Determining the association of surgical setting and implementation of a new electronic health record (EHR) system with ophthalmic operative times is important for surgical planning and resource allocation.

To assess the associations of surgical setting and EHR system replacement with operative times for ophthalmic surgery.

This case series included ophthalmic surgeries from July 2015 to November 2016 in 2 ambulatory surgical centers and 1 hospital outpatient department in a single academic eye institute. Operative times from consecutive surgical cases performed by board-certified ophthalmologists were extracted from 2 EHR systems. Those performed after replacement EHR system implementation were divided into three 50-day time categories (immediate posttransition, intermediate posttransition, and late posttransition periods). Multivariable regression analyses assessed the associations of surgical setting (hospital outpatient department vs ambulatory surgical center) with total operating room times for comparable surgeons performing cataract surgery and deployment of a new EHR system in the OR on several operative time measures. Data were evaluated from November 2016 to March 2018.

Room duration, procedure duration, turnaround time, and total OR time.

A total of 11 064 cases performed by 76 surgeons were included in this analysis. The mean total OR time was 2.9 (95% CI, 0.5-5.4; \( P = .02 \)) minutes longer in the immediate posttransition period and 1.2 (95% CI, 0.1-2.2; \( P = .04 \)) minutes longer in the intermediate posttransition period relative to surgeries performed before EHR system replacement. No difference in the total OR time was found between the late posttransition and pretransition periods. Relative to ambulatory surgical centers, the mean total OR time was 15.9 (95% CI, 14.7-17.0) minutes longer, and the mean turnaround time was 5.1 (95% CI, 4.3-6.0) minutes longer at the hospital outpatient department for comparable surgeons performing cataract surgery (\( P < .001 \) for both).

The mean total OR time per case lengthened after the replacement of an EHR system in the OR, but this increase was small (shorter than 3 minutes) and limited to surgeries performed during the first 100 days after the EHR system transition. Modeling to assess surgical setting demonstrated all operative time measures were longer for cataract cases performed at the hospital outpatient department relative to those at ambulatory surgical centers. These data have implications for the fiscal and logistical management of ophthalmic surgery.
Health care costs in the United States have risen considerably in the past few decades. Operating room (OR) costs have grown in particular, given the costs of skilled support staff and advances in surgical technology. Consequently, maximizing OR efficiency has become a priority for many institutions.

Lengthy surgeries can place a burden on OR systems in several ways. With OR charges ranging from $22 to $133 per minute, lengthy cases represent increased costs for the health care system overall. In addition, in high-volume ORs, lengthy cases cause delays for subsequent cases, often affecting those scheduled later in the day. Third, long case times place burdens on OR staff and pose challenges for institutional operative planning. Surgical setting (eg, hospital vs ambulatory surgical center [ASC]) and electronic health record (EHR) system deployment are 2 factors experiencing changes at many institutions and are both hypothesized to affect OR efficiency.

Recently, many surgical specialties have moved less invasive surgeries to ASCs to cut costs and optimize hospital resources for more demanding cases. In large part, the move favoring surgeries at the ASC was because of the shortened expected case length relative to the hospital, in addition to lower overhead costs, staff needs, and postoperative care for less invasive procedures.

Within the OR, large health care organizations have also incorporated an EHR system for documentation. Both changes have challenged the status quo for operative times. With most large American health care organizations implementing an EHR system in recent years, many financial officers are more actively managing operative times as part of institutional operating room planning.

Prior work from general surgery, otolaryngology, orthopedics, and ophthalmology have all studied how several factors are associated with operative times. Data from these surgical specialties have demonstrated significant effects on operative times from resident trainee involvement, individual surgeon, emergency surgery, and American Society of Anesthesiologists classification of patient surgical risk. Previous studies have also investigated the association of EHR system deployment in ophthalmology with documentation speed, clinic workflow, surgical volume, patient experience, physician behavior, and staffing. Despite such work, few studies have investigated how surgical facility choice (ASC vs hospital) and the implementation of a new EHR system can affect operative times for ophthalmic surgery. It is important to quantify the associations of these factors with operative times for institutions to plan where to perform surgical cases and estimate the resources needed to implement a new EHR system.

In general, operative times is a broadly used term, typically for room duration and procedure duration. However, in this study, we also study turnaround time, which is defined as the elapsed time between the close of a case and the commencement of the next when 2 cases are scheduled immediately after one another in the same OR. Given frequent high demand for ORs, many surgeons and financial officers place considerable importance on minimizing the turnaround time as well.

In this study, we primarily sought to investigate how these 2 changes are associated with a variety of operative time measures. We set out to assess the associations of surgical facility designation with operative times for comparable surgeries and implementation of a new EHR with operative times. We hypothesized that the ASC would experience shorter operative times and implementation of a new EHR would, at least temporarily, lengthen operative times. We also briefly discuss the cost-effectiveness of ophthalmic surgery at the ASC vs hospital for cataract surgery.

Methods
This study was reviewed by the Johns Hopkins University School of Medicine institutional review board. It was determined not to be human subjects research, and thus informed consent procedures were not needed.

Data Query
The electronic data system used in the ophthalmology-specific surgical facilities of The Johns Hopkins Wilmer Eye Institute was queried for all surgical cases between July 2015 and November 2016. Coinciding with a larger hospitalwide transition (eg, notes, order entry, anesthesia data record, nursing documentation) to EpicCare (Epic Systems), there was a transition in the EHR used in the OR from Operating Room Management Information System (ORMIS [GE Healthcare]) to EpicCare on July 1, 2016. We queried each database for comparable operative time data during the timeframe each system was in use (before July 1, 2016, for ORMIS and after that date for Epic). All cases were performed at the hospital outpatient department (HOPD) or 1 of 2 affiliated ASCs. The deployment of the new EHR happened at all facilities simultaneously. Specific data extracted from each system included location (HOPD vs ASC), anesthesia (local vs general), procedure, surgeon identity, and the following OR time stamps: scheduled start, scheduled stop, room start, room stop, procedure start, and procedure stop.

Exclusion Criteria
Operative times were reviewed and excluded for the following reasons: (1) room durations or procedure durations of less than 0 (ie, a data error) or more than 400 minutes; (2) vague, missing, or improperly entered anesthesia; (3) cases in which the time...
of 1 case overlapped with another case in the same room; (4) performance in nonoperative procedure rooms; (5) multiple procedures performed in 1 case; (6) procedures performed less than 3 times; (7) cases with no incisional surgery (eg, a laser procedure only); and (8) procedures that were nonophthalmologic. The remaining cases were categorized into the procedure categories cataract, cornea, glaucoma, oculoplastics, retina, and strabismus.

Outcome Measures
Operative times were defined prior to data analysis. Room duration was defined as the time from the patient entering the OR to the patient exiting, calculated as the time elapsed between room start and stop times. Procedure duration was defined as the time from the surgeon beginning the procedure to the surgeon declaring the procedure complete, calculated as the time elapsed between procedure start and stop times. Turnaround time was defined as the time from the patient exiting the OR to the next patient entering the same OR for cases scheduled immediately after one another. For surgeries taking place on the same date in the same OR, cases were deemed to be scheduled in succession when the scheduled stop time of 1 case either equaled or surpassed the scheduled start time of the next case. Turnaround time was then calculated as the time elapsed between the room stop time of the first case and the room start time of the next case, and this time was assigned to the first case. The total OR time is the sum of room duration and turnaround time.

EHR Go-Live Time Categories
To better understand how the transition to a new EHR is associated with operative times, we organized the EHR data into 4 periods. The pretransition period included the 365 days before the go-live date with the new EHR, the immediate posttransition period included days 1 through 50 after the go-live date, the intermediate posttransition period included days 51 through 100 after the go-live date, and the late posttransition period included days 101 through 150 after the go-live date.

Statistical Methods
Descriptive analyses were performed to characterize cases by EHR, location, anesthesia type, procedure category, time relative to EHR go-live date, and operative times. Additional descriptive analyses were conducted to characterize room durations and turnaround times by procedure category for cases performed at the HOPD. We compared mean (SD) room duration and turnaround times for the procedure categories relative to cataract surgery using t tests. Cataract surgery was chosen as the reference group because those data were felt to be most resistant to bias, given that this procedure had both the highest surgical volume and the highest number of unique surgeons. Cases performed at the ASC were excluded to the heterogeneous distribution of procedure categories at the HOPD vs the ASC. Of note, the ASCs did not have any surgical volume in some noncataract procedure categories, so performance at the hospital was the focus of analyses of these procedures.

To assess how the implementation of a new EHR in the OR affected workflow, analysis of total OR time by period after EHR transition was performed with multivariable linear regression analyses, adjusting for procedure category, location, anesthesia and surgeon identity. The three 50-day time categories following the go-live date were each compared with the pretransition time category in a separate regression model.

Finally, to evaluate how operative times vary by location (HOPD vs ASC), an analysis of all operative times by location was conducted. Because other procedure categories were limited in numbers at the ASCs, only cataract cases were evaluated in these models. In addition, resident and fellow physicians are trained at the HOPD in which this study was conducted, so to minimize bias from resident and fellow participation in cases, we excluded cases performed by attending surgeons with trainee responsibilities. Further, only surgeons performing cataract surgery at each location type (HOPD and ASC) were included. Mean (SD) values for all 4 previously defined operative times were compared for cataract surgery by location (HOPD vs ASC) using multivariable linear regression analyses, adjusted for anesthesia and surgeon identity.

Cases not scheduled in succession in which turnaround time, and thus total OR time, was unable to be measured were excluded from all analyses specific to these 2 outcome measures. All analyses were performed using Stata version 14.0/IC (StataCorp).

Results

Surgical Time Data
Data from 17 397 cases were extracted from the 2 EHR systems (eFigure in the Supplement). Room and procedure durations of negative time spans (n = 11) and time spans longer than 400 minutes (n = 13) were excluded for incorrect time stamp documentation. Cases with missing or incorrect anesthesia (n = 266), overlapping time stamps with another case in the same operating room on the same date (n = 79), and those with multiple procedures performed by several surgeons from different specialties (n = 2589) were excluded. Cases taking place in nonoperative procedure rooms (n = 572), cases involving procedures that occurred less than 3 times (n = 1108), and those with nonophthalmologic procedures (n = 1695) were also excluded. The inclusion criteria were satisfied by 11 064 cases (Table 1).

Mean Room Duration and Turnaround Time by Procedure at HOPD
The operative times for the 7142 cases (64.6%) performed at the HOPD were assessed by procedure category. The mean (SD) room duration and turnaround time for cataract cases were 42 (20) minutes and 16 (13) minutes, respectively (Figure 1). The mean room duration was significantly longer than cataract surgery for all other procedure categories (mean [SD] durations: strabismus procedures, 79 [32] minutes; retina procedures, 94 [49] minutes; oculoplastic procedures, 67 [31] minutes; glaucoma procedures, 55 [24] minutes; cornea procedures, 75 [40] minutes; P < .001 for each). The mean turnaround time was significantly longer for cornea (mean [SD], 20 [17] minutes; P = .001), oculoplastics (mean [SD], 24 [19] minutes; P < .001), retina (mean [SD], 25 [20] minutes; P < .001), and strabismus (mean [SD], 28 [17] minutes; P < .001). The mean turnaround time for glaucoma was not significantly different than mean turnaround time for cataract.

© 2019 American Medical Association. All rights reserved.
Mean OR Time After EHR Go-Live Date

All 11,064 cases were included in the models to assess how total OR times were changed after the new EHR system was deployed. Relative to the pretransition period, the mean total OR time was 2.9 (95% CI, 0.5-5.4) minutes longer in the immediate posttransition period (P = .02) and 1.2 (95% CI, 0.1-2.2) minutes longer in the intermediate posttransition period (P = .04), after controlling for covariates (Figure 2). Mean total OR time in the late posttransition period was not significantly different from that in the pretransition time categories.

OR Times for Cataract Cases by Location

Eight attending surgeons with 4034 cataract cases met inclusion criteria for modeling case time by surgical setting (HOPD vs ASC). This is a subset of the 7487 total cases (Table 2) in which additional exclusion criteria were met for surgeons who operated without trainee responsibilities and at each location type (HOPD and ASC), as described in the Methods section. Relative to the ASC, for comparable surgeons performing cataract surgery, mean room duration in the HOPD was 11.9 (95% CI, 11.1-12.6) minutes longer, mean procedure duration was 10.6 (95% CI, 9.8-11.4) minutes longer, mean turnaround time was 5.1 (95% CI, 4.3-6.0) minutes longer, and mean total OR time was 15.9 (95% CI, 14.7-17.0) minutes longer (P < .001 for each), after adjustment for covariates (Figure 3).

Discussion

These data support the hypothesis that mean total OR time lengthens after implementation of a new EHR system in the OR, but that this increase need not be large (in this case, <3 minutes) and can be limited to just the initial period after the new system goes live. When compared with institutional means for all ophthalmic cases, the 2.9 additional minutes corresponds to a 5.2% increase in total OR time. The surgical volume initially decreased when the institution transitioned EHR systems; however, this study is limited in determining if this decrease was a result of lengthened cases or if there was decreased volume for the institution as a whole at the time. Although the overall lengthening of mean total OR time may not be surprising, the purposes of this analysis were to quantify the amount of time added to each case event.
(2.9 minutes) and to estimate how long this lengthening may last after the EHR implementation date (no longer than 100 days). This information may be useful for institutions planning a similar transition to a new EHR system. Furthermore, given the associated cost of longer cases and potential reduction in the number of cases performed, the hospital system implementing the EHR system must be prepared for these changes.

Before an EHR system go-live date, OR staff need appropriate training on the new system. At the study institution, the OR staff undertook training modules to practice workflows before the EHR system deployment date. Perhaps the lengthening of OR times in the current study after implementation of the new EHR system may have been even longer had this training not occurred. With longer total OR times in the immediate posttransition period, institutions can expect greater costs and perhaps fewer cases to be performed, as demonstrated by these data. Thus, to ensure a successful transition, institutions should likely assign EHR personnel to assist OR staff as they learn the workflows in the new EHR system, particularly in the beginning. The long-term ramifications to the OR system if operative times do not return to the values present before the system went live are likely substantial. Of note, the current study assessed OR times while transitioning from one EHR system to another, so the OR staff already had experience with electronic documentation. The institution used the prior system (ORMIS) for operative time logs and some nursing documentation, so the staff were accustomed to electronic workflows. The staff needed to learn new screen layout, electronic documentation, so the staff were accustomed to electronic workflows. The institution used the
electronic system (ORMIS) for operative time logs and some nursing documentation. The institution used this system.

Figure 3. Differences in Operating Room Times for Cataract Cases at the Hospital Outpatient Department

All values are significant compared with ambulatory surgical centers (reference); in the hospital outpatient department, mean room duration was 11.9 (95% CI, 11.3-11.6) minutes longer, mean procedure duration was 10.6 (95% CI, 10.0-11.2) minutes longer, mean turnaround time was 4.3 (95% CI, 3.9-4.7) minutes longer, and mean total operating room time was 15.9 (95% CI, 14.7-17.0) minutes longer.

outs and where to click to complete documentation. Physicians had to learn to use orders and other perioperative documentation not present in the prior system. Institutions replacing EHR systems in a different manner or transitioning to an EHR from paper-based health records may experience different outcomes. Further, given that switching to a new EHR system temporarily decreased OR efficiency at the facilities, other institutions should consider if expected benefits (eg, possible improved documentation, reporting, billing, user satisfaction, etc) of deploying a new EHR system outweigh the costs.

These data also support the hypothesis of shorter operative times at the ASCs for cataract surgery. Moreover, given the short duration of cataract cases overall, a mean difference of more than 10 minutes for room duration, procedure duration, and total OR time is noteworthy. There are likely several reasons for this significant discrepancy, including surgeons preselecting cases with limited case complexity to be performed at the ASCs (though the data are limited in its ability to confirm this or assess the magnitude), limited case variability and instrumentation at the ASC, allowing for quicker room setup and teardown, and greater OR staff specialization and efficiency in managing similar cases.

Further studies are needed to assess the cost-effectiveness of performing cataract cases at the ASC instead of the HOPD. However, given the decreased OR costs associated with the ASC and the shortened operative times, it seems intuitive that the ASCs must dominate the HOPD for cataract cases. In other words, if we assume that surgical outcomes are the same at both locations (eg, equal quality-adjusted life-year improvements after cataract surgery), cases that do not require the additional resources available at the hospital should all be performed at the ASC. However, in reality, these data show that cataract cases are divided in a near 50/50 split between the HOPD and ASC at the study institution (Table 2). Among surgeons performing cataract surgery at both the HOPD and ASC, even after excluding surgeons with trainee responsibilities, 1976 of 4034 cataract cases (48.9%) were done at the HOPD in this study. The study institution preferentially trains residents and fellows at the HOPD, so perhaps not all cases can be moved to the ASCs. Nonetheless, nearly 2000 cases over
17 months of data were still performed at the hospital, representing increased costs to the health care system. Notably, these data show increased turnaround times for almost all procedures categories relative to cataract surgery at the HOPD (Figure 1). We hypothesized that room duration for these procedure categories would be greater than that of cataract surgery, but turnaround time was unexpectedly found to be greater for most categories as well. Future work is needed to determine possible causes and if other institutions experience similar turn-around time discrepancies. Nonetheless, it is likely that turnaround times for noncataract surgery may be longer because of increased variability of case type and thus increased complexity of instrumentation setup. For example, cornea specialists may perform endothelial keratoplasty, keratoprosthesis, and pterygium surgery, which all require different instrumentation.

Limitations
One limitation of the current study is that the findings may be more generalizable to institutions with similar case characteristics (eg, large academic centers). Thus, Tables 1 and 2 are presented to give the reader perspective regarding the case volume and mean operative times at the study institution. Furthermore, Figure 1 is presented to show the operative time norms within several procedure categories. The current study has additional limitations. We retrospectively reviewed a full year of data in the EHR pretransition period vs 150 days in the posttransition period, and therefore results may be affected if operative times varied by time of year. In addition, this analysis of how operative times vary by location may be affected by case selection at the HOPD vs ASC. For example, surgical cases with complex cataracts and multiple patient comorbidities may be preferentially selected to be performed at the HOPD, potentially confounding results. Third, the OR technicians responsible for inputting information into the EHR system may have changed over time along with the EHR transition. Finally, the EHR transition date coincided with new residents and fellows starting at the study institution; so the slower operative times may be confounded by the new house staff.

Conclusions
In summary, this study shows that surgical setting and deployment of a new EHR system can be associated with OR efficiency. The results demonstrate that total OR time temporarily increased after implementation of a new EHR system, and operative times are reduced at the ASC relative to the hospital for cataract surgery. Further research seems warranted to assess the costs accrued by institutions adjusting to temporarily increased total OR times with EHR system changes. Future work also seems warranted for complete cost-effective analysis to properly compare cataract surgery by surgical facility. Such work may help to deliver quality surgical care at low cost.

**REFERENCES**


