



Provider Access to Legacy Electronic Anesthesia Records Following Implementation of an Electronic Health Record System

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Abstract

Many hospitals are in the process of replacing their legacy anesthesia information management system (AIMS) with an Electronic Health Record (EHR) system, within which the AIMS is integrated. Using the legacy AIMS security access log table, we studied the extent to which anesthesia providers were accessing historical anesthesia records (January 2006 – March 2017) following implementation of an EHR (April 2017). Statistical analysis was by segmented regression. At the time of implementation of the EHR, in 44.8% (SE = 0.3%) of cases, there was a prior anesthetic record for the patient that had been documented in the legacy AIMS. Following EHR implementation, the mean number of preoperative clinical views of all prior anesthetic records divided by the total number of cases performed decreased to 2.3% (0.3%) from the baseline of 25.1% (0.8%). The estimated ratio of the 2 means was 0.18 (95% CI 0.11 to 0.31, $P < 0.00001$). For views of unique records, the decrease was to 2.2% (0.3%) from the baseline of 18.3% (0.5%). The estimated ratio was 0.23 (95% CI 0.15 to 0.35, $P < 0.00001$). These results show that, following conversion to an integrated EHR, providing access to historical anesthesia records by maintaining the legacy AIMS is not an effective strategy to promote review of such records as part of the preoperative evaluation process. Because such records provide important information for many patients, providing linked access to such records within the EHR as part of the patient encounter may be a more effective approach.

Keywords Medical record systems, computerized · Information technology · Process assessment (health care)

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Introduction

Many hospitals have recently replaced or are replacing their stand-alone, legacy anesthesia information management system (AIMS) with an enterprise-wide Electronic Health Record (EHR) system, within which the AIMS is integrated [1]. Because the AIMS contains valuable information related to patients' prior anesthetic experiences (e.g., airway management descriptions, hemodynamic responses, complications) [2], it is desirable to maintain access to these records following conversion to the EHR.

We are unaware of any method to import the discrete data contained in a legacy AIMS database into an EHR database. At many institutions, prior anesthesia records are made available within the EHR as linked records, usually as a portable document format file (PDF), facilitating retrieval and review. In order to provide access to historical records, human resources are required to scan paper anesthesia records or otherwise import PDFs of the old anesthesia records and match them to the correct patient.

An alternative method is to provide such access by maintaining the legacy AIMS. This approach can be cumbersome because the provider must open the AIMS as a separate software application, log in, and then search manually for the relevant records. Maintaining the legacy AIMS incurs long-term licensure and hardware maintenance costs (e.g., servers and workstations) and creates a requirement for personnel to support anesthesia providers needing help with the system.

Given the scope of work and compressed timeline for replacement of multiple stand-alone legacy hospital information systems with an integrated system, maintaining access to the legacy AIMS is often an expedient solution at the time of the EHR go-live. For example, this was the approach followed at Thomas Jefferson University, the University of Miami, Virginia Commonwealth University (Jeffrey Green, personal communication, December 10, 2018), and Children's Hospital of Philadelphia (Allan Simpao, personal communication, December 10, 2018). In contrast, Vanderbilt University Medical Center (Jonathan Wanderer, personal communication, December 10, 2018) imported PDFs of the anesthesia into the EHR and built a custom interface to access the records. A hybrid approach was taken by Mount Sinai Medical Center in New York, where the legacy AIMS continued to be used for several years until implementation of the AIMS module within the EHR (Matt Levin, personal communication, December 17, 2018). During this interval, linked access to PDFs of these anesthesia records was provided within the EHR.

We were unable to locate any published studies describing issues related to accessing historical anesthesia records following migration from a legacy AIMS to an EHR. In the context of Roger's theory of diffusion of innovation [3], the initial adoption of AIMS technology is nearly complete [4], and we have now entered the phase of adoption known as substitution [5]. In this latter phase, newer generations of technology replace the previously adopted innovation. The current study represents an assessment of one important aspect of this process: the frequency with which providers made the effort to look up historical records in the legacy AIMS. Understanding this aspect of patient care is important to teams charged with the responsibility of replacing legacy AIMS with an EHR while balancing the various competing interests attendant to such large-scale projects.

Methods

This study was approved by the Thomas Jefferson University institutional review board with waiver of patient consent on November 26, 2018 (Control #18D.053). The study was conducted using information systems data from 3 hospitals that are part of the associated medical center (i.e., Thomas

Jefferson University Hospital, the Jefferson Hospital for Neuroscience, and the Jefferson Surgical Center).

At the hospitals studied, the legacy AIMS (Innovian, Dräger, Telford PA), the existing hospital electronic medical record system (Centricity, GE HealthCare, Chicago, IL), and multiple other stand-alone hospital and ambulatory patient and laboratory systems were replaced with an EHR (Epic, Epic Systems, Verona, WI) in April 2017. The health system chose not to create and link PDFs of the previous anesthetic records as part of this enterprise-wide transition. The prior anesthetics tab in the EHR only contains references to records completed using the EHR. Instead, the hospitals retained the web-based AIMS software, thus providing a read-only view of the legacy anesthesia records. The link was maintained from the hospital's intranet page to the web-based interface to the legacy system, which providers had used for many years to access anesthesia records when not physically in the operating room.

Data sources

We examined the perioperative data warehouse from our legacy AIMS to determine historical cases performed at hospitals in the health system between January 1, 2006, and May 17, 2017 [6]. We analyzed the security logon table in the AIMS to determine user access to anesthesia records between April 1, 2017, and October 31, 2018 (i.e., following replacement of the AIMS with the EHR). That table documents events related to user access of anesthesia records, including the case identifier, the identified provider opening the record (which was one-way hashed for analysis), the category of provider (from a linked table) and the time of access. We categorized each access of an historical record as clinical (i.e., by an anesthesia provider within 1 business day of the procedure [e.g., including Friday access for Monday cases]) or non-clinical (e.g., billing office, preoperative clinic, health information management department, research). For analyses, we excluded non-clinical accesses (see Supplemental Content Fig. S1). In effect, this was the inverse of the process performed by Wanderer et al. in their study of non-anesthesia provider accesses of preoperative anesthesia assessments [7].

Determination of cases with prior anesthesia records

Data from the legacy AIMS were binned into $N = 81$ sequential 4-week periods. We analyzed each case performed between January 1, 2011, and May 11, 2017 (the final date of last complete 4-week bin), and matched records to the patient's most recent anesthesia record in the data warehouse. Because the cases included in the data warehouse were from January 1, 2006, there were at least 5 years of historical data for each case analyzed. Within each bin, we determined the total number of cases and the number of cases for which a

previous record existed during the following 9 intervals relative to the current date of surgery: ≤ 7 days, 8 days to 30 days, 31 days to 90 days, 91 days to 180 days, 181 days to 1 year, 1 year to 2 years, 2 years to 3 years, 3 years to 4 years, 4 years to 5 years, and > 5 years. Using the method of batch means, we calculated the mean percentage within each time interval and the 95% Student t confidence interval [8, 9]. We calculated the expected percentages of cases with a record available for the patient only in the legacy system after various intervals from the implementation date of the EHR. The calculation was based on the percentages of cases in the legacy AIMS where the interval to the patient's most recent anesthesia record was longer than the interval from implementation of the EHR. For example, if for 30% of cases the most recent previous anesthesia record for the patient was 31 or more days previous to the date of surgery, then within 30 days of implementation of the EHR, 30% of cases would be expected to have a prior record for the patient, but only present in the legacy AIMS.

Each record in the EHR was analyzed to determine if there was a prior record in the EHR or in the legacy AIMS, matching on the patient's medical record number (retained during the conversion to the EHR). For each 4-week bin, we determined the total number of cases performed. We adjusted the total number performed to exclude cases which there was a prior record in the EHR. This adjusted number of cases was used as the denominator for determining the ratio of access of legacy records (see next paragraph). This approach was followed because if there was a prior record in the EHR, that would have been displayed as part of the patient's current encounter when the anesthesia record was opened in the EHR. Thus, there was no expectation that the legacy AIMS would necessarily need to be searched. The consequence of our approach was to bias the ratio of access of historical records to a higher value, as compared to simply using the total count of cases. A higher value is in the opposite direction of the need to maintain access to the legacy system.

Frequency of prior record access during use of the legacy AIMS

To determine the most current frequency of access of previous records when a patient presented for a new procedure during the tenure of the legacy AIMS, we looked at the last year of data, binning by 4-week intervals, as described above. For each case, we identified all previous anesthesia records for that patient. We considered that there had been a review of a previous anesthetic for the patient for the purposes of preoperative evaluation if, within 1 business day of the date of surgery, the provider had viewed an historical record for that patient. If there were multiple such historical records for the patient, review of any of these records was considered as representing access.

Ratio of access of historical records before and after implementation of the EHR

We calculated 2 ratios related to access of historical anesthesia records before and after implementation of the EHR. The first was the ratio of total clinical views of such records divided by the total number of cases performed. This ratio was calculated for each 4-week interval. Then, the mean and the standard error of the mean of the ratios were calculated among the 4-week intervals. The second was the ratio of unique record view divided by the same denominator. For the EHR bins, the total number of cases was the adjusted number of cases, as described above. We took this approach because we were primarily interested in clinical access to historical anesthesia records, and also because the expected fraction of views would be expected to vary proportionally to the number of cases.

Statistical methods

The ratios from each 4-week period were analyzed using segmented regression. There were 3 independent variables: the binary variable of intervention period or baseline, linear slope over time in the log scale, and the difference in slopes in the log scale, intervention minus baseline. Generalized linear modeling was used to obtain the ratios of the means, using a log link function and assuming Gaussian distribution. The calculations were performed using STATA 15.1 (StataCorp, College Station, Texas).

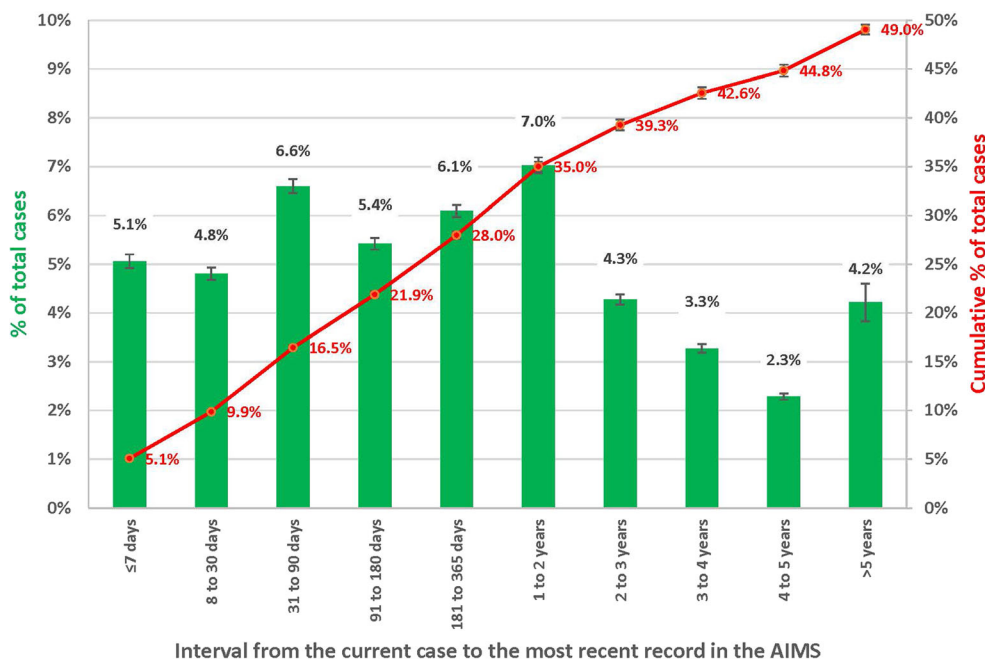
Results

Prevalence of cases where the patient had a previous anesthetic in the legacy AIMS

Among all anesthetics documented in the legacy AIMS between January 1, 2011, and March 11, 2017, in $44.8\% \pm 2.7\%$ (95% CI 44.2% to 45.4%), there was a previous anesthesia record for the patient (Fig. 1). Among all cases where the patient had a previous record in the legacy AIMS (49% of total cases from January 2006 to March 2017), approximately half had a previous anesthetic between 181 days and 1 year of the current case (Fig. 1). Thus, each day there were many cases where previous anesthesia information about the patient was available.

Prevalence of cases where the patient had a previous anesthetic record in the EHR

The prevalence of cases where the patient had undergone an anesthetic within the previous year following conversion to the EHR was essentially unchanged from the prevalence when



Interval from the current case to the most recent record in the AIMS

Fig. 1 Distribution of intervals from anesthesia cases to the nearest historical anesthesia record for the patient from the legacy anesthesia information management system. The percentages and associated 95% confidence intervals (green bars) are shown for the intervals between each case with a prior anesthesia electronic anesthesia record in the $N = 81$ 4-week sequential bins, expressed as a fraction of the total number of cases performed in that bin. For example, in 7.0% all cases (95% CI 6.9% to 7.2%) the patient’s prior anesthetic had been performed within 1 to 2 years

earlier. The cumulative distribution of cases with a previous anesthesia record is plotted on the red line; the error bars indicate the 95% confidence interval. For example, 44.8% (95% CI 42.2% to 49.9%) of patients had a previous anesthetic within 5 years of the current case. Data were from cases performed at Thomas Jefferson University Hospital and the Jefferson Surgery Center between January 1, 2006, and May 11, 2017, with the analysis of prior cases performed starting January 1, 2011. Thus, each case had at least 5 years of prior data

the legacy AIMS was in use (Table 1). The expected percentages of cases for which a previous anesthetic record for the patient would be present, but only in the legacy AIMS, are shown in Fig. 2. These data indicate that 1 year after adoption of the EHR system, it would be expected that in 21.1% of cases involving an anesthesia provider, patients would have their most recent anesthesia record in the legacy AIMS. Even after 4 to 5 years of use of the EHR, legacy AIMS records would still need to be available for 5% of the cases if one wished to have access to the most recent anesthetic. Actual data for the percentage of total cases where the most recent prior anesthesia record for the patient was in the EHR or the

AIMS reasonably matched the modeled data (Supplemental Content Fig. S2).

Frequency of access of previous anesthesia records prior to implementation of the EHR

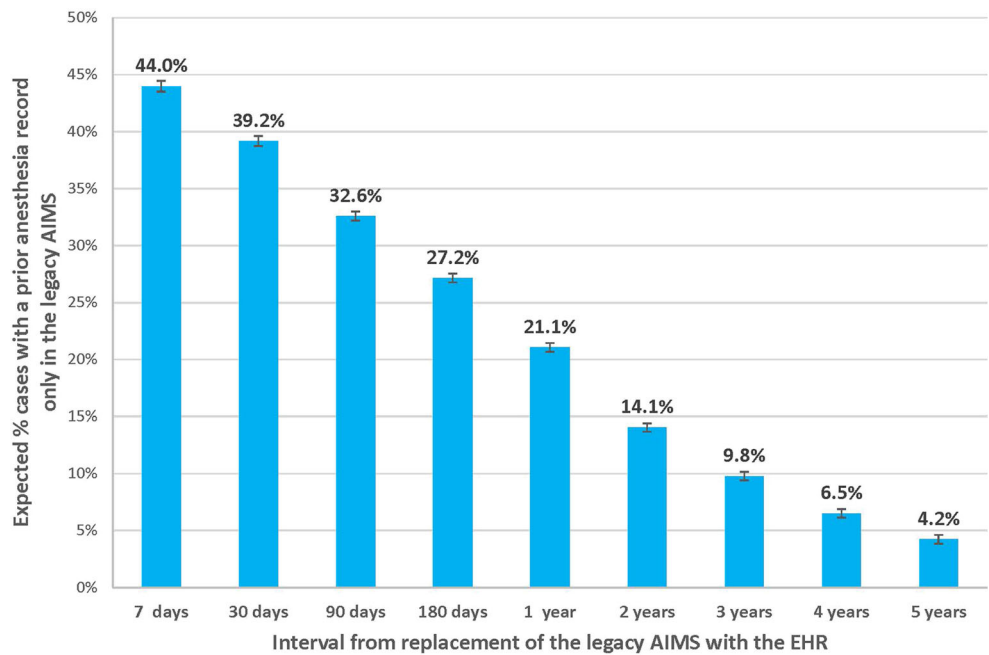
In the last year of use of the legacy system, $54.3\% \pm 0.3\%$ SEM of cases had a previous anesthetic record for the patient in the system (Table 2). However, anesthesia providers accessed an historical anesthesia record for $23.8\% \pm 0.5\%$ SEM of cases where such records were available (Table 2). Thus, review of an available previous anesthesia record was

Table 1 Comparison of cases with a previous anesthetic within the respective system

Interval to the Most Recent Anesthetic	Cumulative % of Cases with a Previous Anesthetic Mean [95% confidence interval]	
	Legacy AIMS ($N = 81$ four-week bins)	EHR System ($N = 7$ four-week bins)
≤ 7 days	5.1% [4.9% to 5.2%]	5.3% [5.0% to 5.6%]
≤ 30 days	9.9% [9.7% to 10.1%]	10.0% [9.4% to 10.5%]
≤ 90 days	16.5% [16.2% to 16.7%]	17.1% [16.3% to 17.9%]
≤ 180 days	21.9% [21.5% to 22.2%]	22.7% [22.1% to 23.3%]
≤ 365 days	28.0% [27.6% to 28.4%]	29.7% [28.9% to 30.4%]

Abbreviations: AIMS anesthesia information management system, EHR electronic health record

Fig. 2 Expected percentages of total cases for which a previous anesthesia record for the patient would be present only in the legacy anesthesia information management system following implementation of an electronic health record system (EHR) on April 1, 2017. Initially, no cases would be present in the EHR, but as time passes, more patients would have care documented in the EHR, reducing the percentages of cases needing access to historical records to view the most recent record



often not included as part of the preoperative evaluation process.

Access of anesthesia records in the legacy AIMS following implementation of the EHR

Following implementation of the AIMS, there was a rapid and immediate drop in the frequency with which historical records in the AIMS were reviewed by providers (Fig. 3). After

correcting the total number of cases after EHR implementation by subtracting cases with a prior record in the EHR, the percentage of the total anesthesia record views for preoperative clinical purposes to the total number of cases decreased to 2.3% (SE = 0.3%) from the baseline of 25.1% (SE = 0.8%). The estimated ratio of the 2 means was 0.18 (95% CI 0.15 to 0.31, $P < 0.00001$). For the number of unique records viewed (i.e., multiple views of the same anesthesia record were counted as 1 view), the percentage of access decreased to 2.2%

Table 2 Access of Previous Anesthesia Records for Patients Presenting for Surgery during the Final Full Year of Use of the Legacy Anesthesia Information Management System (AIMS)

Start of 4-Week Bin ^a	Total Cases	N (%) Cases with a Prior AIMS Record	N (%) of Available Prior AIMS Reviewed
3/13/2016	3551	1941 (54.7%)	418 (21.5%)
4/10/2016	3745	2020 (53.9%)	446 (22.1%)
5/8/2016	3565	1920 (53.9%)	441 (23.0%)
6/5/2016	3694	2008 (54.4%)	426 (21.2%)
7/3/2016	3357	1749 (52.1%)	471 (26.9%)
7/31/2016	3558	1903 (53.5%)	493 (25.9%)
8/28/2016	3418	1852 (54.2%)	453 (24.5%)
9/25/2016	3602	1988 (55.2%)	467 (23.5%)
10/23/2016	3618	2000 (55.3%)	473 (23.7%)
11/20/2016	3405	1903 (55.9%)	497 (26.1%)
12/18/2016	2966	1631 (55.0%)	396 (24.3%)
1/15/2017	3391	1858 (54.8%)	444 (23.9%)
2/12/2017	3428	1804 (52.6%)	409 (22.7%)
Mean ± SEM	3484 ± 55	54.3% ± 0.3%	23.8% ± 0.5%

Abbreviations: AIMS anesthesia information management system, CI confidence interval, SEM standard error of the mean

^a The last day of use of the legacy AIMS was March 17, 2017. Four-week bins were selected starting from January 1, 2006, making the final day of the last full 4-week bin March 11, 2017



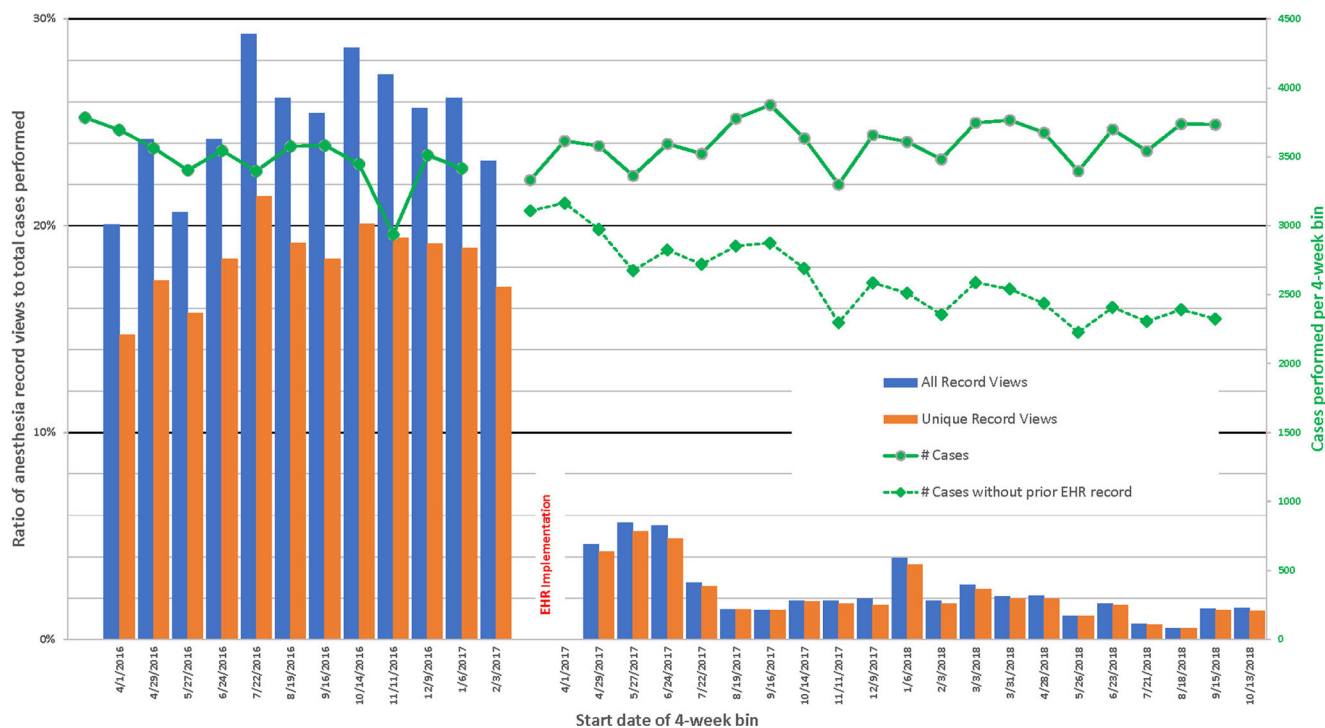


Fig. 3 Caseloads and views of previous anesthesia records in the legacy anesthesia information management system (AIMS) before and after implementation of an Electronic Health Record (EHR) system on April 1, 2017. The ratio of the total number of records viewed by clinicians as part of the preoperative evaluation process to the total number of cases (blue bars) and the same ratio with the unique number of cases viewed in the numerator (orange bars) are displayed. The ratios for the first 4-week bin following implementation were omitted because this represented a transition between full use of the EHR and hybrid use of both systems (mostly for retrieval of preoperative anesthesia evaluations completed before the go-live). Prior to the EHR implementation, the denominator of total cases

(SE = 0.3%) from the baseline of 18.3% (SE = 0.5%). The estimated ratio was 0.23 (95% CI 0.15 to 0.35, $P < 0.00001$). Thus, the solution of maintaining access to the legacy AIMS via the hospital intranet was not successful in maintaining even the relatively low level of anesthesia record review that existed prior to implementation of the EHR. Note that for the segmented regression, there were statistically significant ($P \leq 0.043$) but quantitatively negligible proportional increases in the percentages before intervention and decrease in the slope after intervention. The STATA output is included in the [supplementary content](#).

Distribution of providers accessing legacy AIMS records following EHR implementation

Among the 78 anesthesia providers who viewed at least 1 record in the legacy AIMS as part of the preoperative evaluation process, 5 providers (6.4%) accounted for 50% of the access, and 22 providers (28.2%) accounted for 80% of the access (Fig. 4). Of the 5771 total records in the legacy AIMS that were opened (including both clinical and non-clinical

was the total number of cases performed in the AIMS; after implementation, the denominator was adjusted to equal the total number of cases performed in the EHR minus the number of cases which had an anesthesia record present in the EHR. The solid green line with circles represents the total caseload per 4-week bin; the dotted green line with diamonds represents the adjusted number of cases. The average number of times that each unique record was accessed during use of the legacy AIMS was 1.37 ± 0.03 SD vs 1.07 ± 0.05 SD after implementation of the EHR ($P < 0.0001$). Note that the caseload per 4-week bin remained relatively constant throughout the study interval

access), anesthesiologists, anesthesia residents, and nurse anesthetists were responsible for 45.3%, 43.4%, and 5.0% of the access, respectively (93.7% of the total use, combined). Administrative, research staff, and other clinician access were responsible for 4.3%, 1.8%, and 0.3% of the remainder of the use of the legacy system. Thus, with 28.2% of the providers responsible for 80% of the clinical accesses, use of the legacy AIMS records was highly heterogeneous among anesthesia providers.

Discussion

At the studied hospital, in approximately 50% of cases involving anesthesia care, patients had undergone a previous anesthetic documented in the legacy AIMS within the previous 5 years. Thus, maintaining access to such anesthesia records is important when converting to an EHR. For cases where complications occurred that were not otherwise well-documented in the EHR, such review of the previous anesthesia record may be critical to avoid an undesirable outcome.

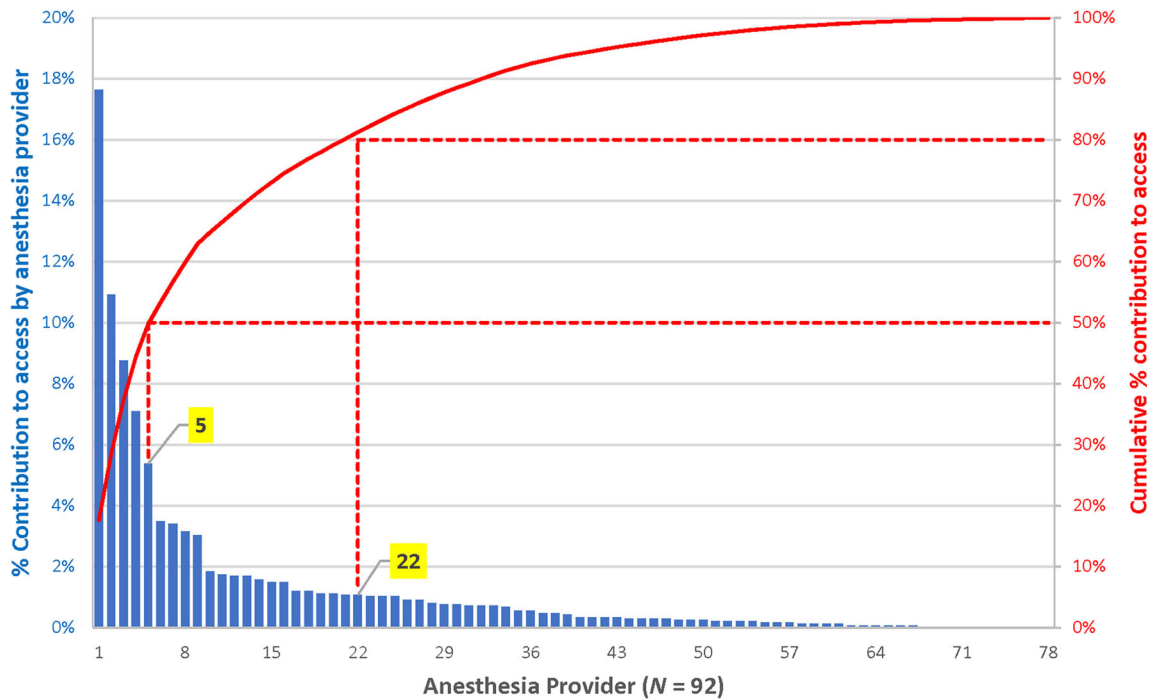


Fig. 4 Distribution of clinical access to the legacy anesthesia information management system records by anesthesia provider. The individual contributions by anesthesia provider as a percentage of total accesses to the legacy system are shown in the blue bars (primary y-axis), with the cumulative contribution displaced by the red line (secondary y-axis). A

single provider was responsible for 16% of the access. Approximately 50% of the access took place from the activities of 5 anesthesia providers among the $N = 92$ individuals who accessed any records during the study interval (red dotted lines). Approximately 80% of the access was from 22 individuals (red dotted lines)

The hospital’s decision to retain access to the legacy AIMS anesthesia records by continuing to maintain the web-based, read-only component of the AIMS over hospital intranet was expedient, but resulted in a substantive decrease in the frequency with which prior anesthesia records were reviewed. This drop-off likely represented the burden of opening a separate software package, logging on with a different set of user credentials than in the EHR, keeping passwords updated, remembering how to use the legacy AIMS, and finding the relevant anesthesia records. Also, new staff usually had no previous experience with the legacy AIMS, and formal training was not provided. We suspect that similar issues exist at other organizations that have chosen the approach of maintaining access to the legacy system. Long-term support of the legacy AIMS is likely impractical, given ongoing-license costs for the AIMS, expenses in maintaining the AIMS servers (e.g., security patches and operating system upgrades), workstations (e.g., separately provided computers used to access the legacy records) where the application is installed, and user support issues. Thus, a process to import the anesthesia records from the legacy AIMS needs to be implemented to simplify and facilitate retrieval of those records.

Study limitations

Our study was conducted at a single large academic health system with 11 years of historical anesthesia records [6]. Thus, the

percentages we report likely will differ at other institutions. For example, we do not know if the frequency with which providers at the study hospital electronically review previous anesthesia records is typical. Nonetheless, the general principles almost certainly apply to all hospitals at which an AIMS has been in use for many years – a substantive percentage of patients anesthetized will have undergone a previous anesthetic at the institution and access to those archived anesthesia records will be needed.

Another limitation is that we only considered the interval from each anesthetic to the previous anesthetic when assessing the need to maintain access to the legacy AIMS. There may be a need to review even earlier anesthetics to retrieve relevant information (e.g., if the most recent anesthetic was for a colonoscopy, but an earlier anesthetic was for a complex surgical procedure with complications). However, this makes our findings conservative with respect to the expected percentage of cases where the legacy records would need to be reviewed; longer duration of access needs to be maintained than we calculated. This strengthens, rather than weakens, our findings as to the importance of providing long-term access to legacy AIMS records.

Another limitation is that some patients may have had multiple medical record numbers that we were not able to identify and merge in our perioperative data warehouse [6], despite processes in place to identify and combine such records [6]. However, this would result in an underestimation of the number of patients with prior anesthetic records (i.e., our P -values and ratios would be even smaller).

We did not have access to the security logon tables in the EHR system to evaluate the extent to which our providers are reviewing prior anesthesia records documented in the EHR. However, because anesthesia records can be accessed within the context of the current patient's record by a few mouse clicks, the effort to do this should be minimal.

We do not have data to analyze why a review of previous anesthesia records was not occurring more frequently than 25% of the time in the legacy AIMS. A partial explanation may be that finding the old records required multiple steps, which may also have represented a barrier. Another possibility is that records were only reviewed consistently when patients reported a previous complication. Of note, the electronic preoperative evaluation software in the legacy AIMS had a comprehensive section in which previous anesthetic complications or their absence were noted, and the vast majority of patients were evaluated prior to the day of surgery at a dedicated preoperative testing clinic [10]. These reports were printed and placed in the patient chart before surgery to facilitate review by the anesthesia provider. However, patients are not always aware of everything that happened during the anesthetic that might be of importance to subsequent care. Wax et al. found that 13% of anesthesia records had at least 1 critical event using an algorithm they developed to screen for such occurrences [11]. In addition, situations exist where review of prior records is needed to explain a patient-reported issue. For example, if a patient described a severe sore throat for several days following an anesthetic, review of the previous record might be illuminating regarding potential difficulty in intubation and what technique was ultimately successful.

Topics for future study

Understanding access patterns to historical anesthesia records during the preoperative evaluation process and barriers to more widespread review of such information would be useful topics for future study. Another potential area of research would be to develop methods to automatically process historical anesthesia records to abstract and present in a compact format relevant aspects of the patients' prior anesthetic experiences that might be relevant to the current anesthetic (e.g., airway issues, complications noted, prolonged emergence, etc.).

Conclusions

When an integrated EHR replaces a legacy AIMS, it is important to maintain access to patients' previous anesthesia records because a substantial number of anesthetics from the legacy system will require review. Even after several years of use of the EHR, there will remain patients for whom reviewing the prior anesthetic would be prudent. Because maintaining a legacy AIMS indefinitely presents numerous difficulties and because accessing

records through such systems can be cumbersome, our results suggest that an electronic image of patients' prior anesthesia records should be made available from within the EHR. Future study into the extent to which anesthesia providers are reviewing prior anesthesia records performed in the EHR as part of the preoperative anesthesia assessment is warranted.

Author's contribution Richard H. Epstein helped design the study, perform the statistical analyses, and write the manuscript. Franklin Dexter helped perform the statistical analyses and write the manuscript. Eric S. Schwenk secured approval from the Institutional Review Board and helped write the manuscript.

Compliance with ethical standards

Conflict of interest The Authors have no conflicts of interest.

Ethical approval This study was approved by the Thomas Jefferson University institutional review board with waiver of patient consent on November 26, 2018 (Control #18D.053).

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