Achieving 100% compliance to perioperative antibiotic administration: a quality-improvement initiative

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ABSTRACT

Introduction: Timely administration of prophylactic antibiotic within 60 minutes before surgical incision is important for reducing surgical site infections. This quality-improvement initiative aimed to work toward achieving 100% compliance to perioperative antibiotic administration.

Methods: We examined the workflow in our Anaesthesia Information Management System (AIMS) and proposed interventions using cause-and-effect analysis on anonymised anaesthetic records of eligible surgical cases extracted from it. This ultimately led to the implementation of an antibiotic pop-up reminder. The overall process was done in a few small plan-do-study-act cycles. These involved raising awareness, education and reorganisation of AIMS before actual implementation of the antibiotic pop-up reminder. There was ongoing data analysis from August 2014 to September 2016. Compliance was defined as documented antibiotic administration within 60 minutes before surgical incision or documented reason for omission.

Results: Median monthly compliance rate, for 33,038 cases before and 28,315 cases after the reminder was implemented, increased from 67.0% at baseline to 94.5%. This increase was consistent and sustained for a year despite frequent personnel turnover. Documentation of antibiotic administration also improved from 81.7% to 99.3%. This allowed us to identify and address novel problems that were not apparent initially, resulting in several department recommendations. These included administering antibiotics later for cases with foreseeably longer-than-expected preparation times, and bringing forward antibiotic administration in lower-segment Caesarean sections.

Conclusion: The use of information technology and implementation of antibiotic pop-up reminder on AIMS streamlined our work processes and brought us closer to achieving 100% on-time compliance with perioperative antibiotic administration.

Keywords: antibiotic prophylaxis, documentation, guideline adherence, reminder system, surgical wound infection
INTRODUCTION

Timely perioperative antibiotic administration is viewed as an important tenet for reducing surgical site infections (SSIs) and is included in many international evidence-based guidelines.\(^{(1-3)}\) These guidelines recommend that the administration of prophylactic antibiotics should occur within 30–60 minutes prior to surgical incision. The rationale is to allow time to establish adequate tissue and serum antibiotic levels at the time of skin incision. Prevention of SSIs is the focus and priority of the Surgical Care Improvement Program (SCIP), with a set of SCIP initiatives published jointly by the Centers for Medicare and Medicaid Services and the Joint Commission.\(^{(4,5)}\) This set of guidelines aims to standardise documentation and track compliance to various SCIP initiatives.

In our institution, anaesthesiologists are major process owners involved in perioperative antibiotic administration. Anaesthesiologists administer prophylactic antibiotics in the operating theatre at the time of anaesthesia induction. The choice of antibiotics is based on the hospital’s published antibiotic guidelines. The difficulties we faced in adhering to the SCIP initiatives were twofold. Firstly, antibiotic administration is often superseded by other aspects during anaesthesia induction. Secondly, it often becomes difficult to keep track of and remember the re-dosing timings as the case progresses.

A preliminary analysis of our Anaesthesia Information Management System (AIMS) records of all eligible surgical cases from August 2014 to November 2014 showed that our median baseline compliance to timely perioperative antibiotic administration was only 67.0%. We found similar reports of low adherence to perioperative antibiotic administration from other centres worldwide,\(^{(6-8)}\) thus highlighting a need for quality improvement at our hospital.

Learning from the experience of other authors utilising AIMS,\(^{(9-11)}\) we hypothesised that modifying our AIMS platform and workflow would have an impact on perioperative antibiotic compliance. Hence, we embarked on a quality-improvement initiative using plan-
do-study-act (PDSA) cycles and implementing an antibiotic pop-up reminder on AIMS, to work toward achieving 100% compliance to administering antibiotic prophylaxis within 0–60 minutes before skin incision over a period of 22 months. The timing of 0–60 minutes before skin incision was adopted based on existing guidelines,\(^1\,4,5\) and for pragmatic reasons, such as ease of administration and feasibility in a setting where high turnover of surgical cases is the norm.

**METHODS**

Anonymised anaesthesia records of all eligible surgical cases from August 2014 to October 2014 were extracted from AIMS for cause-and-effect analysis to identify potential causes of the problem. Data extracted for each month included: location of surgery; procedure type; choice of antibiotic; timing of first dose antibiotic administration relative to surgical procedure start time (or ‘knife to skin’); timing of redoses, where applicable; reason for omission, where applicable; practitioner identity; and, subsequently, key performance indicators met/not met. Cases that had special administration requirements for prophylactic antibiotics, such as vancomycin or fluoroquinolone, were excluded as, due to the longer infusion time required for these antibiotics, they need to be started before arrival in the operating theatre in order to finish the infusions within 60 minutes of surgical incision.

From our cause-and-effect analysis, some causes that were identified included lack of knowledge regarding timing of antibiotic prophylaxis, difficulty in obtaining certain antibiotics, difficulty in anticipating the incision time, uncertainty regarding the choice of antibiotics and lack of documentation when antibiotic prophylaxis was not required. We determined that the largest contributors were failure to document and lack of a time trigger. Because both events could be linked to AIMS in our workflow, we considered whether modifications to AIMS could improve compliance to antibiotic administration.
We examined the existing AIMS workflow and proposed interventions that would provide reminders and improve compliance without affecting complexity or introducing unnecessary interruptions. It had to be intuitive because the high turnover of our junior staff, at irregular intervals, meant that extensive training for a proposed change would not be pragmatic. The end product was an antibiotic pop-up reminder that required mandatory input from the anaesthesiologist. This was first displayed when the start of anaesthesia was documented on AIMS. The anaesthesiologist could then enter the timing and type of antibiotic administered. If an antibiotic was not required, it was mandatory to provide a reason. The system would later also prompt the anaesthesiologist when the antibiotic was due for redosing. At the end of the case, there would be another prompt to enter the reason in case prophylactic antibiotic was not required or given. The intervention workflow is summarised in Fig. 1.

After obtaining approval from the department head, we submitted the change request to the AIMS technical support team. The institution approved funding for this change request. The overall change process involved a few short PDSA cycles that can be largely summarised into three phases.

Phase 1 was meant to: (a) raise awareness of current prophylactic antibiotic guidelines available on the intranet; (b) educate staff on the importance of timely antibiotic administration and need for improved compliance with AIMS documentation through department meetings and emails; and (c) seek buy-in from the department.

Phase 2 aimed to improve organisation of the ‘Antibiotics not given – reasons’ section to improve data capture. This would allow more accurate documentation of reasons why antibiotics were not administered (including ‘Already given in the ward, not due for redosing’ and ‘Surgery does not need antibiotics’), or where there were expected or unexpected delays (e.g. ‘Awaiting intraoperative cultures to be taken’ and ‘Antibiotic had to
be fetched from the ward’). Phases 1 and 2 were implemented from December 2014 to September 2015.

Phase 3 involved actual ‘live’ implementation of the antibiotics pop-up reminder at the end of September 2015 across all operating theatres utilising AIMS. ‘Surgery start time’ or ‘knife to skin’ was made mandatory and had to be recorded before the ‘Prepare to end’ event icon could be pressed, in which case the document could not be finalised. The event icons on AIMS were also rearranged to follow the normal sequence of activities in the course of anaesthesia. Staff were notified and educated about this new pop-up reminder through emails, detailed instructional slides and briefing at department meetings. We also started sending individual antibiotic compliance data to department staff to create awareness.

During these phases, there was ongoing data analysis and surveillance, and identification of areas where there was lack of compliance, with feedback provided to staff.

Data was generated from the AIMS database monthly. After obtaining the compliance data, we plotted run charts to monitor the compliance rate to prophylactic antibiotic administration over the study period.

For purposes of data analysis, a period of four months (August 2014 to November 2014) before the start of any intervention was analysed to determine our baseline compliance rate to prophylactic antibiotic administration. Subsequently, the pre-implementation period (comprising Phases 1 and 2) was taken to be from December 2014 to September 2015, i.e. before the implementation of the antibiotics pop-up reminder in September 2015 (Phase 3). Data in the post-implementation period, from October 2015 to September 2016, was analysed to determine if any sustained change in compliance had occurred. Compliance/key performance indicators met was defined as documented antibiotic administration within 60 minutes before surgical incision or documentation with reason why prophylactic antibiotic was not needed or given. Noncompliant cases were divided into those in which dosing was
too early, too late or not documented. Percentage compliance was defined as the number of cases meeting compliance criteria against the total number of cases with anaesthetic care.

RESULTS

There were a total of 61,353 cases during our study period from August 2014 to September 2016. Out of the 33,038 cases at baseline and the pre-implementation period, 6,034 (18.3%) cases were excluded from analysis due to incomplete data (e.g. surgery start date or time not being available). In the post-implementation period, 198 out of 28,315 (0.7%) cases were likewise excluded from analysis. There was a sustained increase in the median monthly compliance rate from 67.0% at baseline to 75.3% during the pre-implementation period (Phases 1 and 2), and finally to 94.5% during the post-implementation period (Phase 3) (Fig. 2). The breakdown of average compliance and noncompliance rates of all eligible cases at baseline, and in the pre- and post-implementation periods is shown in Table I. There was a large drop in the proportion of ‘Noncompliant – antibiotic given too late’ cases between the baseline and pre-implementation period (from 10.1% to 2.3%). This further reduced to 1.3% in the post-implementation period. Compared to the pre-implementation period, the proportion of ‘Noncompliant – antibiotic not given/not documented’ cases dropped significantly in the post-implementation period (from 20.4% to 2.0%).
Table I. Overall compliance and noncompliance rates to prophylactic antibiotic administration.

<table>
<thead>
<tr>
<th>Variable</th>
<th>%</th>
<th>Noncompliant</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compliant</td>
<td>Given too early</td>
<td>Given too late</td>
<td>Not given/not documented</td>
<td></td>
</tr>
<tr>
<td>At baseline (n = 7,152)</td>
<td>67.0</td>
<td>1.5</td>
<td>10.1</td>
<td>21.4</td>
<td></td>
</tr>
<tr>
<td>Pre-implementation period (n = 19,852)</td>
<td>76.1</td>
<td>1.2</td>
<td>2.3</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td>Post-implementation period (n = 27,919)</td>
<td>95.0</td>
<td>1.7</td>
<td>1.3</td>
<td>2.0</td>
<td></td>
</tr>
</tbody>
</table>

Given too early: antibiotics were administered over 60 minutes before surgical incision; given too late: antibiotics were administered after surgical incision.

Cefazolin was the most commonly used antibiotic (51.5%) for surgical prophylaxis, followed by ceftriaxone (10.3%) and metronidazole (5.4%). In cases where antibiotics were documented as not required, the most often cited reason was that the antibiotic had been given in the ward and was not due for redose.

Table II. Noncompliance to prophylactic antibiotic administration by surgery type.

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>%</th>
<th>Pre-implementation period</th>
<th>Post-implementation period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstetrics</td>
<td>10.4</td>
<td>28.7</td>
<td></td>
</tr>
<tr>
<td>Gynaecology</td>
<td>10.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>General surgery*</td>
<td>13.6</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>Head and neck surgery</td>
<td>2.3</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Hepatopancreaticobiliary/upper gastrointestinal surgery</td>
<td>4.8</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Vascular surgery</td>
<td>4.3</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Colorectal surgery</td>
<td>9.6</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>4.0</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>Oral and maxillofacial surgery</td>
<td>1.1</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Orthopaedics/hand surgery</td>
<td>18.0</td>
<td>19.8</td>
<td></td>
</tr>
<tr>
<td>Otolaryngology/eye surgery</td>
<td>4.3</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Plastic surgery</td>
<td>5.9</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Cardiothoracic surgery</td>
<td>4.6</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Urology</td>
<td>6.5</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>Other†</td>
<td>0.3</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

*Including breast surgery and surgical oncology. †Includes cases done under procedural sedation and which does not fit into any surgical categories, e.g. electroconvulsive therapy.
During the pre-implementation period, orthopaedics/hand surgery (18.0%), general surgery (including breast surgery and surgical oncology; 13.6%), and obstetrics and gynaecology (20.7%) cases constituted the majority of cases where there was noncompliance to prophylactic antibiotic administration. Contrary to our expectations, however, the proportion of noncompliant cases in obstetrics and neurosurgery increased markedly after implementation of the antibiotic pop-up reminder (from 10.4% to 28.7% and from 4.0% to 9.2%, respectively) (Table II). This was unlike the trend observed across other surgical specialties, suggesting that there might be systemic problems, other than documentation of antibiotic administration, at play here that were not addressed by the introduction of the antibiotic pop-up reminder.

Considering this, we classified noncompliant cases based on whether antibiotic administration was not documented, given too late or too early. Under each category, we further analysed the distribution of noncompliant cases according to surgical specialty.

Among cases that were ‘Noncompliant – antibiotic not documented’, a majority (31.3%) of cases involved emergency surgical cases in the emergency operating room, where data regarding the nature of surgery and antibiotics is often neglected. Among cases that were ‘Noncompliant – antibiotic given too late’, this was most commonly observed in obstetric cases, in particular lower-segment Caesarean sections, which made up 37.9% of all cases where antibiotic was given late. This is because it is a common practice in our institution to administer antibiotics only after the baby has been delivered (after the umbilical cord has been clamped) due to concerns that fetal exposure to antibiotics could mask fetal infection and lead to the emergence of resistant bacterial strains. Among cases that were ‘Noncompliant – antibiotic given too early’ (over 60 minutes before surgical incision), most (37.3%) cases were neurosurgical cases in which a longer-than-expected amount of time post
induction was spent positioning and preparing the patient, resulting in antibiotic administration too early relative to ‘knife to skin’ timing.

**DISCUSSION**

SSI is a common cause of postsurgical morbidity and mortality, which adds significantly to the length of hospitalisation and cost of treatment.\(^{(12-14)}\) In addition to measures such as appropriate skin antisepsis and reducing the duration of surgical procedures, international guidelines on SSI prevention also recommend timely administration of prophylactic antibiotics (taken as 30–60 minutes before surgical incision), appropriate choice of antibiotics and supplemental dosing of antibiotics for prolonged cases.\(^{(1-3)}\) These guidelines also encourage audits to monitor adherence to perioperative antibiotic administration. Compliance rates to perioperative antibiotic administration have now become our department’s key performance indicator because of the importance of antibiotic timing and selection for reducing perioperative morbidity and mortality. The SCIP also recommends the reporting of antibiotic timeliness (within one hour before surgical incision) as a quality measure. In this article, we described the implementation of an antibiotic pop-up reminder on AIMS to improve compliance with timely perioperative prophylactic antibiotic administration.

Previous studies have employed various methods incorporated as part of AIMS to improve antibiotic compliance, and our results compare favourably with these. Among methods already reported are the use of interactive visual reminders\(^{(9)}\) and computerised reminder system,\(^{(15)}\) generating reports from the AIMS database, and giving provider-specific feedback.\(^{(10)}\) Nair et al described a strategy of using “real-time guidance and reminders through electronic messages generated by a computerised decision support system (Smart Anaesthesia Messenger, or SAM) which significantly improved compliance with consistency”.\(^{(11)}\) Importantly, they showed that the “mere installation of AIMS itself did not
improve antibiotic compliance over that achieved with paper anaesthesia records”. In our experience, median baseline antibiotic compliance was 67.0% despite the existence of AIMS prior to intervention, which mirrors the observations of Nair et al.

At the start of our quality-improvement initiative, we raised awareness, provided necessary education and emphasised the importance of solving the problem of poor compliance with antibiotic administration at the department level. This, together with the initial reorganisation of AIMS during Phases 1 and 2, produced a modest increase in median monthly compliance rates to 75.3%. Expanding on this, we then modified the existing AIMS platform to add an antibiotic pop-up reminder that required mandatory input by the anaesthesiologist. This addition reinforced perioperative antibiotic administration, improving overall compliance rate from an absolute of 66.5% in the start month of our study period to 96.8% in the final month. It worked predominantly by improving documentation of antibiotic administration, as evidenced by the greater proportion of complete records available for data analysis in the post-implementation period (99.3%) compared to the pre-implementation period (81.7%), and the decrease in the proportion of cases where compliance was not met due to lack of documentation (from 20.4% to 2.0%). Consistent and sustainable results were achieved throughout the one-year post-implementation period despite frequent personnel turnover and resident changes, demonstrating that for a change to be effective and sustainable, it should be re-engineered into a pre-existing workflow, while maintaining the ease of use and not compromising on efficiency. The AIMS database also provided us with actionable data for continual improvement after multiple PDSA reviews.

By leveraging on the use of electronic documentation and data analytics during the quality-improvement initiative, we could identify and address novel problems that were not apparent in the initial planning stage. For example, in cases with foreseeable longer-than-expected patient preparation times, such as neurosurgical cases or high-risk cases that require
setting of invasive lines, anaesthesia providers have been advised to administer prophylactic antibiotics only after all anaesthetic preparation has been completed. Reminder was also given to senior staff covering emergency operating theatres to reinforce the need for strict antibiotic dosing, where applicable, as these cases tended to be higher risk due to their emergent nature. Obstetricians were also engaged on evidence that strongly advocated the administration of antibiotics before ‘knife to skin’ (as opposed to the traditional practice of giving antibiotics only after clamping of the umbilical cord) for lower-segment Caesarean sections.\textsuperscript{16,17} To further improve compliance through feedback and self-improvement, an individualised quarterly performance report was sent to each anaesthesiologist to compare their personal antibiotic prophylaxis compliance rate to the department average.

A limitation of our quality-improvement initiative was that it only focused on the timeliness of antibiotic administration. We anticipate that by adapting AIMS technology, we would be able to evaluate the remaining inconsistencies involving the other tenets of perioperative antibiotic administration, namely appropriateness of the choice of antibiotics, redosing times in lengthy surgical procedures and timely administration of prophylactic antibiotics when given as an infusion.

In summary, electronic documentation can provide actionable data for quality improvement in healthcare. Judicious application of information technology can also facilitate work processes and create conducive platforms for change. By adopting multiple PDSA cycles, we were able to implement an antibiotic pop-up reminder on the AIMS database, increasing our compliance with SCIP guidelines on timely administration of prophylactic antibiotics to 96.8\% in the final month of the study period. We learnt that for change to be sustained, it should be incorporated into a pre-existing workflow in a seamless manner, with the ease of use maintained and efficiency not compromised.
REFERENCES


**FIGURES**

![Diagram showing the intervention workflow on AIMS](image)

**Fig. 1** Diagram shows the intervention (antibiotic pop-up reminder on AIMS) workflow (1 to 5). (1) The event icons on AIMS were arranged in the normal sequence of activities in the course of anaesthesia, i.e. Patient enters induction room → Patient enters operating theatre (OT) → Anaesthesia started/intravenous access → Induction → Ready for surgery → Knife to skin → Prepare to end → Anaesthesia reversal → Patient left OT. (2) The antibiotic pop-up reminder was activated when the user clicked the 'Ready for surgery', 'Anaesthesia started' or 'Induction' buttons. (3) If the user selected that a prophylactic antibiotic was required for the patient, it would trigger additional fields for 'Time given', 'Antibiotic given', 'Dose' and 'Reminder interval'. If the system determined that an antibiotic had already been recorded in the medication panel, then these fields would be auto-populated. (4) A 'Reminder interval' could be set to prompt the user later when the antibiotic was due for redosing. (5) If prophylactic antibiotic was not required or given, the user would need to select the reason from a drop-down menu. This last field was made mandatory. AIMS: Anaesthesia Information Management System
Fig. 2 Run chart shows median monthly antibiotic compliance rate during the intervention phases. Baseline: from August 2014 to November 2014; Phases 1 and 2: from December 2014 to September 2015, before live implementation of antibiotic pop-up reminder in September 2015; Phase 3: from October 2015 to September 2016, after actual ‘live’ implementation of antibiotic pop-up reminder across all operating theatres utilising AIMS in end September 2015. AIMS: Anaesthesia Information Management System