An Automated Critical Event Screening and Notification System to Facilitate Preanesthesia Record Review

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BACKGROUND: Anesthesia information management systems make prior anesthesia records readily available for review when patients return for a subsequent procedure but may create a problem of too much documentation to review in a limited amount of time. We implemented a screening tool to facilitate the identification of critical documentation for review.

METHODS: An algorithm was developed to electronically search prior anesthesia records for predefined critical events and flag records containing these events. Our web-based daily case schedule was modified to contain a warning message for any patient on the schedule who has a prior record flagged by the system, in addition to a preexisting hyperlink to view the relevant record. A retrospective analysis was performed to determine the impact of the warning messages on the frequency with which the care team reviewed these records before providing anesthesia care.

RESULTS: The screening algorithm flagged 13% of archived cases as critical. There were 3329 and 3369 cases in the 6 months before and after system implementation, respectively, that had prior critical records available for review at that time. One or more of these critical records were viewed before the subsequent case start in 39% vs 59% (P < .01) of cases in the pre-versus postimplementation periods. Subgroup analysis revealed that the increase was greatest for attending anesthesiologists working alone.

CONCLUSIONS: We created a system to automatically detect critical events in prior anesthesia records for the purpose of forewarning the anesthesia care team when the same patient returns for another procedure. Inclusion of these warnings on the daily case schedule was associated with an increased frequency of preanesthesia review of old records. (Anesth Analg 2018;126:606–10)

Those who cannot remember the past are condemned to repeat it.
—George Santayana

It is a professional responsibility and regulatory requirement to perform a preanesthesia evaluation before rendering anesthesia care. According to the American Society of Anesthesiologists, the preanesthesia evaluation should include a review of “readily accessible, pertinent” medical records, though evidence of benefit is limited. Historically, review of paper medical records was limited by availability. The adoption of electronic health records (EHR) has created the opposite problem of too much documentation to possibly review in a timely fashion.

Anesthesia information management systems (AIMS) have made prior anesthesia records readily available for review when patients return for a subsequent procedure, but it was unknown how often anesthesia care teams make use of these prior anesthesia records. Therefore, we conducted an audit of how often these old anesthesia records were reviewed when a patient returned for another procedure. We also created a system to automatically screen anesthesia records in our AIMS archive and flag those that had noteworthy events to forewarn clinicians when the patient returns for another procedure. We hypothesized that such a system would increase the frequency with which clinicians reviewed these critical records before rendering anesthesia care again.

METHODS

Our academic anesthesiology group consists of more than 200 attending anesthesiologists, resident anesthesiologists, and certified registered nurse anesthetists (CRNAs) who perform more than 50,000 anesthetics per year. Our AIMS (CompuRecord; Philips, Andover, MA) has been in continuous use since 2002, and all case data have also been aggregated into a custom departmental data warehouse/archive. The formatted anesthetic record for each case is also printed as a portable document format (PDF) file and stored on a departmental file server. These prior anesthesia records can be viewed using our AIMS software, our hospital EHR (Epic Systems, Madison, WI), or a custom web-based application (which we call “OR Watch”). An audit trail of views of these records through all 3 mechanisms is maintained by our department.

For several years, our web-based case schedule for the next day included an icon/link indicating that a scheduled patient had prior anesthesia records in our archive. Clicking this link...
would (after credential verification) take the user to a list of all the patient’s prior anesthesia records, each with a link that could be clicked to immediately open the record to review in PDF format. In February 2016, we implemented a system that automatically searches for critical events in archived anesthesia records. Cases of patients with any prior records that were flagged by this screening are shown on the web-based case schedule with a special exclamation point icon, distinguishing them from cases of patients with unflagged prior records, which are displayed with a magnifying glass icon (Figure 1). As with the old system, clicking the icon presents a list of all prior records available for that patient, each with a PDF link. For critical (ie, flagged) cases, an additional icon appears next to the case listing that allows the user to hover the mouse pointer over the icon to quickly see the triggering event details even without opening the full PDF (Figure 2).

The development of the automated case screening algorithm was done using a Delphi method. Beginning with the Anesthesia Quality Institute’s lists of outcome indicators as starting points, a set of noteworthy (ie, “critical”) events was developed. Critical events included difficulties (eg, difficult intravenous access, difficult ventilation, difficult intubation, failed/delayed extubation), rescue medication administrations (eg, epinephrine, vasopressin, naloxone), physiologic disturbances (eg, hypotension, hypoxemia, dysrhythmias), adverse reactions (eg, anaphylaxis, local anesthetic toxicity, aspiration), and others (eg, case cancellations, wet tap, failed monitored anesthesia care/ regional technique). Structured query language (SQL) queries were designed to search our anesthesia data warehouse (which contains all elements of the anesthesia records) to find these events among the vital signs, medication administrations, events, and comments (some of which are predefined and others that are free text). The Table details the search criteria for the critical events.

Each SQL query was designed, tested, and refined to remove frequent/obvious false positives (eg, epinephrine received intrathecally as part of a spinal anesthetic would not be noteworthy, but intravenously it would suggest a critical hemodynamic problem). Multiple spellings of free text and use of wildcards for pattern matching were utilized to maximize detection. Some criteria were suppressed for certain case types (eg, vasopressor use during cardiopulmonary bypass or liver transplantation cases where vasopressor use is common/unremarkable). Some criteria were time dependent (eg, succinylcholine or albuterol given before procedure start may have been planned but given after procedure start may indicate acute bronchospasm or laryngospasm or conversion to general anesthesia or reintubation). Some were context dependent (eg, the absence of an “extubation” event is normal for a monitored anesthesia care or regional anesthesia case but may indicate delayed emergence/extubation during a general anesthesia case).

Once all the queries had been codified, they were run on the full archive of cases. To reduce false positives, a random subset of 100 flagged cases was manually reviewed by three of the authors. Any cases that were considered to be inappropriately flagged as critical were referred back for algorithm refinement to exclude these false positives. False negatives were not specifically sought out among unflagged cases since the chance of finding rare events in a manual chart review of a small number of random cases is low. Once the algorithm was finalized, it was run on all cases in the archive and continues to run daily on new cases. Staff were notified of the new system feature and encouraged to report false negatives and false positives to help future refinement of the algorithm.

With local institutional review board (Mount Sinai Program for the Protection of Human Subjects) approval and waiver of consent, the audit trails for anesthesia record views were obtained for the 6 months before (August 2015–January 2016) and after (February 2016–July 2016) system implementation. For each scheduled case during those periods involving a patient with a prior record in our archive, the audit trail was examined to see whether 1 or more of the old records (or at least the triggering event details for a flagged record) was viewed by anyone at least once within 26 hours before the start of anesthesia—a time period that typically includes the time from when staff would have been assigned to their next day cases until the actual start of those cases. The proportion of cases that had any prior records viewed versus not viewed was then compared between the periods using $\chi^2$ analysis. This analysis was first done for all prior records combined (both critical and noncritical) and then only for the subset of critical records (ie, excluding noncritical records).

**RESULTS**

The final screening algorithm flagged 13% of prior cases in our archive. Each flagged case had a median of 1 triggering event. Triggering events were 41% medication related, 39% comment related, 9% vital sign related, 10% predefined event related, and 1% case cancellations.

**Figure 1.** Screen capture of web-based case schedule. The web-based (OR Watch) daily case schedule includes icons for those patients with prior anesthesia records in our archive that were (exclamation icon) or were not (magnifying glass) flagged by our critical event screening tool. No icon indicates a patient without any prior records in the archive. Clicking the icons leads to a list of the patient's old anesthesia records.
AIMS Critical Event Screening System

There were 13,052 and 13,984 cases in the 6 months before and after system implementation for which prior records (critical or not) were available for review. One or more of these prior critical or noncritical records were viewed in the 26 hours before case start in 44% vs 50% ($P < .01$) in the pre- and postimplementation periods, respectively.

There were 3329 and 3369 cases performed in the periods before and after system implementation for which prior anesthesia records with critical events were available. One or more of these old critical records were viewed before the subsequent case start in 39% vs 59% ($P < .01$) of cases in the pre- versus postimplementation periods. When these cases were grouped based on care team composition, attendings working alone viewed prior critical records in 20% vs 47% ($P < .01$) of cases, attending + resident teams viewed prior critical records in 48% vs 69% ($P < .01$) of cases, and attending + CRNA teams viewed prior critical records in 24% vs 30% ($P < .05$) of cases in the pre- versus postimplementation periods, respectively.

For 6634 critical records that were listed on the schedule with the new alert icon, 33% had the alert icon accessed to reveal the triggering event details, 20% had the full record accessed without checking the icon details, and 47% were not reviewed at all.

**DISCUSSION**

We implemented an automated alerting tool that flags upcoming cases if the scheduled patient has had a critical event documented during a prior anesthetic at our institution using a screening algorithm customized for our AIMS. Implementation of the critical case flagging was associated with an overall relative increase of 51% in the rate of review of old critical records. The impact was greatest for attendings working alone who showed a 135% relative increase in prior critical record views.

Overall, at baseline, prior anesthesia records were only reviewed in less than half of cases for which they were available. This is not surprising given the fact that evidence of benefit of such review is lacking. Also, for patients who return for a minor procedure, or have had only minor procedures in the past, the expected yield of record review may be low. The differences in review rates by different practitioner types are also not surprising. Resident physicians may be more vigilant about reviewing old records because they are expected by their supervising attendings to be well prepared, whereas attendings and CRNAs may be more confident in their experience and abilities to deal with any problems that arise without advance warning/preparation.

There was a concern that the system could have unintended consequences and actually lead to a decrease in review of old records because staff would become overreliant on the system and stop checking old records unless they were flagged. Our data, however, suggest that this did not occur since overall views of records (most of which were not flagged as critical) did not decrease.

Prior studies of automated detection of adverse events from AIMS records have shown rates of 3% to 9% for physiologic abnormalities and 19% for “common adverse events” and also demonstrated that electronic queries of records are significantly more reliable than manual reporting of incidents. Our 13% alert rate is in line with those previous

### Table. Automated Critical Event Screening Algorithm Items

<table>
<thead>
<tr>
<th>Event</th>
<th>Example Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>General difficulty</td>
<td>%diff%, %fail%, %unable%</td>
</tr>
<tr>
<td>Difficult ventilation/</td>
<td>%grade 2B%, %grade IV%, %video%, %fiber%, %glide%, &gt;15 min from induction to intubation, &gt;20 min from procedure finish to extubation</td>
</tr>
<tr>
<td>intubation/extubation</td>
<td></td>
</tr>
<tr>
<td>Airway/respiratory issues</td>
<td>%spasm%, %aspir%, %vomit%, %dysp%, %reintub%, %embo%, %edema%, %ptx%, %trach%, %SOB%, SpO$_2$ &lt; 85% &gt; 10 min</td>
</tr>
<tr>
<td>Drug reactions</td>
<td>%anaphyl%, %allerg%, %rash%, %MH%, %seizure%, %tox%</td>
</tr>
<tr>
<td>Medications</td>
<td>Naloxone, hydrocortisone, dantrolene, flumazenil, succinylcholine or albuterol after procedure start, epinephrine, adenosine, atropine, amiodarone</td>
</tr>
<tr>
<td>Hemodynamics</td>
<td>Average MAP &lt; 55 mm Hg, HR &lt; 40/ min (all &gt;10 min), ACLS (%arrest%, %CPR%, %defib%, %chest compress%, dysrhythmias (%VT%, %VF%, %fibil%), ECG changes</td>
</tr>
<tr>
<td>Other</td>
<td>Case cancellation in OR, wet tap</td>
</tr>
</tbody>
</table>

Abbreviations: %, wild card pattern search within text comments; ECG, electrocardiography; HR, heart rate; MAP, mean arterial pressure; OR, operating room.
works. We have presented the first system to screen AIMS records for critical events for the purpose of forewarning practitioners when the patient returns rather than simply for retrospective peer review. We also believe this is the first report of the actual frequency with which prior anesthesia records are reviewed as part of the preanesthesia evaluation.

Our study has several limitations. We did not include record views that occurred outside the 24-hour window yet still may have influenced care. For example, a patient may be seen in pretesting clinic a week before surgery (outside our 24-hour window) when an anesthesiologist may have reviewed old records and documented any significant findings in a note for the future care team. However, <10% of our patients are seen in the pretesting clinic, and such a visit does not preclude the anesthesia team from conducting their own record review on the day of surgery. Cases where the old record was reviewed last minute only after the patient had already been brought into the operating room but before anesthesia induction were also outside our study window. Record reviews done on Friday or Saturday for Monday cases would also not be captured, though such case preparation typically takes place on Sunday (since this is when residents are expected to contact their Monday attending to discuss the cases) or on Monday for cases not prepared in advance. We were also unable to definitively ascertain that the person viewing the record was part of the actual care team rather than a peripherally involved clinician or administrator, as that information is not contained in the audit logs. Still, these limitations would have affected both study periods equally, so while they may slightly underestimate the frequency of record reviews, they should not discount the difference seen between periods associated with system implementation. Finally, our system is limited to screening of anesthesia records, but there are myriad other records types in the EHR containing critical information that might be mined with similar techniques.

False positives were minimized by multiple iterations of review and query modification. Remaining false positives are tolerable because not all patients on our schedule have prior records, and only a minority of those records are flagged, so the false alert rate for any individual practitioner is minimized to avoid alert fatigue. There was no practical way to search for false negatives since improvements in anesthesia safety have made major adverse events rare. Minor events may be difficult to detect, and even in cases where our screening tool programmatically detected a critical event, these were sometimes not noticed during manual review until the details of the triggering event were revealed to the reviewer. Our results demonstrate the effect of the implementation of such a screening and alert system rather than validating the particular algorithm itself.

We were unable to correlate old record reviews with changes in anesthesia care or patient outcomes. For example, knowledge of a difficult airway history might lead the team to have a fiberscope in the room and ready for possible use, but this extra preparation may not have been documented in the record if it proved unnecessary. Also, this prior knowledge could have come from interviewing the patient rather than chart review. It is also difficult to correlate outcomes with old record views because most perioperative complications are not clearly attributable to suboptimal anesthesia care. For example, ignorance of an episode of laryngospasm during a prior endoscopy is unlikely to have led to the fatal pulmonary embolus after a subsequent knee replacement. Searching for repeated critical events in the same patient is also problematic because repeats of the triggering events may not necessarily indicate suboptimal care (eg, hydrocortisone for adrenal insufficiency, repeated difficult direct laryngoscopies). Still, we believe that specialists with “vigilance” as their motto would be upset to unexpectedly encounter a problem that turned out to have been noted in a prior (but unviewed) record, even without an adverse outcome. If there is a bad outcome, failure to have reviewed old records that might have prevented it may be a basis for a malpractice claim. As for other medical decision-making, the benefits of record review must be weighed against the risks (ie, decreased productivity). We believe our system helps inform this decision by targeting records that are more likely to yield relevant data (even though our “critical” designation encompasses issues of various severity/significance).

The manner and format in which these events are captured or documented are specific to our AIMS and local documentation practices. However, the critical events we screen for and the burdens of record review are common across centers, so our system concept is generalizable to other centers that utilize an AIMS. Therefore, to implement this elsewhere, the group would have to modify the SQL queries to reflect their own AIMS architecture, configuration, and documentation habits.

In summary, we created a system to automatically detect critical events and other difficulties in prior anesthesia records for the purpose of forewarning the anesthesia care team when the same patient returns for another procedure. Inclusion of these warnings on the daily case schedule was associated with a relative increase in preanesthesia old record views of 51%. The impact of this on patient safety is unknown but likely to be neutral or positive.

DISCLOSURES

Name: David B. Wax, MD.

Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript, and this author is responsible for archiving the study files.

Name: Patrick J. McCormick, MD.

Contribution: This author helped design the study, conduct the study, and write the manuscript.

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Contribution: This author helped design the study, conduct the study, and write the manuscript.

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Contribution: This author helped design the study, conduct the study, and write the manuscript.

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REFERENCES


