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Improving Timely Surgical Antibiotic Prophylaxis Redosing Administration Using Computerized Record Prompts

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ABSTRACT

***Background*: Timely prophylactic antibiotic administration aids in preventing postoperative superficial surgical site infections. However, during lengthy surgical procedures, redosing of prophylactic antibiotics may be unintentionally omitted. We assessed the utility of a computerized reminder as part of the anesthesia charting system to increase the rate of timely intraoperative prophylactic antibiotic redosing.**

***Methods*: A retrospective observational analysis was performed on consecutive patients undergoing non-cardiac surgical procedures at a university-affiliated hospital prior to and after the institution of a computerized reminder system. The reminder system presented the clinician with a series of on-screen dialog boxes prior to the redose time for the specific prophylactic antibiotic administered preoperatively. Antibiotic redosing was defined as appropriate if it occurred within 30 min prior to or after the due time, calculated as twice the half-life of the specific antibiotic. Patients were excluded if the case duration was less than twice the half-life of the administered prophylactic antibiotic, or if no prophylactic antibiotic was given.**

***Results*: A total of 287 cases were included in the study (148 pre-intervention, 139 post-intervention). Patient age, case length, and American Society of Anesthesiologists (ASA) score stratification did not differ between the groups. Use of the reminder system resulted in an increase in the appropriate redosing of antibiotics from 20% prior to institution of the reminder to 58% after institution ($p < 0.001$).**

***Conclusions*: A computerized reminder system is an effective tool to assist in appropriate intraoperative redosing of prophylactic antibiotics during lengthy surgical procedures.**

SURGICAL SITE INFECTIONS (SSI) have been associated with increased morbidity, mortality, and excess healthcare costs [1]. Prevention of SSI is multimodal and focused on the application of standard protocols, such as surgical preoperative scrub techniques, surgical instrument preparation, and utilization of sterile barriers and drapes. Key to this process is appropriate antibiotic prophylaxis. In particular, timely administration of perioperative prophylactic antibiotics allows for complete penetration of the drug into the surgical site tissue prior to incision and has been shown to decrease SSI rates [1,2]. Failure to administer or

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inappropriate delay of the initial dose of these antibiotics has been shown to produce an increased risk for SSI [3]. Due to a variety of factors, appropriate delivery of antibiotic prophylaxis is frequently not achieved. Some estimates note administration of prophylactic antibiotics prior to incision in only 46–83% of surgical cases [4].

In prolonged surgical procedures in which the tissue concentration of the prophylactic antibiotic may fall below the necessary mean inhibitory concentration (MIC) of target organisms, intraoperative redosing of antibiotics is as crucial as the initial administration. Recommended to occur after two half-lives of the prophylactic agent, timely intraoperative redosing has been found to reduce SSI rates in cardiac surgical patients [3,5]. However, despite ample evidence showing the importance of redosing, adherence to appropriate intraoperative redosing is usually poor [6], and novel methods to insure appropriate delivery of intraoperative antibiotics have not been investigated widely. Therefore, we performed a retrospective observational analysis after the institution of a computerized reminder directed at intraoperative antibiotic redosing at our institution, to determine the impact of such an intervention on the frequency of appropriate intraoperative antibiotic redosing. Our hypothesis was that a computerized reminder prompt would increase the rate of timely surgical prophylactic antibiotic redosing.

MATERIALS AND METHODS

Computerized redosing reminder

At Vanderbilt University Medical Center, the antibiotic reminder series is presented to the anesthesiology clinician in the operating room as part of the computerized record system, the Vanderbilt Perioperative Information Management System (VPIMS). This computer charting software, used by the anesthesia provider (attending or resident physician, nurse anesthetist) present in the operating room, utilizes a dedicated computer and flat panel display attached to the anesthesia delivery machine. The display is plainly visible at all times to the anesthesiology clinicians, and is the screen upon which the intra-operative anesthesia record is recorded. After administration of the initial preoperative prophylactic antibiotic, the dose of antibiotic and the time of drug administration are entered into VPIMS. This documentation of the initial dose activates a timer built into the charting application.

The first notification of an approaching antibiotic redose time occurs at 30 min prior to a specified time interval. This interval is based on approximately twice the elimination half-life of the agent for each antibiotic given (Table 1) [3]. The notification appears as a pop-up dialog box, presented on the charting screen, to notify the clinician that it is time to consider antibiotic redosing (Fig. 1). A 30-min window was chosen to allow the user to consult with other care team members regarding the necessity of a redose, order the drug, obtain the drug from pharmacy, and start the administration at the appropriate time. The dialog box can be dismissed by the selection of one of three options: (1) “OK,” which, if pressed without the entry of an antibiotic dose into the system within a five-minute time period, results in another reminder dialog box; (2) “Remind Me in 15 Minutes,” which functions similarly, but with a 15-min delay; and (3) “Don’t remind me any-

T1

F1

Table 1. Appropriate Prophylactic Antibiotic Redose Time

Antibiotic	*Time due (min)*
Cefoxitin	120
Ampicillin	240
Ampicillin-sulbactam	240
Cefazolin	240
Cefotaxime	240
Piperacillin	240
Piperacillin-tazobactam	240
Chloramphenicol	360
Clindamycin	360
Erythromycin	360
Metronidazole	360
Cefotetan	480
Ciprofloxacin	480
Cefepime	720
Ceftazidime	720
Cefuroxime	720
Linezolid	720
Vancomycin	720

Times are based on approximately twice the elimination half-life of the listed antibiotic.

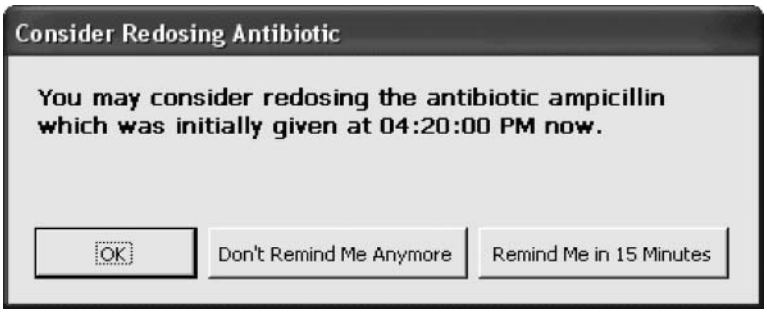

FIG. 1. Example of computer antibiotic redose screen prompt, displayed beginning 30 min prior to the antibiotic due time (two times the half-life of the antibiotic used). Users were given three options to clear the box.

more." If this last choice is selected, the user is prompted to confirm the selection. At each selection of the "Remind me" option, the system will prompt the user at later time with a similar box except for a decrease in the reminder time and, ultimately, a past due notification, which will appear 30 min after the due time (Fig. 2).

Ordering and administration of the antibiotic are handled in the usual fashion. The order is relayed to the circulating nurse, who obtains the antibiotic from the surgical pharmacy and delivers it to the anesthesiology clinician for administration. Once administration is begun, the antibiotic dose and time are recorded in the charting system, and the timer is reset. In the case of multiple antibiotics administered during the course of a single procedure, the system keeps track of each drug individually, with a separate timer and set of reminders for each.

Clinical data collection

Inclusion criteria. Antibiotic administration data were retrieved from all surgical procedures performed in the general operating room (OR) suite at the Vanderbilt University Medical Center, a tertiary-care facility located in Nashville, Tennessee. The procedures in this suite were predominantly general surgical, neurosurgical, and orthopedic, but plastic surgical, otolaryngologic, urologic, and vascular procedures were also performed. Obstetric, pediatric surgical, and ophthalmology services were not performed in the suite and were therefore not included in the analysis. In order to evaluate the impact of the initiation of the computerized reminder, two time periods were studied: Pre-intervention, defined as the four weeks before implementation, and post-intervention, defined as the four weeks after implementation. A five-day buffer between the intervention and the post-intervention analysis period was allowed for users to be trained on and become accustomed to the new system.

Exclusion criteria. Cardiac surgery patients were excluded, antibiotics are redosed routinely at the time of separation from car-

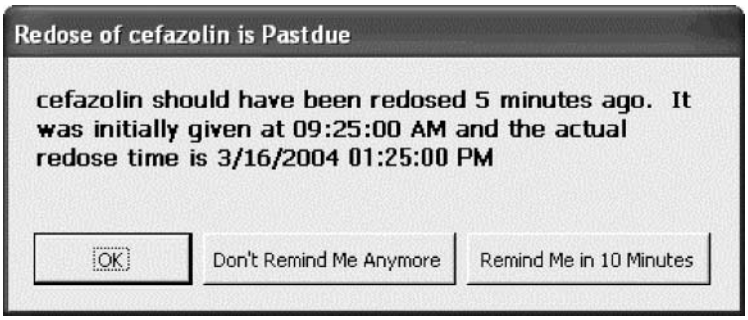

FIG. 2. Example of computerized past due antibiotic redose screen prompt displayed beginning 5 min past the antibiotic due time.

diopulmonary bypass (CPB). Separation from CPB therefore serves as a discrete reminder to redose antibiotics and could have confounded the results. Also excluded were patients undergoing procedures in which no pre-incision prophylactic antibiotic dose was recorded, or procedures for which the duration was less than twice the half-life of the initial antibiotic administered for prophylaxis, thus eliminating the need for a second antibiotic dose. There were no other perioperative initiatives focused on antibiotic redosing immediately before or after the intervention.

All data were entered into the computer at the time and point of service. Redosing administration rates were calculated prior to and after the implementation of the reminder. Redoses were considered to be on time if they occurred within 30 min before or after the time due. Redoses were considered late if they were beyond 30 min after the due time, or if they never occurred for the remainder of the case and the case continued more than 30 min past the expected redose time. This study was approved by the Vanderbilt University Institutional Review Board.

Analysis

Data were queried from the VPIMS database by an analyst using a standard query language. Data were then imported into a spreadsheet for formatting and analysis using Fisher's Exact testing via SPSS v.10 (SPSS Inc., Chicago, IL). Statistical significance was determined at $p < 0.05$.

RESULTS

A total of 287 procedures met inclusion criteria during the study period: 148 procedures during the pre-intervention period (52%) and 139 procedures during the post-intervention time period (48%). Mean patient age, case length, and percent of patients categorized as American Society of Anesthesiologists (ASA) score class 1 or 2 were comparable between the two groups (Table 2). An analysis of the pre- and post-intervention on-time administration rates showed that on-time antibiotic redosing increased after the implementation of the reminder system, from 20% to 57% ($p < 0.001$; Fig. 3).

Improvement was noted in all procedures studied, ranging from a 14% improvement among urologic procedures to a 100% improvement among thoracic and oral surgery procedures. Due to higher procedure volumes, the improvements in redosing during neurosurgical and otolaryngologic procedure had the greatest impact on the overall improvement during the study period (Table 3).

A post-hoc analysis of the 43% of procedures ($n = 60$) that did not have on-time antibiotic redosing despite the intervention found that 20% ($n = 12$) of these procedures had a closed incision (indicated by documentation of a "dressing on" time) within 30 min of the time the antibiotic was due. Additionally, another 54% ($n = 32$) were classified as having clean wounds, indicating that the decision to not redose the antibiotic may have been made on the basis of the clean wound designation. However,

Table 2. Demographics of Surgical Patients Undergoing a Procedure of Given Sufficient Length (Two Times the Elimination Half-Life of the Antibiotic Used) to Warrant Consideration of an Antibiotic Redose who Also Received an Initial Dose of Prophylactic Antibiotic

	Pre-reminder period	*Post-reminder period*
Total procedures	148	139
Mean age (years ± SD)	50 ± 17	48 ± 19
Mean case length (min ± SD)	346 ± 128	358 ± 139
ASA Class 1 or 2 (%)	39%	44%

Four-week periods pre- and post-reminder system implementation were used. There were no statistical differences between groups.

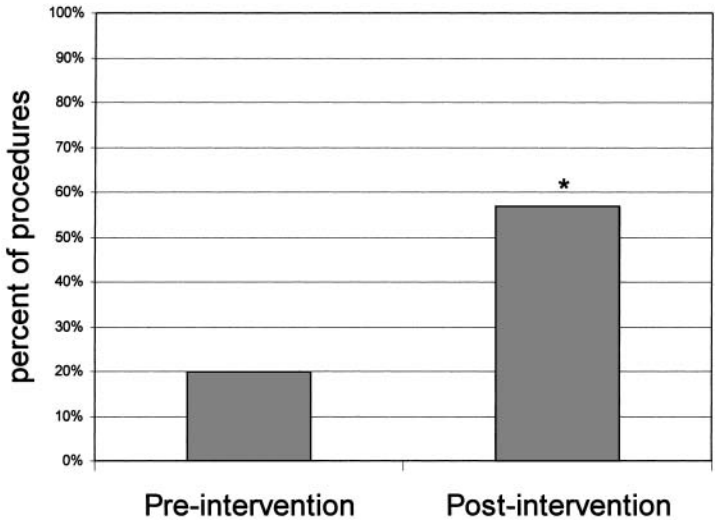

FIG. 3. Frequency of appropriate intraoperative prophylactic antibiotic redosing in relation to initiation of computerized prompt for redosing. An appropriate redose was defined as one given no later than 30 min after the calculated appropriate due time, based upon the specific antibiotic given for preoperative prophylaxis (*$p < 0.001$).

analysis of the clean wound, non-redosed procedures showed that these were predominantly orthopedic and neurosurgical procedures (Table 4). A similar analysis of the procedures designated clean/contaminated showed a concentration in general surgery (Table 4).

DISCUSSION

The OR is a complex environment in which clinicians must be attentive to multiple simultaneous tasks, including the assurance of delivery of prophylactic antibiotics in a timely manner. We examined the use of a computerized, automated prompting system as a mechanism of improving administration of doses of prophylactic antibiotics perioperatively, and found that such a tool improved intraoperative antibiotic redosing. Careful attention to antibiotic administration is a major component of reducing surgical site infections, which comprise an estimated 25% of all

TABLE 3. PERCENT IMPROVEMENT IN PROPHYLACTIC ANTIBIOTIC REDOSING BY SERVICE, AND PERCENT CONTRIBUTION OF EACH SERVICE TO THE OVERALL IMPROVEMENT SEEN AFTER THE IMPLEMENTATION OF THE COMPUTERIZED REDOSING REMINDER SYSTEM

Service	*Percent service improvement of on-time antibiotic redosing*	*Percent contribution to overall improvement*
General Oncology Surgery	25.0	3.2
General Surgery	40.0	6.3
Hepatobiliary/Liver Transplant	66.7	9.5
Neurosurgery	69.2	28.6
Oral and Maxillofacial Surgery	100.0	4.8
Orthopedic Trauma	60.0	9.5
Orthopedics	20.0	3.2
Otolaryngology	57.1	12.7
Plastic Surgery	33.3	3.2
Renal Surgery	66.7	3.2
Thoracic	100.0	3.2
Trauma	71.4	7.9
Urology Surgery	14.3	1.6
Vascular Surgery	40.0	3.2

TABLE 4. SURGICAL SERVICE ANALYSIS OF 60 PROCEDURES WITHOUT AN ANTIBIOTIC REDOSE DESPITE THE PRESENCE OF A COMPUTERIZED REMINDER PROMPT

Service	*Percentage of procedures that were classified as clean/contaminated (n = 24)*	*Percentage of procedures that were classified as clean wound (n = 36)*
General Oncology Surgery	0	3
General Surgery	38	6
Hepatobiliary/Liver Transplant	0	3
Neurosurgery	0	25
Oral and Maxillofacial Surgery	0	0
Orthopedic Trauma	8	3
Orthopedics	8	22
Otolaryngology	13	3
Plastic Surgery	13	9
Renal Surgery	0	3
Thoracic	0	0
Trauma	4	3
Urology Surgery	17	9
Vascular Surgery	0	9

nosocomial infections with commensurate cost and morbidity.

Unlike the preoperative or pre-incision prophylactic antibiotic dose, defined protocols or reminder tools for repeat intraoperative dosing are not typically in place in most institutions. In addition, there are no easily identifiable time markers between incision time and case completion time that could serve to trigger the need for antibiotic redosing. Clinicians in the OR suite may be occupied with multiple aspects of a complex surgical procedure, and either errantly omit or delay the antibiotic redose, typically four to six h after the start of the procedure. In the past, individuals have developed visual reminders such as documentation of the planned antibiotic redose time on a piece of tape or paper placed in the line of sight of the anesthesia practitioner. Such systems are user-dependent, not practiced universally, and ineffective as shown in our preintervention analysis.

Most of the previous work on the use of systematic tools designed to improve delivery of prophylactic antibiotics has focused on improving adherence only to preoperative or preincision antibiotic regimens [7,8]. Larsen et al. demonstrated that computerized decision support increased preoperative prophylactic antibiotic administration from 40% to 58% via a computer-generated reminder placed in patient's medical record prior to surgery [9]. However, for longer surgical cases, antibiotics must be redosed during surgery to maintain therapeutic tissue concentrations throughout, which may reduce surgical site infection rates by as much as 16% [5]. The widespread institution of computerized record keeping systems in ORs creates an opportunity to have a programmed system provide a reminder of the impending need for antibiotic redosing. We have now shown that computerized decision support can improve dramatically the rate of timely prophylactic antibiotic redose administration.

Our results compare favorably with previous work in cardiac surgical patients done by Zanetti et al., who also employed a computerized antibiotic reminder, showing an increase in the frequency of timely antibiotic redose receipt from 40% to 68% [5]. Our study builds on this previous work in that Zanetti et al. only studied the administration of one antibiotic and only in cardiac surgery patients, cases in which separation from CPB serves as a reminder for antibiotic redosing.

Our study did not include obstetric, pediatric surgical, or ophthalmologic procedures. However, the fundamental process of antibiotic administration does not differ with these procedures. In addition, we would not expect a different outcome on those services, as there is

nothing unique to those procedures that should change the response to an intraoperative reminder. It is also unlikely that another unmeasured process contributed to the change in timely redosing frequency, as there were no other large-scale interventions in this OR suite during the time period studied. We also were unable to collect data from the anesthesiology practitioners as to why the redose wasn't performed.

As described in an editorial by Lee, we have sought to illustrate that a computerized prompting system can effectively improve compliance with standard antibiotic regimens [10]. Further work will be required to elucidate the reasoning for the continued presence of procedures where antibiotics are not redosed despite the reminder. We found that, of those procedures, many were near completion or had wounds classified as clean, leading us to believe that the practitioner declined to redose on that basis. Similarly, the previous study of Zanetti et al. showed that, in 14% of cases, the physician actively refused a prompted redose request [6]. Further work in this area may include evaluating the management of procedures that are in the process of ending or that will end at the time the redose is due, to examine the clinical judgment that redosing is not needed.

Computerized reminders appear to serve as an effective and valuable tool to assist in timely redosing of prophylactic antibiotics. This information should be helpful to hospitals and practices looking for novel means to assist in the prevention of SSI.

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Please define what you mean by “clean/contaminated” (vs. “clean wound”) in text and Table 4.