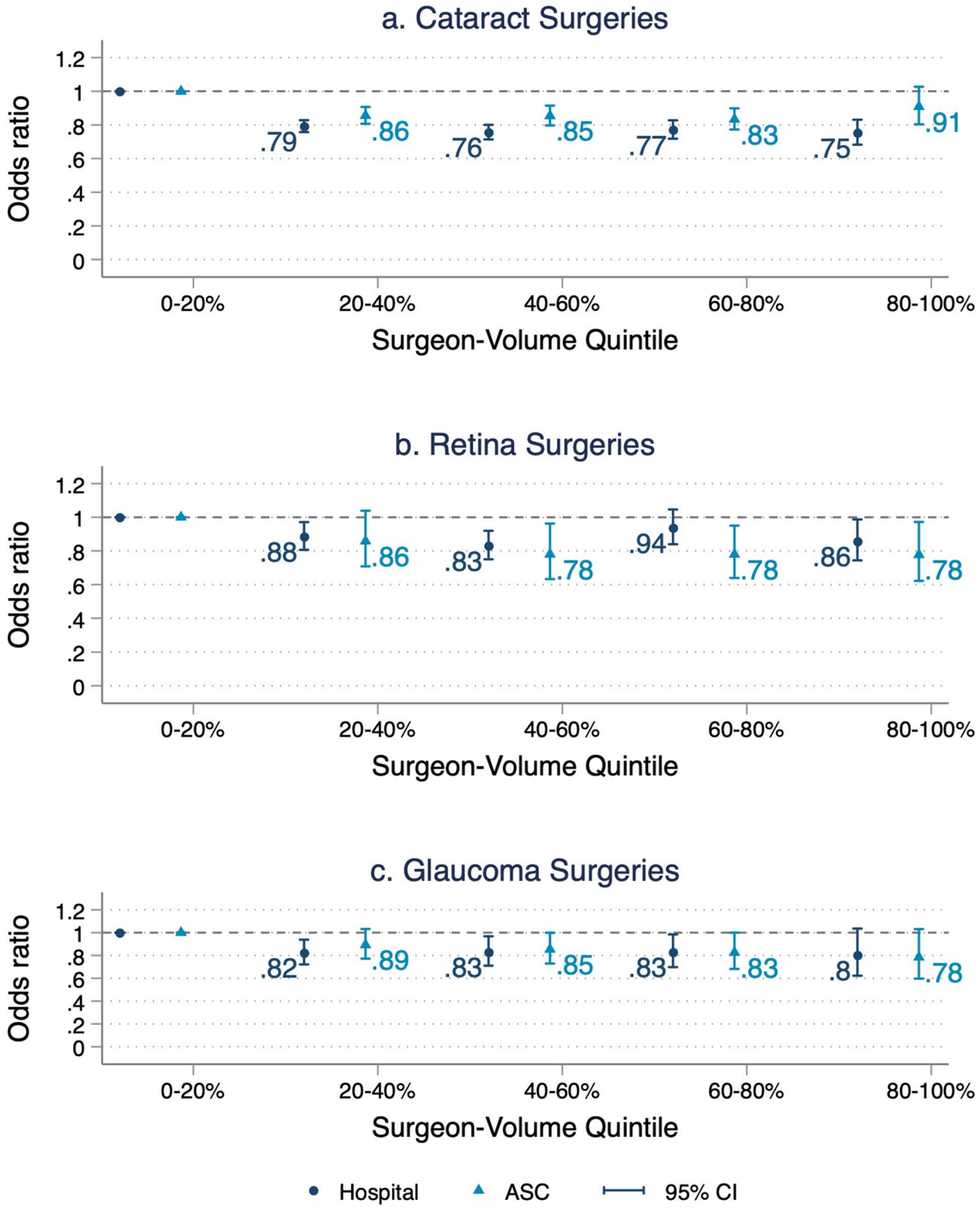

Fig. 2. Association of Adverse Events and Surgeon Volume by ASC or Hospital. Each panel of the figure illustrates the volume-outcome relationship for a specific type of eye surgery by place of service (hospital vs. ASC), depicting the regression-adjusted odds ratios and corresponding 95% confidence intervals of adverse outcomes across surgeon-volume quintiles. Panel a plots the relationship for cataract surgeries, panel b plots the relationship for retinal detachment surgeries, and panel c plots the relationship for traditional glaucoma surgeries. The outcome is a binary indicator for an adverse outcome within 30 days of a procedure. For cataract surgeries, volume quintiles were: 0–105, 106–200, 201–315, 316–520, and 521–1360 surgeries in the last year. For retinal detachment surgeries, volume quintiles were: 0–25, 26–45, 46–65, 66–100, and 101–275 surgeries. For traditional glaucoma, volume quintiles were: 0–5, 6–20, 21–40, 41–70, and 71–180 surgeries.

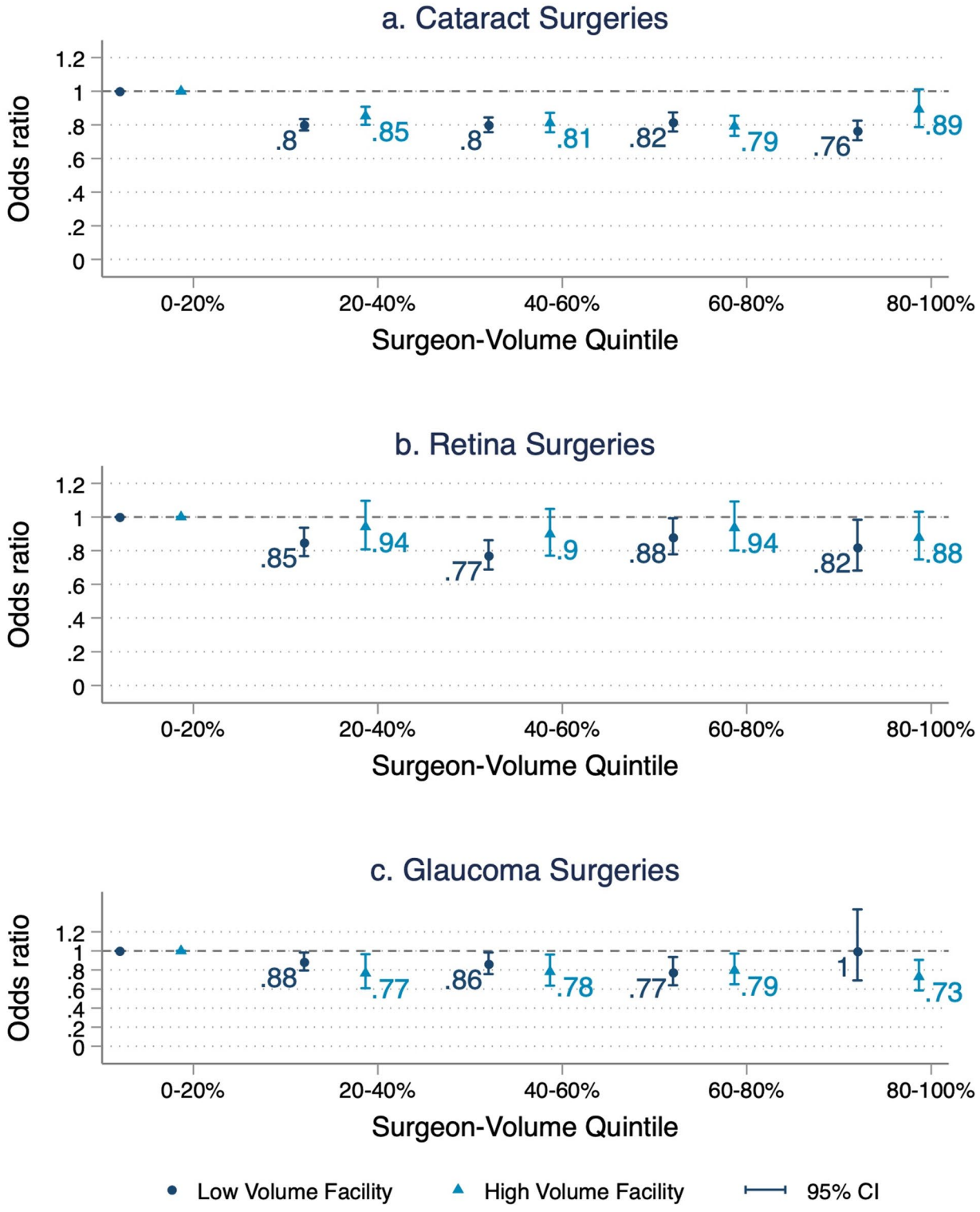

Fig. 3. Association of adverse events and surgeon volume by facility volume. Each panel of the figure illustrates the volume-outcome relationship for a specific type of eye surgery by above (high) or below (low) median facility volume (weighted by procedure), depicting the regression-adjusted odds ratios and corresponding 95% confidence intervals of adverse outcomes across surgeon-volume quintiles. Panel a plots the relationship for cataract surgeries, panel b plots the relationship for retinal detachment surgeries, and panel c plots the relationship for traditional glaucoma surgeries. The outcome is a binary indicator for an adverse outcome within 30 days of a procedure. For cataract surgeries, volume quintiles were: 0–105, 106–200, 201–315, 316–520, and 521–1360 surgeries in the last year. For retinal detachment surgeries, volume quintiles were: 0–25, 26–45, 46–65, 66–100, and 101–275 surgeries. For traditional glaucoma surgeries, volume quintiles were: 0–5, 6–20, 21–40, 41–70, and 71–180 surgeries.

Another limitation is that the outcome variable is derived from claims data, which means I could not definitively tie the procedure to the adverse event diagnosis. Nevertheless, using post-operative claims to measure adverse outcomes is comparable to other studies[7,15]. While there are eye registries in the U.S. that may be linked with Medicare claims to study effects on vision acuity, there is limited historical data[23]. Future studies could aim to incorporate these more detailed measures.

Traditional Medicare claims also do not capture the entire population for eye surgery, which also includes younger individuals and adults enrolled in MA. MA penetration has increased over time and innovations like yttrium aluminium garnet (YAG laser eye surgeries have mitigated patient risk for younger age groups, perhaps increasing their importance[24]. I adjusted for these confounders in my regression estimates by including state-level MA penetration rates, census region, and year fixed effects. If anything, increased eye surgeries from MA or younger patients would understate the volume-outcome gradient. Despite these secular trends, the raw volume-outcome relationship persisted over time within Traditional Medicare (Supplemental Figure S5).

This paper also only measured an association and not a causal relationship. Volume-outcome associations can reflect learning-by-doing or selective referral. While learning-by-doing is a causal relationship between volume and outcomes, selective referral implies that high-volume surgeons see healthier patients, which leads to lower adverse events. Selective referral by surgeons may also lead riskier patients to sort into hospitals rather than ASCs. This may lead to attenuated differences in the volume-outcome relationship between facility types. For example, greater case variety at hospitals may lead to faster learning (fewer complications) but would be confounded by unobservably higher-risk patients. To address some concerns with selective referral in the analysis, logistic regressions controlled for observable characteristics such as patient risk, site of service (ASC or hospital), physician characteristics, region, and year fixed effects. The volume-outcome relationship was robust to these control variables, suggesting learning-by-doing. The point estimates from regressions on cataracts and glaucoma surgeries were consistent with faster learning at hospitals rather than ASCs, but these were not statistically significantly different from each other. Future work could use more sophisticated approaches to estimate causal relationships and test these hypotheses more rigorously.

The United States faces a shortage of physicians, which is exacerbated by limited training opportunities[25]. This study found that physician practice remains a key input for quality, which cautions against increasing residency slots if volume is held constant. However, since facility type did not appear to affect the volume-outcome gradient, pairing increased training opportunities (and volume) with more teaching locations could mitigate concern about reduced quality. Future studies could examine policy interventions and trade-offs explicitly, expand the study data to focus on the growing role of MIGS and other innovations, and incorporate clinical measures of health such as vision acuity.

Data availability

The data that support the findings of this study are available from the Research Data Assistance Center (ResDAC) at the Centers for Medicare and Medicaid Services (CMS), but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from ResDAC (resdac@umn.edu) and instructions to obtain the data are available from the author (ayu@rand.org).

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Author contributions

A.Y. wrote and reviewed the manuscript and prepared all figures and tables.

Declarations

Competing interests

The authors declare no competing interests.

Ethics statement

This study involving human subjects was reviewed and approved by Institutional Review Board (IRB) of the National Bureau of Economic Research (Approval Number: 19_475). The study was determined to fall under Exemption #4 as detailed at 45 CFR 46.104(d)(4) publicly available identifiable private information, the identity of the subjects cannot be readily ascertained, and the investigator will neither contact the subjects nor re-identify subjects, use of identifiable health information when that use is regulated by HIPAA, or Analysis of data on behalf of a federal agency. All methods were performed under the relevant guidelines and regulations.

Additional information

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Correspondence and requests for materials should be addressed to A.Y.

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