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Assessing Resident Cataract Surgical Outcomes Using Electronic Health Record Data

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Objective: To demonstrate that electronic health record (EHR) data can be used in an automated approach to evaluate cataract surgery outcomes.

Design: Retrospective analysis.

Subjects: Resident and faculty surgeons.

Methods: Electronic health record data were collected from cataract surgeries performed at the Johns Hopkins Wilmer Eye Institute, and cases were categorized into resident or attending as primary surgeon. Preoperative and postoperative visual acuity (VA) and unplanned return to operating room were extracted from the EHR.

Main Outcome Measures: Postoperative VA and reoperation rate within 90 days.

Results: This study analyzed 14 537 cataract surgery cases over 32 months. Data were extracted from the EHR using an automated approach to assess surgical outcomes for resident and attending surgeons. Of 337 resident surgeries with both preoperative and postoperative VA data, 248 cases (74%) had better postoperative VA, and 170 cases (51%) had more than 2 lines improvement. There was no statistical difference in the proportion of cases with better postoperative VA or more than 2 lines improvement between resident and attending cases. Attending surgeons had a statistically greater proportion of cases with postoperative VA better than 20/40, but this finding has to be considered in the context that, on average, resident cases started out with poorer baseline VA. A multivariable regression model of VA outcomes vs. resident/attending status that controlled for preoperative VA, patient age, American Society of Anesthesiologists (ASA) score, and estimated income found that resident status, preoperative VA, patient age, ASA score, and estimated income were all significant predictors of VA. The rate of unplanned return to the operating room within 90 days of cataract surgery was not statistically different between resident (1.8%) and attending (1.2%) surgeons.

Conclusions: This study demonstrates that EHR data can be used to evaluate and monitor surgical outcomes in an ongoing way. Analysis of EHR-extracted cataract outcome data showed that preoperative VA, ASA classification, and attending/resident status were important in predicting postoperative VA outcomes. These findings suggest that the utilization of EHR data could enable continuous assessment of surgical outcomes and inform interventions to improve resident training.

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Given that cataract surgery is one of the most commonly performed surgeries in the world, it is an important foundational procedure in ophthalmology residency training. It is estimated that 21% to 39% of cataract surgery cases in developed countries are performed by residents.[1] The Accreditation Council for Graduate Medical Education (ACGME) Ophthalmology National Resident Report showed that residents who completed programs in 2019 to 2020 logged an average of 160 cataract procedures.[2] Despite the known learning curve associated with cataract surgeries[3] that has led to many residency programs increasing the number of resident-performed cataract cases, it remains a challenge to evaluate surgical outcomes on an ongoing basis throughout resident training. Analysis of resident cataract outcomes has historically required manual review of patient records, which is either time consuming, expensive, or both. The utilization of EHR data has potential to automate this process and serve as an ongoing method of monitoring surgical outcomes without the need for manual review.

One valuable use of electronic health record (EHR) data is to evaluate the relationship between resident experience

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and cataract surgery outcomes like postoperative complications and visual acuity because this association is unclear and varies across studies.[4-7] Intraoperative complication rates for resident cataract surgery cases vary widely between studies, ranging from 2% to 15%.[3,6,8-10] The majority of studies show worse outcomes with less experience. A longitudinal study found that specific complications decreased throughout residency training, with a protective odds ratio of 0.75 for vitreous loss for each additional 10 cases of resident experience.[10] A retrospective study on reoperation after resident-performed cataract surgery found a reoperation rate of 2%, and the most common indications for reoperation included retained nuclear fragment, dislocated intraocular lens, incision leak, and retinal detachment.[11] In addition to complication and reoperation rates, visual acuity (VA) is an important measure that helps inform whether cataract surgery outcomes are affected by resident experience. VA outcomes after resident-performed cataract surgery vary from 74% to 98% achieving 20/40 vision or better.[3,4,7,12]

The purpose of this study was to leverage EHR data to investigate the relationship between resident experience and cataract surgery outcome measures, including VA outcomes and reoperation rates, and to compare those outcomes to attending surgeons. This study extracted data from the EHR to compare resident and attending outcomes including best postoperative VA, change in VA, proportion with better than 20/40 acuity (< 0.3 logarithm of the minimum angle of resolution [logMAR]) after surgery, proportion with more than 2 lines improvement ($\geq$ 0.2 decrease in logMAR) in VA, proportion with better postoperative VA, and proportion with reoperation within 90 days. This study also investigated the longitudinal effect of resident experience on cataract surgery outcomes by analyzing the relationship between case number and VA outcomes.

Methods

This study was approved by the Institutional Review Board of the Johns Hopkins University School of Medicine, Baltimore, Maryland, and adhered to the tenets of the Declaration of Helsinki.

Data Collection

Data were extracted from the institutional EHR (Epic Systems Corporation, Verona, WI) for cataract surgeries performed at the Johns Hopkins Wilmer Eye Institute from July 1, 2016, to March 1, 2020, using an automated approach. Cases were included if cataract extraction was the only procedure performed and then categorized into resident or attending as primary surgeon. The use of EHR data and the existence of a resident continuity care clinic made it possible to analyze a large number of cataract surgery cases while distinguishing between resident- and attending-managed cases. A case was classified as having a resident provider if there was $\geq$ 1 visit with a resident in a resident continuity clinic before surgery, and the initial postoperative visit was scheduled with a resident in the EHR. Cases with these characteristics are known to be performed by residents under supervision by faculty, both in the clinic and the operating room. Although this approach does not capture all resident cases, it did allow us to reliably identify a subset of them, which is not possible with EHR data alone given the lack of metadata regarding the role of trainees in a given case.

For cases attributed to attending surgeons, we selected only those surgeons who do not work with residents or were operating in a location where residents were not present. This selection process was included to avoid overlap between the 2 groups.

For this study, we chose to analyze in a standardized and comprehensive way cataract surgery outcome measures that were recorded in the EHR so that we could reliably extract that data for both resident and attending cases. Preoperative and postoperative VA were recorded for each surgery. Preoperative acuity was the last recorded VA before the surgery while postoperative acuity was selected from encounters closest to 30 days after the surgery, within a range of 20 to 90 days. The following VA measures were recorded for the surgical eye: distance with and without correction, distance with final refraction, distance with manifest refraction, and near with manifest refraction. The best of these values was used as the value for acuity pre- and postoperatively. The American Society of Anesthesiologists (ASA) classification was recorded as a proxy for general medical complexity given that it is required for every surgical case and has been associated with postoperative outcomes in ocular surgery.[13] Findings and diagnoses associated with ocular comorbidities are not systematically recorded at any point in the clinical or perioperative workflow and so were not relied upon to assess case complexity. Data from any unplanned return to the operating room were collected if there was another surgery performed on the same eye within 90 days.

For each preoperative or postoperative visit, the best of all recorded VA measures at each visit was identified and converted to logMAR. For each resident surgeon, each of their cases was assigned a case number in chronological order throughout the academic year to provide a proxy for their surgical experience. Demographic information including race, age, insurance (Medicare, Medicaid, Private, None), and zip code were recorded for each patient. Public census data were used to extract estimated income data for each zip code.

Statistical Analysis

The relationship between preoperative and best postoperative VA was visualized with scatterplots for residents and attendings. The proportion of specific outcomes was compared between residents and nonresidents using unpaired, 2-tailed t tests. This study examined the proportion of patients with post-operative VA better than 20/40 (< 0.3 logMAR) and the proportion of patients who returned to the operating room within 90 days between the 2 groups. The change in best VA between preoperative and post-operative visits was also assessed. The proportion of patients with more than 2 lines improvement ($\geq$ 0.2 decrease in logMAR) was compared between residents and attendings. The proportion of patients with improved VA after surgery and the proportion of patients with another operation on the same eye within 90 days were also compared between the 2 groups.

Next, the longitudinal relationship between resident experience (chronological case number) and VA outcomes (best recorded final VA and change in VA) was examined using a scatterplot and linear regression model. A multivariable regression model was created including resident/attending status, patient age, median income based on zip code, and ASA classification.

Results

This study analyzed 14 537 cataract surgery cases that were extracted from EHR records from July 1, 2016, to March 1, 2020, (Table 1) using an automated approach. Based on EHR data from the resident continuity clinic, 392 cases were categorized as having a resident as the primary

Table 1. Demographics of Resident Cases Compared with Attending Cases

Patient Demographics	Resident Cases (n = 392)	Attending Cases (n = 14 145)
Preoperative logMAR (SD) ***	0.60 (0.65)	0.46 (0.46)
Age at surgery (SD) ***	65.3 (11.7)	70.0 (10.3)
ASA class (no., %) ***	Healthy = 7 (1.8)	Healthy = 382 (2.7)
	Mild Systemic Disease = 194 (49.5)	Mild Systemic Disease = 8341 (59.0)
	Severe Systemic Disease = 182 (46.4)	Severe Systemic Disease = 5191 (36.7)
	Incapacitating Disease = 9 (2.3)	Incapacitating Disease = 231 (1.6)
Estimated income (SD) ***	51 463 (21 831)	74 393 (29 616)

ASA = American Society of Anesthesiologists; logMAR = logarithm of the minimum angle of resolution; SD = standard deviation.
*** *P*-value < 0.001.

surgeon. This represents 13% of all cases logged by residents during the study period and reflects the fact that the criteria needed to identify resident-performed cases are necessarily strict, given the lack of EHR metadata related to primary surgeon. During the same study period, 14 145 cases were categorized as having an attending physician as the primary surgeon. Resident cases had worse baseline VA, younger age, more severe ASA class distribution, and lower estimated income compared with attending cases ($P < 0.001$). Scatterplots of pre- vs. postoperative VA were created for residents and attendings (Figure 1).

Analysis of outcomes showed that out of the 365 surgeries that could reliably be attributed to residents and that had postoperative VA outcome data, 249 cases (68.2%) had a postoperative VA better than 20/40 (< 0.3 logMAR). Out of 13 045 attending surgeries with available postoperative VA outcome data, 10 228 (78%) had a postoperative VA better than 20/40 ($P < 0.001$). Out of 337 resident surgeries with both preoperative and postoperative VA outcome data, 170 cases (51%) had more than 2 lines improvement (≥ 0.2 decrease in logMAR) compared with 5840/10 871 (53.7%) for attending surgeries ($P = 0.24$). In addition, 248/337 resident cases (74%) had better postoperative VA (decrease in logMAR) compared with 8440/10 871 (78%) of attending surgeries ($P = 0.08$). The median improvement in logMAR VA was −0.20 and −0.22 logMAR for resident and attending surgeons, respectively. Out of 392 resident surgeries, 7 cases (1.8%) returned to operating room within 90 days. Out of 14 145 attending surgeries, 165 (1.2%) returned to the operating room ($P = 0.26$ for comparison of the 2 groups). Causes for return to operating room included removal of lens material, vitrectomy, and repositioning of intraocular lens (Table 2).

Using linear regression, there was no statistical association between resident experience (case number) and postoperative VA ($P = 0.64$) or between resident experience and change in VA ($P = 0.35$) (Figure 2). Multivariable regression models of VA outcomes (postoperative VA and difference in VA) vs. resident experience and controlled for preoperative VA, patient age, ASA score, and estimated income showed that only preoperative VA was a significant predictor of VA outcome (Table 3). Multivariable regression models of VA outcomes (postoperative VA and change in VA) vs. physician status (resident or attending), controlled for preoperative VA, patient age, ASA score, and estimated income showed that attending or resident physician status, preoperative VA, age at surgery, ASA score, and estimated income were all significant predictors of VA outcomes (Table 4).

Discussion

This study provides a proof of concept for the utilization of EHR data to analyze cataract outcomes on an ongoing basis. In this study, automatically extracted EHR data were used to compare surgical outcome measures including VA and reoperation rates between resident and attending surgeons. We found no statistically significant difference between attendings and residents in the proportion of cases with more than 2 lines of VA improvement. There was also no difference in the rate of returning to the operating room after cataract surgery between resident and attending surgeons. The proportion of cases with better post-operative VA was also not statistically different between attending and resident surgeons.

We found that attendings had a significantly greater proportion of cases with postoperative VA better than 20/40. This finding has to be considered in the context that, on average, resident cases started out with worse VA and worse ASA classification. This suggests that worse initial VA and systemic disease in those patients may have contributed to visual outcomes. In addition, resident cases had lower estimated income based on zip code analysis so socioeconomic factors could have contributed to systemic disease and surgical outcomes. These differences in patient characteristics are likely related to the fact that the resident continuity clinic serves otherwise underserved patients from the local community whereas the faculty practices tend to be referral practices. The fact that outcomes are similar for the 2 groups may be related to the fact that cases are performed under close supervision of faculty.

To better understand the difference in outcomes, multivariable regressions found that preoperative VA and patient characteristics such as age and ASA score play a more significant role in predicting outcome than resident stage of training, which was not a predictor of surgical outcome in this study. This finding corresponds with a previous study which found no differences in VA over the course of residency training.[6] This could be due to the difficulty in

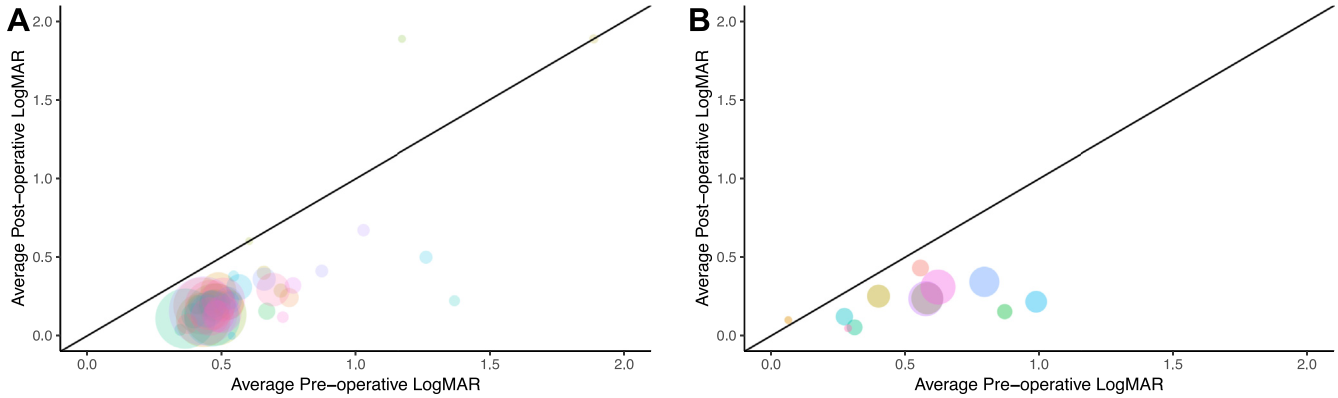

Figure 1. Preoperative and postoperative visual acuity for attending cases (**A**) and resident cases (**B**). Scatterplots of the average pre- and postoperative visual acuity for individual attending and resident surgeons. The size of each circle represents the number of surgeries for a single surgeon. Circles falling below the diagonal reference line indicate improved visual acuity postsurgery. logMAR = logarithm of the minimum angle of resolution.

separating the effects of incrementally improving skill of residents with the increasing complexity of cases as residents progress in their training. In addition, the level of resident involvement in a case could increase with their skill set, with residents taking on more responsibility later in their training. The stability in surgical outcomes despite increasing resident experience could suggest that effective supervision by faculty throughout resident training may mitigate the effect of resident inexperience. This is supported by previous studies that have found that newly independent attendings have significantly higher complication rates than more experienced attendings.[14,15] Although resident experience was not a significant predictor of surgical outcome in our study, resident or attending status was a significant predictor of VA outcomes. Since resident cases in this dataset did not include cases when they may have assisted in operating on faculty patients, the use of resident case number could have underestimated resident surgical experience. Further analysis of total surgical times and resident case number could provide additional context for the relationship between increasing resident experience and related factors (e.g. attending supervision) affecting surgical outcomes.

A challenge with any study of trainee surgical outcomes is identification of each case as having a trainee or attending surgeon. A previous study demonstrated that automated extraction of electronic health data could be used to assess surgical outcomes including VA,[16] but identifying trainee

Table 2. Reasons for Reoperation Compared Between Resident and Attending Surgeons

Reason	Resident Number (% of Reoperations)	Attending Number (% of Reoperations)
Possibly related to original surgery		
Removal of lens material	2 (29)	42 (26)
Vitrectomy	1 (14)	32 (20)
Repositioning of intraocular lens prosthesis	1 (14)	24 (15)
Exchange of intraocular lens		16 (9.9)
Repair of retinal detachment	1 (14)	10 (6.2)
Revision or repair of operative wound of anterior segment	1 (14)	4 (2.5)
Insertion of intraocular lens prosthesis		3 (1.9)
Severing adhesions of anterior segment of eye		2 (1.2)
Biopsy of cornea		1 (0.6)
Placement of amniotic membrane on the ocular surface		1 (0.6)
Paracentesis of anterior chamber of eye		1 (0.6)
Removal of implanted material, anterior segment of eye		1 (0.6)
Injection, anterior chamber of eye		1 (0.6)
Suture of iris, ciliary body		1 (0.6)
Unlisted procedure, anterior segment of eye		1 (0.6)
Unlikely related to original surgery		
Blepharoplasty/ptosis repair	1 (14)	5 (3.1)
Endothelial keratoplasty		4 (2.5)
Aqueous shunt to extraocular-reservoir		3 (1.9)
Repair of entropion		3 (1.9)
Penetrating keratoplasty		2 (1.2)
Conjunctivoplasty		2 (1.2)
Treatment of extensive or progressive retinopathy		1 (0.6)
Strabismus surgery		1 (0.6)

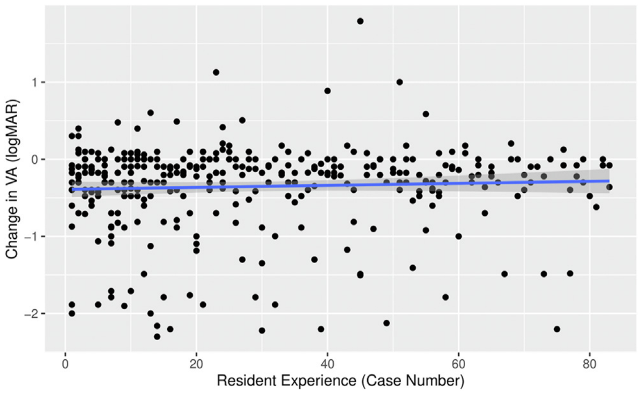

Figure 2. Scatterplot of resident surgical experience (case number) and change in VA (logMAR) with a linear regression trend line. The change in VA is the difference between best recorded postoperative and preoperative VA. LogMAR = logarithm of the minimum angle of resolution; VA = visual acuity.

cases presents an additional step. Since the concept of "primary surgeon" is not recorded in the EHR, residents could have operated on faculty patients since attending cases were defined here by the surgeon who did the primary pre and postoperative care instead of the surgical procedure. We limited this effect by including cases from attending surgeons who do not routinely operate with residents or were operating in a location where residents were not present. Even though there were more cases with resident involvement during the period of the study, we had to use surrogate parameters to help identify resident-performed cases. Prospective studies would benefit from more clear identification in the medical record as to the extent of resident involvement, though this may have medico-legal implications. Since this study analyzed cases from the resident continuity clinic to reliably assess cataract surgery outcomes, a limitation of this study is the difference in patient population in the resident continuity clinic compared to the attending clinics. Because the resident continuity clinic has more patients from the local community while attending clinics have a greater number of external referrals, there is a demographic difference in the patient population (e.g. age, comorbidities, socioeconomic status) that could have affected surgical outcomes.

Table 3. Multivariable Regression Model of VA Outcome and Resident Experience

Variable	Postoperative VA (logMAR) Beta (*P*-value)
Resident experience (case number)	1.10×10^{-4} (0.903)
Pre-operative VA (logMAR)	0.033 (< 0.001)
Age at surgery (in years)	0.002 (0.336)
ASA score	−0.055 (0.126)
Estimated income	-5.17×10^{-7} (0.589)

LogMar = logarithm of the minimum angle of resolution; VA = visual acuity.

Table 4. Multivariable Regression Model of VA Outcome and Resident/Attending Status

Variable	Postoperative VA (logMAR) Beta (*P*-value)
Physician status (resident vs. attending)	0.043 (< 0.001)
Preoperative VA (logMAR)	0.316 (< 0.001)
Age at surgery (in years)	0.001 (< 0.001)
ASA score	0.020 (< 0.001)
Estimated income	-3.13×10^{-7} (< 0.001)

LogMAR = logarithm of the minimum angle of resolution; VA = visual acuity.

Additional limitations of this study and comparable studies on cataract surgery outcomes involve the use of specific outcome measures that can be systematically extracted from the EHR. For this study, we chose to analyze surgical outcome metrics and patient characteristics that can be reliably extracted from the EHR and are generalizable across institutions. We used the best recorded VA instead of specific types of VA (ie uncorrected VA, best corrected VA) as a surgical outcome measure from the encounter closest to 30 days after the surgery. Similarly, the best available proxy for patient complexity we could use in this study was the ASA score since relevant comorbidities are not all recorded in the EHR problem list in a standardized and comprehensive way. Although specific ocular comorbidities were not included in this study, a previous study on cataract outcomes found that higher ASA class was positively associated with risk of adverse events and readmission within 30 days of surgery and negatively associated with the proportion achieving CDVA of 20/40 or better.[13]

Cataract surgery is an essential procedure in resident training so a better understanding of the factors affecting resident surgical outcomes is important for improving residency training and patient care. This study found that resident experience did not have a significant impact on acuity outcomes but patient factors including preoperative VA and ASA classification were important in predicting postoperative VA. Even though resident cases had worse preoperative VA and severity of disease, there was no significant difference in proportion of cases with better postoperative VA or more than 2 lines improvement between resident and attending cases. Attending cases had a greater proportion with better than 20/40 but comparable reoperation rate. Given the impact of preoperative VA on postoperative outcomes, VA outcomes are not a reliable quality metric to assess resident competency and experience.

Historically, this type of analysis has required detailed chart review but this project demonstrates it is possible to do this type of analyses on an ongoing basis if institutions can clearly define their resident cases and extract data from EHR directly to allow for ongoing quality assessments. By using a query of EHR data (Appendix), this study introduced an automated approach that can return timely results that would have previously required abstraction of data from thousands of chart reviews. The EHR extraction process can be repeated with updated dates and standardized analysis code to generate periodic reports on resident outcomes. One key challenge for this kind of analysis is that it is, in general, not possible to tell from EHR data whether a trainee was the "primary" surgeon on the case per ACGME criteria. The ACGME case logs also do not help us here as they do not include patient identifiers that would allow extraction of the associated clinical data. This particular application (evaluation of surgical outcomes for trainees) supports development of methods to record case metadata regarding the role of trainees in a case. The data limitations of this study (e.g. using best recorded VA instead of best corrected VA as an outcome measure) demonstrate that large-scale analysis of surgical outcomes from the EHR is dependent on standardized and comprehensive records across many years. This challenge can be addressed by standardizing fields in the EHR for case metadata like trainee role and providing trainees fields to record specific preoperative and postoperative measures that are valuable for evaluating surgical outcomes.

This EHR-based approach provides a proof of concept that EHR data could be used in an automated and ongoing way to evaluate cataract surgery outcomes. This utilization of EHR data can inform educational changes by making it easy to analyze outcomes before and after an intervention to improve resident training. The process of extracting and then reanalyzing the data can be done in minutes to hours whereas reviewing charts manually would take days to weeks of someone's time. Leveraging EHR data in this way can provide an ongoing way to monitor surgical outcomes both during and after training.

Footnotes and Disclosures

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Author Contribution:

Conception and design: Xiao, Srikumaran, Sikder, Woreta, Boland; Analysis and interpretation: Xiao, Srikumaran, Sikder, Woreta, Boland; Data collection: Xiao, Boland; Obtained funding: N/A

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Abbreviations and Acronyms:
ACGME = Accreditation Council for Graduate Medical Education; **ASA** = American Society of Anesthesiologists; **EHR** = electronic health record; **logMAR** = Logarithm of the Minimum Angle of Resolution; **VA** = visual acuity.

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