# *IMPACT OF AN ELECTRONIC HEALTH RECORD OPERATING ROOM MANAGEMENT SYSTEM ON DOCUMENTATION TIME, SURGICAL VOLUME, OPERATING ROOM TURNOVER TIME AND STAFFING IN OPHTHALMOLOGY*

By

David S. Sanders

A THESIS

Presented to the Department of Public Health and Preventive Medicine
and the Oregon Health & Science University School of Medicine
in partial fulfillment of the requirements for the degree of

Master of Public Health

April 14, 2014

Department of Public Health and Preventive Medicine

School of Medicine

Oregon Health & Science University

---

CERTIFICATE OF APPROVAL

---

This is to certify that the Master's thesis of

David S. Sanders

has been approved

_____

Mentor/Advisor: Michael Chiang, MD

_____

Member: Dongseok Choi, PhD

_____

Member/Chair: William Lambert, PhD

**Table of Contents**

**Figures, Tables & Appendices**

Figures:



Tables:



Appendices

**Abbreviations & Glossary**

**Electronic Health Record (EHR)** - a digital version of a patient's chart that is real-time, patient-centered, and makes information available instantly and securely to authorized users.

**Operating Room (OR)** – this study took place in an operating suite containing several ophthalmic operating rooms at Casey Eye Institute of Oregon Health & Science University

**Percentage of Operating Time Documenting (POTD, %)** - the absolute intraoperative nursing documentation time divided by the total procedure time (defined as the time elapsed between first surgical incision [or beginning examination under anesthesia] and completion of the procedure).

**Percent of Procedure Time Documenting (PPTD, %)** - the total intraoperative documentation time divided by the "total procedure time", which was defined as the total time a patient spent in the operating room (from entering to exiting the operating room).

**Full-time equivalent (FTE)** - units of work performed by OR nurses and technicians. One individual working full-time is equivalent to 1.0 FTE. "Productive" FTEs refer to net hours on-duty including clinical responsibilities, education time, and meetings (i.e. excluding paid vacation or sick leave).

**Analysis of variance** (**ANOVA**) – a group of statistical models used to detect differences between group means in more than two groups

**Acknowledgments**

Foremost, I would like to thank my thesis committee, including Drs. Michael Chiang, Dongseok Choi, William Lambert, who have provided excellent advice and mentorship prior to and throughout the course of this thesis.

Additionally, I am indebted to Ms. Sarah Read-Brown, who spent many days in the operating room, performing data collection on the OpTime project. Sarah was invaluable in providing advice on the subtleties of the data set during data cleaning and analysis. Additionally ,Ms. Read-Brown, Ms. Bella Almario, Ms. Anna Brown, and Drs. Daniel Tu, Dongseok Choi, William Lambert, Thomas Yackel and Michael Chiang all significantly contributed to manuscripts resulting from the OpTime project, which established the framework for this thesis.

The faculty of the Department of Public Health and Preventive Medicine at Oregon Health & Science University has supported me throughout my education at Oregon Health & Science University. I am especially thankful for the Dr. John Stull who has contributed to my education in epidemiology and life.

I am incredibly grateful to my wife, Krisanna, the rest of my incredible family (including my dog, Fiona) and friends, who provided unconditional support throughout the MD/MPH journey.

**Abstract**

**Importance**: Although electronic health record (EHR) systems have potential benefits such as improved safety and quality of care, the majority of 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 management systems on clinical efficiency in the ophthalmic surgery setting is unknown.
**Objective**: To determine the impact of an EHR operating room management system on intraoperative nursing documentation time, surgical volume and staffing requirements.
**Design**: For documentation time and circulating nurses per procedure, a prospective cohort design was employed between 2012 and 2013. For surgical volume, overall staffing requirements, and documentation elements, case series designs were employed.
**Setting**: Ophthalmic operating rooms at an academic medical center.
**Participants**: All ophthalmic operating room nurses and surgeons.
**Exposure**: EHR operating room management system implementation.
**Main Outcome Measures**: 1) Documentation time (absolute documentation time [minutes], percentage of operating time documenting [POTD]), 2) Surgical volume (procedures/time), 3) Staffing requirements (full-time equivalents [FTEs], circulating nurses/procedure), 4) Operating room turnover times (minutes). Outcomes were measured during paper baseline, and during the early (first 3 months) and late (4-12 months) periods after 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 late EHR (46%, $P$=0.28), although POTD in the "cataract" group remained worse than 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 late EHR (9.2 minutes), but remained worse than baseline ($P$<.001). There was significant differences in documentation times among nurses in the early EHR period ($P$=.03). Two-way ANOVA analysis revealed significant main effects of nurses ($P$=.005), time period ($P$<.0001), and the interaction between these variables ($P$=.008). While cataract procedures required more circulating nurses in early EHR (mean 1.9 nurses/procedure) and late EHR (mean 1.5 nurses/procedure) than paper (mean 1.0 nurses/procedure) ($P$<.001), overall staffing requirements, operating room turnover time and surgical volume were not significantly different between time periods.
**Conclusions**: EHR operating room management system implementation was associated with worsening of intraoperative nursing documentation time, especially in shorter procedures. However, it is possible to implement an EHR operating room management system without serious negative impacts on surgical volume, operating room turnover times, and staffing requirement.

## INTRODUCTION

Electronic health record (EHR) systems have been identified as an essential technology for improving the safety, quality, and efficiency of medical care.[1] The federal government instituted an aggressive program to promote EHR adoption through the Health Information Technology for Economic and Clinical Health (HITECH) act, which provides financial incentives to physicians and hospitals for "meaningful use" of these systems.[2-4] 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, compared to a similar survey in 2007 which found 12% adoption.[5,6]

Despite this increase in adoption, there are persistent concerns regarding unique challenges of EHRs in specialized fields such as ophthalmology.[7-9] Many EHRs used by ophthalmologists are institution-wide systems that were originally designed for primary care practices. They were not designed for the unique workflow and documentation requirements of ophthalmology, in which paper charting methods have traditionally relied on drawings and annotations using examination templates.[7] Clinicians have voiced concerns that EHRs may be associated with increasing time requirements, workflow disruption, and negative impact on clinical volume and patient care.[5,6,10-12] 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).

There are few published studies on how EHR systems affect overall clinical efficiency and documentation speed.[11-17] Due to 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 that have been associated with the quality, cost, and efficiency of surgical care.[18-21] Additionally, operating room procedures and associated stays have been estimated to account for 47% of U.S. hospitals' costs, totalling $161 billion in 2007.[22] 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 thesis, I aim to evaluate effects of implementing an EHR OR management system on intraoperative nursing documentation time, surgical volume, staffing requirements and operating room turnover time. Comparison is 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 (OHSU), and was granted an exemption because data were collected in a manner in which patients could not be identified.

### Description of study institution and pre-existing electronic health record system

Casey Eye Institute (CEI) is the ophthalmology department at OHSU, a large academic medical center in Portland, Oregon. There are over 50 faculty providers who perform over 4,000 surgical procedures annually in 4 ophthalmic ORs. Every procedure is staffed by an ophthalmologist; an anesthesiologist or certified registered nurse anesthetist; a scrub nurse or technician; and a circulating nurse who manages surgical inventory, performs direct patient care, and completes documentation. A fellow or resident physician assists with most

procedures. In 2006, an institution-wide EHR system (EpicCare; Epic Systems, Madison, WI) was implemented at OHSU. This vendor develops software for mid-size and large medical practices, is a market share leader among large hospitals, and has implemented its EHR systems at over 200 hospital systems in the United States. Since 2006, all tasks involving clinical documentation, ambulatory practice management, and billing have been performed using components of this institution-wide EHR.

EHR OR management system

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

The institution-wide planning related to the OpTime operating room management system began one year earlier (January 2011). Within the ophthalmology department, this involved an institution-wide nurse champion, a departmental nurse champion, a physician champion, the director of peri-operative services, the materials coordinator, and the senior quality assurance manager. Preparations included attending validation and planning meetings with the vendor, work flow analysis, pre-populating the software with relevant information, supply chain management, and end-user education.

In December 2011 (1 month prior to implementation), seven nurse “super-users” were selected based on their job roles and perceived computer skills. Super-users received an early 8-hour system training session, were given an extensive preview of the software, and were

taught to act as peer instructors. All other nurses received 8 hours of system training prior to implementation.

In January 2012, the system implementation occurred. Anticipating difficulties with EHR adoption during the first 2 weeks, the department increased nurse staffing (from 1 to 2 circulating nurses) in rooms with short procedures. Additionally, 2 information technology consultants and 2 nurse super-users were present each day during the first 2 weeks after implementation.

The EHR OR management system contains tools for surgical processes such as scheduling, staffing, and materials management. It also includes anesthesiology, intraoperative, and perioperative nursing documentation capabilities.

Time-motion analysis of nursing documentation time

Precise documentation times were captured by observation of nurses using a time-motion method.[12,23] Data were collected by an observer (SRB) who monitored actions of circulating nurses using a paper log sheet and a handheld computer with time-stamping software (Emerald Timestamp; Emerald Sequoia, Los Gatos, CA). This data collection method underwent 3 cycles of pilot testing and modification prior to beginning the study. Data were gathered on type of procedure, intraoperative documentation times, procedure start and stop times, and number of staff 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 one year before to one year after implementation of the EHR OR management system. To control for changes in the number of surgeons over time, a group of 21 "stable surgeons" was identified as those who operated continuously throughout the study period (i.e. gap of <1 month in procedures performed) (**Table 1**). Surgeon characteristics were obtained using publicly-available data sources.[24-26] Surgical volumes (procedures/time) were compared before vs. after EHR implementation.

Staffing Requirements

OR staffing requirements were determined by querying the payroll system from one year before to one year after EHR implementation. Results were measured in monthly productive full-time equivalent (FTE) units worked by all OR nurses and technicians. One individual working full-time is equivalent to 1.0 FTE,[27] and "productive" FTEs refer to net hours on-duty including clinical responsibilities, education time, and meetings (i.e. excluding paid vacation or sick leave). The number of circulating nurses (responsible for documentation) was also recorded for each procedure.

Operating Room Turnover Time

Turnover times for each room were determined by marking the time elapsed between one patient leaving the operating room and the subsequent patient entering the operating room. Turnover times were excluded if the previous case ended early or if there was a scheduled gap between procedures.

Quantity and Type of Documentation

To examine the amount of documentation performed in paper vs. EHR systems, discrete "documentation elements" (e.g., free text, checkboxes) in both systems were counted for two

representative procedure types: cataract extraction and blepharoplasty (1 procedure each in paper and EHR). Two authors (DSS, SRB) independently counted and categorized elements according to portions of the surgery they corresponded to. Discrepancies were resolved through verbal discussion.

Data Analysis

The absolute intraoperative nursing documentation time was calculated for each procedure based on time-motion data collected. Due to variability in the duration of each surgery and distribution of procedure types across different time periods of the study, the "Percent Procedure Time Documenting" (PPTD, %) and the "percentage of operating time documenting (POTD, %) were also calculated for each procedure. The PPTD was calculated by dividing the total intraoperative documentation time by the total procedure time, which was defined as the total time a patient spent in the operating room. POTD was calculated by dividing the absolute intraoperative nursing documentation time by the total procedure time (defined as the time elapsed between first surgical incision [or beginning examination under anesthesia] and completion of the procedure).

Surgical procedures were clustered into 4 broad categories to facilitate data analysis and display: (1) Cataract (isolated cataract extraction with intraocular lens implantation); (2) Cornea & glaucoma (anterior segment procedures other than cataract extraction, and incisional glaucoma procedures); (3) Vitreoretinal (scleral buckle, vitrectomy); and (4) Extraocular (procedures involving the eyelids, lacrimal system, orbit, extraocular muscles, and examinations under anesthesia).

Operating room "turnover times" were defined as the time elapsed between one patient leaving the operating room and the subsequent patient entering the operating room for

another procedure. Turnover times were excluded from analysis if the previous case ended early or if there was a scheduled gap between procedures.

Data were compared over three time periods: (1) *Paper baseline*. For documentation time, this was defined as three weeks before EHR implementation. For surgical volume and staffing requirements, this was defined as one year before implementation. (2) *Early EHR period*, defined as the first three months after implementation of the OR management system. (3) *Late EHR period*, defined as months 4-12 after implementation.

Descriptive statistics, Wilcoxon rank-sum tests, independent sample *t* tests and paired *t* tests and one-way and two-way ANOVA models were performed as appropriate, for comparison of absolute intraoperative documentation times, PPTD, POTD, surgical volume, staffing requirements, and operating room turnover times. Analyses were performed using statistical software (Stata v12; StataCorp, College Station, TX).

## RESULTS

### General characteristics of the ORs and surgical procedures

Throughout the study period (one year prior to and one year after EHR implementation), there were 9,331 surgical procedures performed by 54 different surgeons, involving 13 nurses. Overall, 259 surgical procedures were observed for this study on 52 different days, yielding complete data on 236 procedures (58 procedures on 10 days with 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 sub-specialties represented (comprehensive, cornea, glaucoma, oculoplastics, pediatric, vitreoretinal). The 236 procedures were clustered

into 4 broad groups: 107 (45%) cataract, 34 (14%) cornea & glaucoma, 37 (16%) vitreoretinal, and 58 (25%) extraocular.

Intraoperative Documentation Time

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

**Table 3** summarizes absolute intraoperative documentation time (minutes). During the early EHR period, there was significant overall worsening in absolute intraoperative documentation time in all 4 procedure categories, with subsequent improvement to baseline in the cornea & glaucoma category during the late EHR period. All other categories improved, but remained significantly worse than paper baseline.

Among the 8 nurses who documented in both paper and early EHR implementation periods (**Table 2**), all had worsening in documentation time during the early EHR period. A separate analysis including 6 nurses with the most observations showed that 4 of 6 had statistically significant worsening ($P<.05$). During the early EHR implementation period, the fastest nurse had documentation time of 10.6 ± 3.8 minutes/procedure, compared to 34.5 ± 27.4 minutes/procedure in the slowest nurse. During the late EHR period, the fastest nurse had documentation time of 7.5 ± 2.7 minutes/procedure, compared to 10.8 ± 2.5 minutes/procedure in the slowest nurse. By one-way ANOVA analysis, there was no significant difference in documentation time among individual nurses during paper ($P=.08$) or late EHR periods ($P=.14$), but there were statistically significant differences among nurses during the early EHR period ($P=.03$). The variation in documentation time among nurses decreased significantly from early EHR to late EHR ($P=.004$, by two-sample variance comparison test). Two-way ANOVA

analysis revealed significant main effects of nurses (*P*=.005), time period (*P*<.0001), and the interaction between these variables (*P*=.008).

Surgical Volume

**Figure 2** displays the surgical volume before vs. after implementation of the EHR OR management system. The 21 stable providers performed a total of 3,581 surgical procedures (mean ± standard deviation [SD] 14.2 ± 8.3 procedures/month) during the 12 months before implementation, compared with 3,765 surgical procedures (mean ± SD 14.9 ± 9.5 procedures/month) during the 12 months after implementation. There were no significant differences in surgical volume between paper vs. early EHR (mean ± SD 15.6 ± 9.7 procedures/month) periods (*P*=.11), or between paper vs. late EHR (mean ± SD 14.7 ± 9.7 procedures/month) periods (*P*=.55), by paired *t* test.

OR Staffing Requirements

**Figure 2** also displays the OR staffing requirements before vs. after implementation. There were a total of 190.1 FTEs (mean ± SD 15.8 ± 2.1 FTEs/month) during the 12 months before implementation, compared with 191.6 FTEs (mean ± SD 16.0 ± 1.8 FTEs/month) during the 12 months after implementation. **Table 5** 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. paper.

Turnover Time and unintended consequences

**Table 6** summarizes operating room turnover times before vs. after EHR implementation. There were no statistically significant differences in the mean operating room turnover times between paper vs. early EHR, early EHR vs. late EHR, or paper vs. late EHR periods ($P \geq .18$ by Wilcoxon rank-sum test). After implementation, a change in the documentation style among circulating nurses was observed. This was characterized by an

increased tendency to document aspects of the following procedure in between procedures or during the downtime of the ongoing procedure. In the paper baseline period, we observed a single nurse document in this style in 1.7% (1/58) of procedures. This increased significantly after implementation, in the early EHR period 7 nurses documented 25.9% (22/85) of procedures in the new style (*P*<.001), and 5 nurses documented 16.5% (17/103) of procedures this way in the late EHR period.

Quantity and Type of Documentation

**Table 7** displays the total number of possible documentation elements and those documented in 2 paper cases and 2 EHR cases. Documentation categories with the highest number of manually entered documentation elements in paper and EHR are displayed in **Table 8** and **Table 9**, respectively.

## DISCUSSION

To our knowledge, this is the first study to analyze the impact of an EHR OR management system in ophthalmology, or any other surgical field. The key findings were: (1) There was overall worsening in intraoperative documentation time following implementation of an EHR OR management system, which eventually improved to near-paper baseline levels for most procedure categories; (2) There were significant differences among nurses with regard to mean documentation time during the early EHR period; (3) Surgical volume and overall OR staffing requirements did not change significantly after implementation, although an increase in circulating nurses persisted through the study period in cataract procedures; and (4) Operating room turnover times were not affected by implementation.

The first key study finding was that overall intraoperative documentation time worsened significantly after EHR implementation. When expressed as percentage of operating

time documenting (POTD), this worsened during the early EHR period in all procedural categories except cornea & glaucoma (**Table 3**), but improved to baseline levels during the late EHR period in all procedural categories except cataract. When expressed as absolute intraoperative documentation time, this worsened in all 4 procedure categories during the early EHR period (**Table 4**) and remained significantly worse than paper baseline in the late EHR period in all categories except cornea & 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 that were optimized for efficiency over many years. For example, the study EHR requires users to navigate checkboxes to select route of medication administration (e.g. intraocular vs. topical), site of administration (e.g. left eye), and name of prescribing surgeon for every medication. Previously, we have found that ophthalmology documentation time in the outpatient setting is 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 (**Tables 7-9**). 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 is worse when expressed as absolute time than POTD.

There was a significant variation among nurses regarding EHR documentation time. During the early EHR period, all nurses had worsened documentation time, with large variation among nurses ranging from 10.6-34.5 minutes/procedure (**Table 2**). This variation decreased over time. It is encouraging that documentation time improved in all nurses between the early and late EHR periods, and that variation among nurses also decreased. Previous research on EHRs and nursing documentation has reported varying conclusions.[17,29] A study of nursing

documentation in psychiatry reported an increase in the time required for computer-based documentation.[30] Several studies have reported that after the introduction of EHRs, the proportion of time nurses spent documenting was unchanged.[31,32] Additional qualitative research studies may help elucidate the factors related to early differences in nursing documentation time. This may have implications for operation and training for EHR systems, and for future research involving the design and usability of surgical EHR documentation systems.[7,33]

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 per 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.[12-14,16,17,34,35] A review on the impact of EHRs on efficiency of physicians and nurses found overall worsening of documentation times with EHR.[12] A study in primary care internal medicine practices found that documentation times initially worsened but returned to near-baseline after an adjustment period, while another study found significant improvements in documentation time 6 months after implementation in an intensive care unit.[16,17] In ophthalmology, Pandit et al found worsening of physician documentation times with a concurrent increase in time spent

examining and talking with patients following EHR implementation in a glaucoma practice.[36] In a separate study at our institution, outpatient providers spent significantly more time documenting outside of work hours, and each patient encounter took longer using an EHR vs. a paper-based system.[11] Overall, large knowledge gaps remain regarding the impact of EHRs on care delivery, particularly in surgical settings.

A third 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 impact of EHR systems on clinical volume has been limited.[6,11,36] Pandit et al found that annual clinical volumes before vs. after EHR implementation in a glaucoma practice were not significantly different.[36] In contrast, a study at our institution found that compared with the 3 months of paper baseline, outpatient clinical volume worsened 3-7% during the first three years after EHR implementation.[11] Outside ophthalmology, findings have also been mixed. A pediatric surgery practice found a 35% increase in surgical volume following EHR and operations management implementation.[34] A separate study conducted in ambulatory clinics at an academic medical center found no obvious impact on clinical efficiency following EHR implementation.[37] Two studies conducted in primary care settings reported a trend of initial worsening in clinical volume after EHR implementation, with subsequent recovery.[38,39] With regard to OR staffing in our study, one additional circulating nurse (approximately 0.6 FTE) 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 3**). Staff members were requested 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 utilize the EHR.

While remaining significantly worse than paper baseline for cataract, staffing requirements improved to baseline in all other procedure types in the late EHR period (**Table 5**). We feel that EHR optimization may have contributed to this improvement. Further details regarding this optimization (and findings of the Optime project that have contributed to this thesis) are described elsewhere.[40, 41] It should be noted that this study was not designed to explain changes in surgical volume or evaluate the cost-effectiveness of implementing EHR systems. Yet, 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. There are few agreed-upon methods to assess case complexity, or quality and amount of documentation. However, we attempted to characterize the documentation burden by quantifying documentation elements in example surgical cases (**Tables 7-9**). (2) Different procedure types and individual nurses were not evenly represented across all time periods. This may have created bias, due 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 time periods, due to the pattern of nurses working in different procedure types during different time periods. We adjusted for some of this variability by analyzing the percentage of operating time documenting (POTD) metric. Additionally, we note that 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, whereas surgical volumes, operating room turnover times and staffing requirements remained stable, although there was a persistent 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 quality and efficiency of clinical care.

**REFERENCES**


**1.** Committee on Improving the Patient Record, Institute of Medicine. *The Computer-Based Patient Record: An Essential Technology for Health Care, Revised edition.* Washington, DC: National Academy Press;1997.

**2.** Jha AK, Burke MF, DesRoches C, et al. Progress toward meaningful use: hospitals' adoption of electronic health records. *Am J Manag Care.* Dec 2011;17. SP117-124.

**3.** Boland MV. Meaningful use of electronic health records in ophthalmology. *Ophthalmology.* Dec 2010;117(12):2239-2240.

**4.** Goldstein MM, Thorpe Jane H. The First Anniversary of the Health Information Technology for Economic and Clinical Health (HITECH) Act: the regulatory outlook for implementation. *Perspect Health Inf Manag.* 2010;7.

**5.** Boland MV, Chiang MF, Lim MC, et al. Adoption of Electronic Health Records and Preparations for Demonstrating Meaningful Use: An American Academy of Ophthalmology Survey. *Ophthalmology.* Jun 2013.

**6.** Chiang MF, Boland MV, Margolis JW, et al. Adoption and perceptions of electronic health record systems by ophthalmologists: an American Academy of Ophthalmology survey. *Ophthalmology.* Sep 2008;115(9):1591-1597; quiz 1597 e1591-1595.

**7.** Chiang MF, Boland MV, Brewer A, et al. Special requirements for electronic health record systems in ophthalmology. *Ophthalmology.* Aug 2011;118(8):1681-1687.

**8.** Kokkonen EW, Davis SA, Lin HC, Dabade TS, Feldman SR, Fleischer AB. Use of electronic medical records differs by specialty and office settings. *Journal of the American Medical Informatics Association : JAMIA.* Jun 2013;20(e1):e33-38.

**9.** Wagner M, Rich M; KLAS. Ambulatory EMR Specialty 2012: Finding the Fit. http://klasresearch.com/content/PDF/SampleReport/Summary_Amb_EMR_by_Specialty_Summary_2-16-12_129739074468914821.pdf. Published February 2012. Accessed July 15, 2013.

**10.** Miller RH, Sim I. Physicians' use of electronic medical records: barriers and solutions. *Health Aff (Millwood).* 2004 Mar-Apr 2004;23(2):116-126.

**11.** Chiang MF, Read-Brown S, Tu DC, et al. Evaluation of electronic health record implementation in ophthalmology at an academic medical center. *Trans Am Ophthalmol Soc.* 2013 Sep;111:70-92.

**12.** Poissant L, Pereira J, Tamblyn R, Kawasumi Y. The impact of electronic health records on time efficiency of physicians and nurses: a systematic review. *Journal of the American Medical Informatics Association: JAMIA.* Sep-Oct 2005;12(5):505-516.

**13.** Chan P, Thyparampil PJ, Chiang MF. Accuracy and speed of electronic health record versus paper-based ophthalmic documentation strategies. *American Journal of Ophthalmology.* Jul 2013;156(1):165-172.e162.

**14.** Chaudhry B, Wang J, Wu S, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Ann Intern Med.* May 2006;144(10):742-752.

**15.** Menke JA, Broner CW, Campbell DY, McKissick MY, Edwards-Beckett JA. Computerized clinical documentation system in the pediatric intensive care unit. *BMC Med Inform Decis Mak.* 2001;1:3.

**16.** Overhage JM, Perkins S, Tierney WM, McDonald CJ. Controlled trial of direct physician order entry: effects on physicians' time utilization in ambulatory primary care internal medicine practices. *Journal of the American Medical Informatics Association : JAMIA.* 2001 Jul-Aug 2001;8(4):361-371.

**17.** Wong DH, Gallegos Y, Weinger MB, Clack S, Slagle J, Anderson CT. Changes in intensive care unit nurse task activity after installation of a third-generation intensive care unit information system. *Crit Care Med.* Oct 2003;31(10):2488-2494.

**18.** Greenberg CC, Regenbogen SE, Lipsitz SR, Diaz-Flores R, Gawande AA. The frequency and significance of discrepancies in the surgical count. *Ann Surg.* Aug 2008;248(2):337-341.

**19.** Park KW, Dickerson C. Can efficient supply management in the operating room save millions? *Curr Opin Anaesthesiol.* Apr 2009;22(2):242-248.

**20.** Stabile M, Cooper L. Review article: the evolving role of information technology in perioperative patient safety. *Can J Anaesth.* Feb 2013;60(2):119-126.

**21.** Wu RL, Aufses AH. Characteristics and costs of surgical scheduling errors. *Am J Surg.* Oct 2012;204(4):468-473.

**22.** Agency for Healthcare Research and Quality. Operating room procedures account for nearly half of hospitals' treatment costs. *Research Activities.*

http://www.ahrq.gov/news/newsletters/research-activities/mar11/0311RA32.html.

**23.** Finkler SA, Knickman JR, Hendrickson G, Lipkin M, Thompson WG. A comparison of work-sampling and time-and-motion techniques for studies in health services research. *Health Serv Res.* Dec 1993;28(5):577-597.

**24.** Casey Eye Institute. Casey Eye Institute Care Providers website. http://www.ohsu.edu/xd/health/services/casey-eye/clinical-services/casey-providers.cfm. Accessed July 15, 2013.

**25.** Oregon Academy of Ophthalmology: Eye physicians and surgeons. Find an Eye M.D. website. http://www.oregoneyephysicians.org. Accessed July 15, 2013.

**26.** State of Oregon Medical Board. License Verification Search website. 2013. https://techmedweb.omb.state.or.us/Clients/ORMB/Public/VerificationRequest.aspx. Accessed July 15, 2013.

**27.** Zimmerman PG, ed. *Nursing Management Secrets*. Philadelphia, PA: Hanley & Belfus; 2002:55.

**28.** Sanders DS, Lattin DJ, Read-Brown S, Tu DC, Wilson DJ, Hwang TS, Morrison JC, Yackel TR, Chiang MF. Electronic health record systems in ophthalmology: impact on clinical documentation. *Ophthalmology* 2013 Sep;120(9):1745-55

**29.** Saarinen K, Aho M. Does the implementation of a clinical information system decrease the time intensive care nurses spend on documentation of care? *Acta Anaesthesiol Scand*. 2005;49:62-5.

**30.** Ammenwerth E, Eichstädter R, Haux R, Pohl U, Rebel S, Ziegler S. A randomized evaluation of a computer-based nursing documentation system. *Methods Inf Med.* May 2001;40(2):61-68.

**31.** Munyisia EN, Yu P, Hailey D. Does the introduction of an electronic nursing documentation system in a nursing home reduce time on documentation for the nursing staff? *Int J Med Inform*. 2011;80:782-92.

**32.** Yee T, Needleman J, Pearson M, Parkerton P, Parkerton M, Wolstein J. The influence of integrated electronic medical records and computerized nursing notes on nurses' time spent in documentation. *Comput Inform Nurs.* 2012;30:287-92.

**33.** Armijo D, McDonnell C, Werner K. Electronic Health Record Usability: Interface Design Considerations. AHRQ Publication No. 09(10)-0091-2-EF. 2009 Oct. Rockville, MD: AHRQ.

**34.** Foglia RP, Alder AC, Ruiz G. Improving perioperative performance: the use of operations management and the electronic health record. *J Pediatr Surg.* Jan 2013;48(1):95-98.

**35.** Tierney WM, Miller ME, Overhage JM, McDonald CJ. Physician inpatient order writing on microcomputer workstations. Effects on resource utilization. *JAMA : the journal of the American Medical Association.* Jan 1993;269(3):379-383.

**36.** Pandit RR, Boland MV. The impact of an electronic health record transition on a glaucoma subspecialty practice. *Ophthalmology.* Apr 2013;120(4):753-760.

**37.** Grieger DL, Cohen SH, Krusch DA. A pilot study to document the return on investment for implementing an ambulatory electronic health record at an academic medical center. *J Am Coll Surg.* Jul 2007;205(1):89-96.

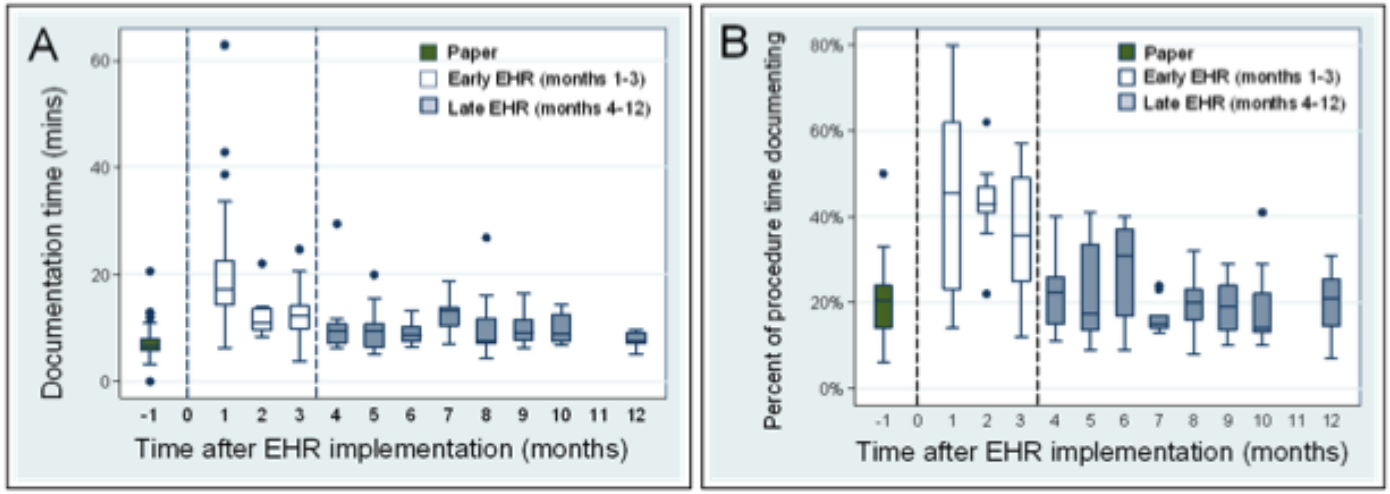
**38.** Miller RH, Sim I, Newman J. Electronic medical records in solo/small groups: a qualitative study of physician user types. *Studies in health technology and informatics.* 2004;107(Pt 1):658-62.

**39.** Wang SJ, Middleton B, Prosser LA, et al. A cost-benefit analysis of electronic medical records in primary care. *Am J Med.* Apr 2003;114(5):397-403.

**40.** Read-Brown S, Sanders DS, Brown AS, Yackel TR, Choi D, Tu DC, Chiang MF. Time-motion analysis of clinical nursing documentation during implementation of an electronic operating room management system for ophthalmic surgery. *AMIA Annu Symp Proc*. Nov 2013;2013:1195-204.

**41.** Sanders DS, Read-Brown S, Tu DC, Lambert WE, Choi D, Almario BM, Yackel TR, Brown AS, Chiang MF. Impact of an electronic health record operating room management system in ophthalmology on documentation time, surgical volume, and staffing. *JAMA Ophthalmol*. May 2014;132(5):586-92.

**Figure 1. Monthly (A) intraoperative nursing documentation time and (B) percent of procedure time documenting after EHR implementation.** Data are shown using boxplots* over three time periods: paper baseline, early EHR (months 1-3), and late EHR (months 4-12). Vertical dashed lines indicate transitions between time periods.




* Median documentation time is indicated by the central horizontal line of each box, while the ends of each box represent the first and third quartiles (25th and 75th percentile). Upper and lower whiskers represent the most extreme values within 1.5 times the interquartile range from these quartiles. Dots represent potential outlier values.

**Figure 2. Surgical volume and staffing requirements in ophthalmic operating rooms during electronic health record (EHR) implementation**. Monthly totals for volume (number of procedures) and full-time equivalents (FTE) were collected the year before and the year after implementation. Differences between time periods were not found to be statistically significant.

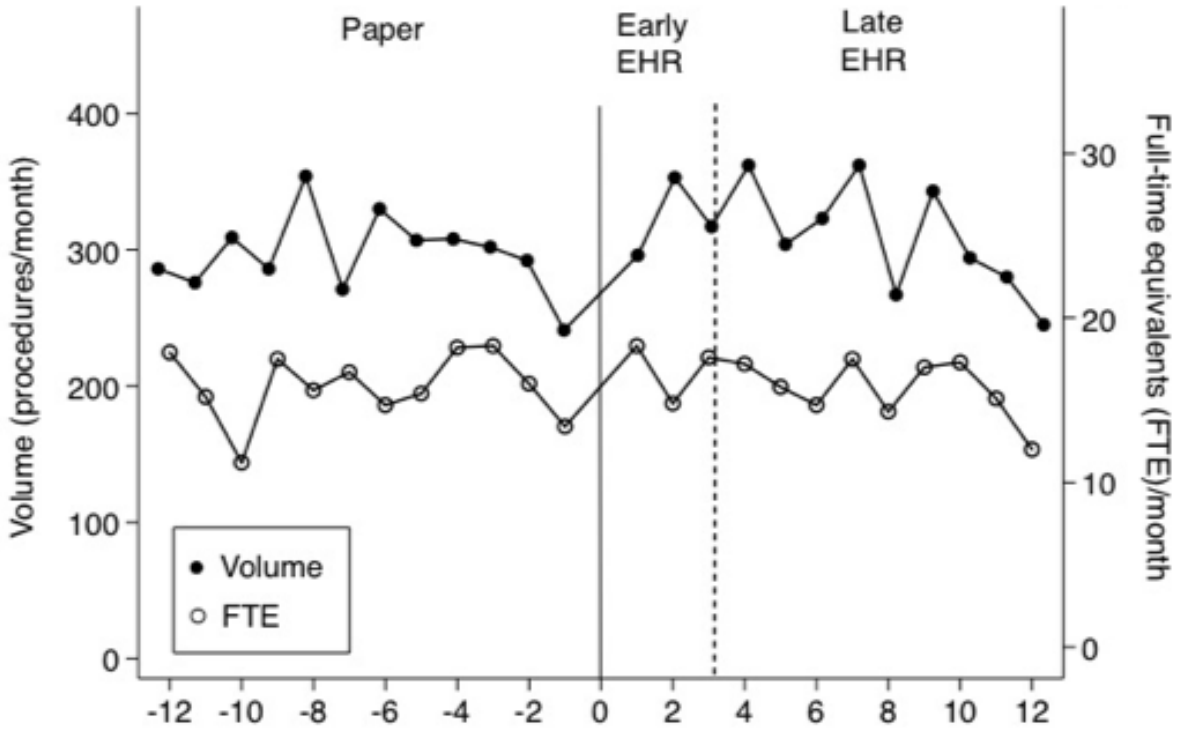


**Figure 3. Example of documentation challenges using an EHR operating room management system compared to paper.** (A) Displays multiple steps involved in documenting administration of medications in the EHR. (B) Shows the paper form used to document medication administration.

A


B

| INTRA OPERATIVE | | | |
|---|---|---|---|
| MEDICATION ROUTE | LOC. | DOSE | INITIAL |
| Lidocaine ☐ 1% ☐ 2% ☐ 2% w/ EPI ☐ 1% w/ EPI ☐ Hyaluronidase | | LOCAL | |
| Bupivacaine ☐ 0.5% ☐ 0.75% ☐ 0.5% w/ EPI | | LOCAL | |
| Lidocaine 1% PF ☐ Non Buffered ☐ Buffered ☐ Shugarcaine | | LOCAL | |
| ☐ Proparacaine 0.5% drops ☐ Tetracaine 0.5% ☐ Cocaine 4% sol. ☐ Afrin | | TOPICAL | |
| ☐ BSS ☐ BSS PLUS | | | |

**Table 1. Characteristics of 21 stable ophthalmic surgeons who operated throughout study period** [a]

| | |
|---|---|
| Male gender, n (%) | 15 (71%) |
| Surgeon age, mean ± SD (range) [b] | 46.5 ± 10.2 (31-65) |
| Years in Practice [b] | |
| Mean ± SD (range) | 15.9 ± 8.5 (3-30) |
| <10 years, n (%) | 6 (29%) |
| 10-19 years, n (%) | 8 (38%) |
| >19 years, n (%) | 7 (33%) |
| Sub-specialty, n (%) | |
| Comprehensive | 1 (5%) |
| Cornea | 3 (14%) |
| Glaucoma | 3 (14%) |
| Oculoplastics | 3 (14%) |
| Pediatric ophthalmology | 5 (24%) |
| Vitreoretinal | 6 (29%) |

a "Stable ophthalmic surgeons" were identified as those who operated continuously one year prior to and one year following implementation of the EHR (<1 month gap in operating out of the 24 months)
b "Surgeon age" and "years in practice" refer to the beginning of the study period (2011)

**Table 2. Intraoperative nursing documentation time (in minutes) by individual nurse over three time periods: paper baseline, early EHR (months 1-3), and late EHR (months 4-12).** Data are displayed by individual nurse for the number of procedures recorded, mean documentation time, and percent of procedure time documenting (PPTD).

| Nurse | Paper | | | Early EHR | | | Late EHR | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | Documentation Time (mean ±SD) | PPTD | n | Documentation Time (mean ±SD) | PPTD | n | Documentation Time (mean ±SD) | PPTD |
| A | 15 | 7.6 ± 2.0 | 23% | 6 | 19.4 ± 12.8 | 39% | 9 | 9.9 ± 2.0 | 19% |
| B | 3 | 4.8 ± 1.4 | 8% | 9 | 10.6 ± 3.8 | 30% | 4 | 7.6 ± 1.8 | 27% |
| C | 7 | 8.1 ± 5.6 | 21% | 9 | 21.7 ± 10.0 | 39% | 16 | 9.0 ± 2.5 | 17% |
| D | 4 | 10.3 ± 2.7 | 21% | 3 | 34.5 ± 27.4 | 43% | 13 | 7.5 ± 2.7 | 18% |
| E | 7 | 8.7 ± 2.3 | 19% | 4 | 20.1 ± 5.9 | 27% | 1 | 8.7 | 37% |
| F | 15 | 6.4 ± 0.8 | 23% | 1 | 15.7 | 16% | 13 | 9.1 ± 2.2 | 22% |
| G | 3 | 8.2 ± 2.3 | 13% | 7 | 13.9 ± 7.4 | 35% | 1 | 10.8 | 15% |
| H | 1 | 7.9 | 14% | 8 | 17.1 ± 4.7 | 34% | 7 | 8.5 ± 1.6 | 30% |
| I | – | – | – | 2 | 13.8 ± 0.7 | 47% | – | – | – |
| J | 3 | 6.2 ± 0.8 | 11% | – | – | – | 5 | 8.1 ± 1.2 | 25% |
| K | – | – | – | 21 | 13.4 ± 3.2 | 48% | 17 | 10.4 ± 4.1 | 20% |
| L | – | – | – | 6 | 15.3 ± 4.4 | 57% | 3 | 10.0 ± 2.1 | 23% |
| M | – | – | – | 9 | 18.4 ± 5.2 | 49% | 14 | 10.8 ± 2.5 | 22% |
| **Total** | **58** | **7.5 ± 2.7** | **20%** | **85** | **16.5 ± 8.6** | **41%** | **103** | **9.3 ± 2.8** | **21%** |

**Table 3. Mean percentage of operating time documenting (POTD, %) before and after electronic health record (EHR) implementation in the operating rooms.** 45 The three time periods studied included paper (baseline before EHR implementation), early EHR (months 1-3), and late EHR (months 4-12).

| | Paper | | Early EHR (months 1-3) | | | Late EHR (months 4-12) | | |
|---|---|---|---|---|---|---|---|---|
| **Procedure type** | n | POTD ± SD (%) | n | POTD ± SD (%) | *P* [a] | n | POTD ± SD (%) | *P* [a] |
| Cataract | 25 | 48 ± 12 | 47 | 102 ± 39 | <.001 | 35 | 64 ± 18 | <.001 |
| Cornea & Glaucoma | 10 | 47 ± 45 | 6 | 32 ± 11 | .59 | 18 | 42 ± 41 | .47 |
| Vitreoretinal | 10 | 22 ± 13 | 18 | 52 ± 50 | .01 | 9 | 26 ± 8 | .11 |
| Extraocular [b] | 13 | 37 ± 33 | 12 | 82 ± 67 | .04 | 33 | 35 ± 29 | .57 |
| Total | 58 | 41 ± 27 | 83 | 83 ± 51 | <.001 | 95 | 46 ± 30 | .28 |

Abbreviation: SD, standard deviation

a Comparison of percentage of operating time documenting (POTD) in paper vs. early EHR & paper vs. late EHR. Two sample *t* tests with unequal variance were performed in "cataract" group. Wilcoxon rank-sum tests were employed in all other groups.

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

**Table 4. Mean absolute intraoperative documentation time (minutes) before and after electronic health record (EHR) implementation in the operating rooms.** The three time periods studied included paper (baseline before EHR implementation), early EHR (months 1-3), and late EHR (months 4-12).

| Procedure type | Paper | | Early EHR (months 1-3) | | | Late EHR (months 4-12) | | |
|---|---|---|---|---|---|---|---|---|
| | n | Documentation time ± SD | n | Documentation time ± SD | *P* [a] | n | Documentation time ± SD | *P* [a] |
| Cataract | 25 | 6.6 ± 0.9 | 47 | 14.6 ± 4.4 | <.001 | 35 | 8.1 ± 1.5 | <.001 |
| Cornea & Glaucoma | 10 | 9.5 ± 2.6 | 6 | 15.9 ± 9.0 | .02 | 18 | 10.2 ± 3.0 | .56 |
| Vitreoretinal | 10 | 7.6 ± 2.5 | 18 | 24.3 ± 12.7 | <.001 | 9 | 10.1 ± 2.2 | .03 |
| Extraocular [b] | 13 | 7.6 ± 4.2 | 12 | 13.6 ± 8.6 | .04 | 33 | 9.5 ± 3.3 | .03 |
| Total | 58 | 7.5 ± 2.7 | 83 | 16.7 ± 8.7 | <.001 | 95 | 9.2 ± 2.7 | <.001 |

Abbreviation: SD, standard deviation

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

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

**Table 5. Circulating nurses per procedure before and after electronic health record (EHR) implementation in the operating rooms.** The three time periods studied included paper (baseline before EHR implementation), early EHR (months 1-3), and late EHR (months 4-12).

| | Paper | | Early EHR (months 1-3) | | | Late EHR (months 4-12) | | |
|---|---|---|---|---|---|---|---|---|
| **Procedure type** | n | Nurses ± SD | n | Nurses ± SD | *P* [a] | n | Nurses ± SD | *P* [b] |
| Cataract | 25 | 1.0 ± 0.0 | 47 | 1.9 ± 0.5 | <.001 | 35 | 1.5 ± 0.5 | <.001 |
| Cornea & Glaucoma | 10 | 1.0 ± 0.0 | 6 | 1.2 ± 0.4 | .20 | 18 | 1.0 ± 0.0 | |
| Vitreoretinal | 10 | 1.0 ± 0.0 | 18 | 1.6 ± 0.8 | .03 | 9 | 1.0 ± 0.0 | |
| Extraocular [c] | 13 | 1.0 ± 0.0 | 12 | 1.2 ± 0.4 | .13 | 33 | 1.0 ± 0.0 | |
| Mean total | 58 | 1.0 ± 0 | 83 | 1.6 ± 0.6 | <.001 | 95 | 1.2 ± 0.4 | <.001 |

Abbreviation: SD, standard deviation

a Comparison of circulating nurses per procedure in paper vs. early EHR & paper. Two sample *t* tests with unequal variance were performed within the "cataract" group. Wilcoxon rank-sum tests were performed in all other groups.

b Comparison of circulating nurses per procedure in paper vs. late EHR in cataract group. The number of nurses in paper vs. late EHR was identical in all procedure groups except cataract. Therefore, no testing for statistical significance of a difference was performed in these groups.

c "Extraocular" category includes procedures of the eyelid, lacrimal system, orbit, extraocular muscles, and examinations under anesthesia.

**Table 6. Operating room turnover time* between surgical procedures over three time periods:** paper baseline, early EHR (months 1-3), and late EHR (months 4-12).

| | Paper | Early EHR | Late EHR |
|---|---|---|---|
| **Surgical procedures** | 41 | 64 | 78 |
| **Turnover time (minutes)** | | | |
| **Mean ± SD*** | 17.3 ± 6.5 | 16.2 ± 8.2 | 15.6 ± 4.8 |
| **Minimum** | 8.8 | 7.4 | 4.5 |
| **Maximum** | 37.5 | 56.2 | 31.3 |

**Table 7. Total number of documentation elements in paper and electronic health record (EHR) forms [a]**

| | Paper (n) | | EHR (n) | |
|---|---|---|---|---|
| | Cataract | Blepharoplasty | Cataract | Blepharoplasty |
| Manually entered | 101 | 90 | 195 | 152 |
| Pre-populated | 17 | 11 | 88 | 63 |
| Not utilized | 160 | 168 | 129 | 25 |
| Total documented [b] | 118 | 101 | 283 | 215 |
| Total possible | 278 | 269 | 412 | 240 |

a Documentation elements were counted in 4 total cases of two procedure types: cataract (1 paper and 1 EHR), blepharoplasty (1 paper and 1 EHR)

b "Total documented" is equal to the sum of all elements that were manually entered and those that were pre-populated

**Table 8. Paper documentation categories with the most manually entered elements [a]**

| | Cataract n (%) (N=101) | Blepharoplasty n (%) (N=90) |
|---|---|---|
| Staff members | 8 (8%) | 11 (12%) |
| Patient position | 12 (12%) | 12 (13%) |
| Team pause | 15 (15%) | 14 (16%) |
| Procedure | 7 (7%) | 8 (9%) |
| Medications | 31 (31%) | 15 (17%) |
| Patient outcome | 7 (7%) | 7 (8%) |

a Elements were counted in two total cases: 1 cataract and 1 blepharoplasty. Elements were recorded as a percentage of the total number of manually entered elements (N).

**Table 9. Electronic health record (EHR) documentation categories with the most manually entered elements [a]**

| | Cataract n (%) (N=195) | Blepharoplasty n (%) (N=152) |
|---|---|---|
| Surgical counts | 20 (10%) | 20 (13%) |
| Team pause | 18 (9%) | 18 (12%) |
| Supplies | 14 (7%) | 12 (8%) |
| Medications | 49 (25%) | 35 (23%) |
| Implants | 16 (8%) | 1 (1%) |
| Patient outcome | 10 (5%) | 10 (7%) |

APPENDIX I: Variables under study

| ***Variable Name*** | ***Type of Variable*** | ***Measurement*** | ***Additional information*** |
|---|---|---|---|
| Absolute intraoperative documentation time | Outcome, Continuous | Minutes | The sum of all documentation time by all involved nurses that takes place while the patient is in the operating room. |
| Total intraoperative nursing documentation time (as % of total procedure time) | Outcome, Continuous | Percentage | |
| Surgical volume | Outcome, continuous | Number of cases per month and per year | |
| Operating room turnover time | Outcome, Continuous | Minutes | The total time between one patient leaving the operating room and the subsequent patient entering the operating room |
| Nurse performing documentation | Predictor, Categorical | Numeric identifier, 1-7 | |
| Procedure type | Predictor, Categorical | Procedure group numeric identifier 1-5 | 5 procedure type groups: (1) cataract (2) cornea/glaucoma (3) retina/vitreous (4) Extraocular **(**eyelid, muscle, orbit/Exam under anesthesia) |
| Time since EHR implementation | Predictor, Ordinal | Paper baseline: -3 weeks to 0 weeks, Early EHR: 1-3 months, Late EHR: 4-12 months | Data was gathered during the following weeks: -3,-2,-1, 2, 5, 10, 13, 17, 22, 27, 33, 38, 42, 50. Grouped into paper baseline, early and late EHR. |
| Documentation elements | Outcome, continuous | Count of discrete documentation elements | Discrete "documentation elements" (e.g., free text, checkboxes) in both systems were counted for two representative procedure types: cataract extraction and blepharoplasty (1 procedure each in paper and EHR) |

APPENDIX II: Select statistical output – ANOVA model for intraoperative nursing documentation time and time period

```
. anova  intraop_proc docum_nurse wksgroups docum_nurse#wksgroups

                          Number of obs =     138     R-squared     =  0.4324
                          Root MSE      = .094016     Adj R-squared =  0.3354

                   Source | Partial SS    df       MS           F     Prob > F
--------------------------+----------------------------------------------------
                    Model |  .787796656    20  .039389833        4.46     0.0000
                          |
                docum_nurse |  .091728541     6   .01528809        1.73     0.1201
                  wksgroups |   .29485678     2   .14742839       16.68     0.0000
      docum_nurse#wksgroups |  .242109436    12  .020175786        2.28     0.0121
                          |
                 Residual |  1.03416349   117  .008839004
--------------------------+----------------------------------------------------
                    Total |  1.82196015   137  .013298979
```