Impact of an Electronic Health Record Operating Room Management System in Ophthalmology on Documentation Time, Surgical Volume, and Staffing

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**IMPORTANCE** Although electronic health record (EHR) systems have potential benefits, such as improved safety and quality of care, most ophthalmology practices in the United States have not adopted these systems. Concerns persist regarding potential negative impacts on clinical workflow. In particular, the impact of EHR operating room (OR) management systems on clinical efficiency in the ophthalmic surgery setting is unknown.

**OBJECTIVE** To determine the impact of an EHR OR management system on intraoperative nursing documentation time, surgical volume, and staffing requirements.

**DESIGN, SETTING, AND PARTICIPANTS** For documentation time and circulating nurses per procedure, a prospective cohort design was used between January 10, 2012, and January 10, 2013. For surgical volume and overall staffing requirements, a case series design was used between January 29, 2011, and January 28, 2013. This study involved ophthalmic OR nurses (n = 13) and surgeons (n = 25) at an academic medical center.

**EXPOSURES** Electronic health record OR management system implementation.

**MAIN OUTCOMES AND MEASURES** (1) Documentation time (percentage of operating time documenting [POTD], absolute documentation time in minutes), (2) surgical volume (procedures/time), and (3) staffing requirements (full-time equivalents, circulating nurses/procedure). Outcomes were measured during a baseline period when paper documentation was used and during the early (first 3 months) and late (4-12 months) periods after EHR implementation.

**RESULTS** There was a worsening in total POTD in the early EHR period (83%) vs paper baseline (41%) (P < .001). This improved to baseline levels by the late EHR period (46%, P = .28), although POTD in the cataract group remained worse than at baseline (64%, P < .001). There was a worsening in absolute mean documentation time in the early EHR period (16.7 minutes) vs paper baseline (7.5 minutes) (P < .001). This improved in the late EHR period (9.2 minutes) but remained worse than in the paper baseline (P < .001). While cataract procedures required more circulating nurses in the early EHR (mean, 1.9 nurses/procedure) and late EHR (mean, 1.5 nurses/procedure) periods than in the paper baseline (mean, 1.0 nurses/procedure) (P < .001), overall staffing requirements and surgical volume were not significantly different between the periods.

**CONCLUSIONS AND RELEVANCE** Electronic health record OR management system implementation was associated with worsening of intraoperative nursing documentation time especially in shorter procedures. However, it is possible to implement an EHR OR management system without serious negative impacts on surgical volume and staffing requirements.

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electronic health record (EHR) systems have been identified as an essential technology for improving the safety, quality, and efficiency of medical care. The federal government instituted an aggressive program to promote EHR adoption through the Health Information Technology for Economic and Clinical Health Act, which provides financial incentives to physicians and hospitals for meaningful use of these systems. In response, EHR adoption in ophthalmology has steadily increased. An American Academy of Ophthalmology survey performed in 2012 found that 32% of ophthalmology practices had implemented an EHR system compared with a similar survey in 2007 that found 12% adoption.

Despite this increase in adoption, there are persistent concerns regarding unique challenges of EHRs in specialized fields such as ophthalmology. Many EHRs used by ophthalmologists are institutionwide systems originally designed for primary care practices. They were not designed for the unique workflow and documentation requirements of ophthalmology, in which paper medical record methods have traditionally relied on drawings and annotations using examination templates. Clinicians have voiced concerns that EHRs may be associated with increasing time requirements, workflow disruption, and negative impact on clinical volume and patient care. Furthermore, the steep learning curve associated with EHRs may create particular difficulty in high-volume specialties, such as ophthalmology, and in fast-paced, time-sensitive areas such as operating rooms (ORs).

To our knowledge, there are few published studies on how EHR systems affect overall clinical efficiency and documentation speed. Owing to the fundamental differences among clinical settings, research findings from studies performed in other specialties may not extrapolate to ophthalmology. Furthermore, studies performed in ambulatory office settings may not extrapolate to other settings such as ORs. In particular, EHR OR management systems are used by enterprise-wide EHRs for surgical nursing documentation, anesthesia documentation, surgical materials management, and scheduling. These are critical tasks associated with the quality, cost, and efficiency of surgical care. We are not aware of any published research examining the impact of EHR OR management system implementation in ophthalmology or other surgical specialties. This is an important gap in knowledge because ORs require high quality and efficiency of care, with low tolerance for error.

In this study, we aimed to evaluate the effects of implementing an EHR OR management system on intraoperative nursing documentation time, surgical volume, and staffing requirements. This analysis extends our preliminary work by focusing on the impact on different ophthalmic procedure types. Comparison was made to baseline levels with paper documentation before EHR implementation.

### Methods

This study was reviewed by the institutional review board at Oregon Health & Science University and was granted an exemption because data were collected in a manner in which patients could not be identified.

### EHR OR Management System

The EHR OR management system (OpTime; Epic Systems) was implemented and integrated into the existing institutionwide EHR system in January 2012, replacing the paper-based nursing documentation system in ORs. Previously, anesthesia providers had used a different anesthesia-specific EHR system (Centricity; GE Healthcare) in the ORs.

The EHR OR management system contains tools for surgical processes such as scheduling, staffing, and materials management. It includes anesthesiology and intraoperative and perioperative nursing documentation capabilities. All nurses received 8 hours of system training prior to implementation. Additionally, 7 nurse super users (out of 13 total nurses) were selected owing to their perceived computer skills and roles. Prior to implementation, these super users received additional training with the EHR system and with peer-instruction techniques.

### Time-Motion Analysis of Nursing Documentation Time

Documentation times were captured by observation of nurses using a time-motion method. Data were collected by an observer (S.R.-B.) who monitored the actions of circulating nurses using a paper log sheet and a handheld computer with timestamping software (Emerald Timestamp; Emerald Sequoia). To maximize accuracy and precision, this data collection method underwent 3 cycles of pilot testing and modification prior to beginning the study. Additional data were gathered on the types of procedures, intraoperative documentation times, procedure start and stop times, and number of staff members in the OR.

Using these methods, baseline paper documentation data were collected during the 3 weeks prior to implementation, and post-EHR data were collected for 12 months after implementation. Data were gathered for different surgical procedures in different ORs and following different nurses each day, with the goal of obtaining the most representative data possible.

### Surgical Volume

Surgical volume was assessed by querying the enterprise-wide data warehouse to identify all OR procedures performed from 1 year before to 1 year after implementation of the EHR OR management system. To control for changes in the
Table 1. Characteristics of 21 Stable Ophthalmic Surgeons Who Operated Throughout Study Period

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>15 (71)</td>
</tr>
<tr>
<td>Surgeon age, mean (SD)</td>
<td>46.5 (10.2) [31-65]</td>
</tr>
<tr>
<td>Time in practice, mean (SD) [range], y</td>
<td>15.9 (8.5) [3-30]</td>
</tr>
<tr>
<td>&lt;10</td>
<td>6 (29)</td>
</tr>
<tr>
<td>10-19</td>
<td>8 (38)</td>
</tr>
<tr>
<td>&gt;19</td>
<td>7 (33)</td>
</tr>
<tr>
<td>Subspecialty</td>
<td></td>
</tr>
<tr>
<td>Comprehensive</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Cornea</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Oculoplastics</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Pediatric ophthalmology</td>
<td>5 (24)</td>
</tr>
<tr>
<td>Vitreoretinal</td>
<td>6 (29)</td>
</tr>
</tbody>
</table>

* Stable ophthalmic surgeons were identified as those who operated continuously 1 year prior to and 1 year following implementation of the electronic health record system (<1 month gap in operating out of the 24 months).

Data were compared over 3 periods: (1) For documentation time, the paper baseline was defined as the 3 weeks before EHR implementation. For surgical volume and staffing requirements, this was defined as the 1 year before implementation. (2) The early EHR period was defined as the first 3 months after implementation of the OR management system. (3) The late EHR period was defined as months 4 through 12 after implementation.

Descriptive statistics, Wilcoxon rank-sum tests, independent-sample t tests, and paired t tests were performed as appropriate for comparison of absolute intraoperative documentation times, POTD, surgical volume, and staffing requirements. Analyses were conducted using statistical software (Stata version 12; StataCorp).

Results

General Characteristics of the ORs and Surgical Procedures

Throughout the study (1 year prior to and 1 year after EHR implementation), there were 9331 surgical procedures performed by 54 different surgeons and involving 13 nurses. Complete data from 236 of these procedures were collected for this study on 52 different days (58 procedures on 10 days with the paper system before EHR implementation, 178 procedures on 42 days after EHR implementation) performed by 25 ophthalmologists and involving 13 nurses.

There were 6 different ophthalmologic subspecialties represented (comprehensive, cornea, glaucoma, oculoplastics, pediatric, and vitreoretinal). The 236 total procedures were clustered into 4 broad groups: 107 cataract (45%), 34 cornea and glaucoma (14%), 37 vitreoretinal (16%), and 58 extraocular (25%).

Intraoperative Documentation Time

Table 2 summarizes the findings involving intraoperative documentation time as POTD. During the early EHR period, there was significant overall worsening of POTD in all procedure types except in the cornea and glaucoma category, with subsequent improvement to baseline in the vitreoretinal and extraocular procedure categories.

Table 3 summarizes the absolute intraoperative documentation time in minutes. During the early EHR period, there was significant overall worsening in absolute intraop-
Abbreviation: EHR, electronic health record.

Table 2. Mean POTD Before and After EHR Implementation in the Operating Rooms

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Paper Baseline Before EHR</th>
<th>Early EHR (mo 1-3)</th>
<th>Late EHR (mo 4-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>POTD (SD), %</td>
<td>No.</td>
</tr>
<tr>
<td>Cataract</td>
<td>25</td>
<td>48 (12)</td>
<td>47</td>
</tr>
<tr>
<td>Cornea and glaucoma</td>
<td>10</td>
<td>47 (45)</td>
<td>6</td>
</tr>
<tr>
<td>Vitreoretinal</td>
<td>10</td>
<td>22 (13)</td>
<td>18</td>
</tr>
<tr>
<td>Extraocularb</td>
<td>13</td>
<td>37 (33)</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>41 (27)</td>
<td>83</td>
</tr>
</tbody>
</table>

Abbreviations: EHR, electronic health record; POTD, percentage of operating time documenting.

* Comparison of POTD in paper vs early EHR and paper vs late EHR periods. Two sample t tests with unequal variance were performed in the cataract group. Wilcoxon rank-sum tests were used in all other groups.

b The extraocular category includes procedures of the eyelid, lacrimal system, orbit, and extraocular muscles, and examinations under anesthesia.

Table 3. Mean Absolute Intraoperative Documentation Time Before and After EHR Implementation in the Operating Rooms

<table>
<thead>
<tr>
<th>Procedure Type</th>
<th>Paper Baseline Before EHR</th>
<th>Early EHR (mo 1-3)</th>
<th>Late EHR (mo 4-12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Documentation Time (SD), min</td>
<td>No.</td>
</tr>
<tr>
<td>Cataract</td>
<td>25</td>
<td>6.6 (0.9)</td>
<td>47</td>
</tr>
<tr>
<td>Cornea and glaucoma</td>
<td>10</td>
<td>9.5 (2.6)</td>
<td>6</td>
</tr>
<tr>
<td>Vitreoretinal</td>
<td>10</td>
<td>7.6 (2.5)</td>
<td>18</td>
</tr>
<tr>
<td>Extraocularb</td>
<td>13</td>
<td>7.6 (4.2)</td>
<td>12</td>
</tr>
<tr>
<td>Mean total</td>
<td>58</td>
<td>7.5 (2.7)</td>
<td>83</td>
</tr>
</tbody>
</table>

Abbreviation: EHR, electronic health record.

* Comparison of absolute intraoperative documentation time in minutes in paper vs early EHR or paper vs late EHR periods. Two sample t tests with unequal variances were performed in the cataract group. Wilcoxon rank-sum tests were used in all other groups.

b The extraocular category includes procedures of the eyelid, lacrimal system, orbit, and extraocular muscles, and examinations under anesthesia.

Surgical Volume

The Figure displays the surgical volume before vs after implementation of the EHR OR management system. The 21 stable ophthalmic providers performed a total of 3581 procedures (mean [SD], 14.2 [8.3] procedures/mo) during the 12 months before implementation compared with 3765 surgical procedures (mean [SD], 14.9 [9.5] procedures/mo) during the 12 months after implementation. There were no significant differences in surgical volume between the paper vs early EHR (mean [SD], 15.6 [9.7] procedures/mo) periods (P = .11) or between the paper vs late EHR (mean [SD], 14.7 [9.7] procedures/mo) periods (P = .55) by paired t test.

OR Staffing Requirements

The Figure also displays the OR staffing requirements before vs after EHR implementation. There were a total of 190.1 FTEs (mean [SD], 15.8 [2.1] FTEs/mo) during the 12 months before implementation compared with 191.6 FTEs (mean [SD], 16.0 [1.8] FTEs/mo) during the 12 months after implementation. Table 4 displays the number of circulating nurses required per procedure before vs after EHR implementation. Cataract procedures were most affected, requiring more circulating nurses in both early and late EHR periods vs in the paper baseline.

Table 4

Impact of EHR in Ophthalmology
mentation time, this worsened in all 4 procedure categories during the early EHR period (Table 3) and remained significantly worse than in the paper baseline and in the late EHR period in all categories except cornea and glaucoma.

We believe the worsening in documentation time after EHR implementation may be primarily attributed to several factors. First, documentation using point-and-click EHR interfaces may be slower than paper-based forms, which were optimized for efficiency over many years. For example, the study EHR requires users to navigate checkboxes to select the route of medication administration (eg, intraocular vs topical), site of administration (eg, left eye), and name of prescribing surgeon for every medication. Previously, we found that ophthalmology documentation time in the outpatient setting was slower with EHR than paper forms for these reasons.11,13 Second, overall documentation volume required by the EHR system was greater than with the baseline paper system (eTables 1-3 in Supplement). We have also demonstrated this in the ophthalmology outpatient clinic setting.28 It is not surprising that these factors have less relative effect on longer surgical procedures and that the overall impact was worse when expressed as absolute time than POTD.

With regard to the overall improvement in documentation times during the late EHR period, we believe this may be attributed to natural learning curves, as well as several actions performed by OR staff. First, the department prepared for the transition by providing substantial EHR training (8 hours/nurse). Second, optimization of the EHR by nurses was initiated following implementation. For example, nurses initially had difficulty adjusting to terms used for supplies and medications imposed by the EHR. The supply lists were optimized by adding more intuitive titles and customized to each surgeon and procedure type. We feel these continuous optimizations will be required to improve documentation speed and overall efficiency.

More generally, previous studies regarding the quantitative impacts of EHR implementation on clinical efficiency have
reported mixed results. A review on the impact of EHRs on the efficiency of physicians and nurses found overall worsening of documentation times with EHR systems. A study in primary care internal medicine practices found that documentation times initially worsened but returned to near-baseline levels after an adjustment period, while another study found significant improvements in documentation time 6 months after implementation in an intensive care unit. In ophthalmology, Pandit and Boland found worsening of physician documentation times with a concurrent increase in the time spent examining and talking with patients following EHR implementation in a glaucoma practice. In a separate study at our institution, outpatient health care providers spent significantly more time documenting outside of work hours, and each patient encounter took longer using an EHR vs a paper-based system. Overall, large knowledge gaps remain regarding the impact of EHRs on care delivery particularly in surgical settings.

A second key finding was that surgical volume and total OR staffing did not change significantly throughout the EHR implementation period. From a practice management perspective, it is reassuring that no negative impact was observed. Within ophthalmology, research on the impact of EHR systems on clinical volume has been limited. Pandit and Boland found that annual clinical volumes before vs after EHR implementation in a glaucoma practice were not significantly different. In contrast, a study at our institution found that compared with the 3 months of paper baseline, outpatient clinical volume worsened 3% to 7% during the first 3 years after EHR implementation. Outside ophthalmology, findings have also been mixed. A pediatric surgery practice found a 35% increase in surgical volume following EHR and operations management implementation. A separate study conducted in ambulatory clinics at an academic medical center found no obvious impact on clinical efficiency following EHR implementation.

Two studies conducted in primary care settings reported a trend of initial worsening in clinical volume after EHR implementation, with subsequent recovery. With regard to OR staffing in our study, an additional circulating nurse (approximately 0.6 FTEs) was required during the early EHR period. This was attributed to the higher relative increase in documentation burden in cataract and other shorter procedures (Table 2). Staff members were asked to work additional hours during the early EHR period following the observation during the pre-implementation training period that documentation took longer. These additional staff members helped provide patient care while other staff members learned to use the EHR. While remaining significantly above paper baseline for cataract, staffing requirements improved to baseline in all other procedure types in the late EHR period (Table 4). We feel that EHR optimization may have contributed to this improvement, but we note that this study was not designed to explain changes in surgical volume or evaluate the cost-effectiveness of implementing EHR systems. Taken together, these findings highlight the importance of developing systems and user interfaces that will ultimately improve the quality and efficiency of patient care.

There are several additional potential study limitations: (1) The complexity of surgical procedures and the quality or completeness of intraoperative documentation were not fully accounted for. These factors may have affected documentation times (eTables 1-3 in Supplement). There are few agreed-on methods to assess case complexity or the quality and amount of documentation. (2) Different procedure types and individual nurses were not evenly represented across all periods. This may have created bias owing to differences in distribution among surgical procedures or nurses and differences in documentation speed among nurses. It was difficult to capture standard data sets from nurses and procedures across all periods owing to the pattern of nurses working in different procedure types during different periods. We adjusted for some of this variability by analyzing the POTD metric. Additionally, documentation time trends were generally consistent across procedure types in this study. (3) Our study was limited to ophthalmic ORs in an academic medical center. Ophthalmic procedures are commonly shorter than many other procedures, and documentation amount may not increase linearly with procedure time. Findings may not be generalizable to practices with differing patient, nurse, physician, or specialty characteristics.

Conclusions

Overall, this study found that intraoperative documentation times worsened after EHR implementation. Surgical volumes and staffing requirements remained relatively constant, although we observed an increase in the number of circulating nurses required for cataract procedures. These findings have implications for clinicians and institutions planning to implement EHRs in surgical settings and for those interested in the impact of EHRs on the quality and efficiency of clinical care.
Previous Presentation: Portions of this study were presented at the Association for Research in Vision and Ophthalmology Annual Meeting; May 8, 2013; Seattle, Washington.

REFERENCES