ORIGINAL ARTICLE

Exploring obstacles to proper timing of prophylactic antibiotics for surgical site infections

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Background: Surgical site infections remain one of the leading types of nosocomial infections. The administration of prophylactic antibiotics within a specific interval has been shown to reduce the burden of surgical site infections, but adherence to proper timing guidelines remains problematic. This study examined perceived obstacles to the use of evidence-based guidelines for the timely administration of prophylactic antibiotics to prevent surgical site infections.

Methods: 27 semi-structured interviews were conducted with anesthesiologists (n = 12), surgeons (n = 11), and perioperative administrators (n = 4) in two large academic hospitals to elicit their perceptions of the factors that prevent the timely administration of prophylactic antibiotics. Using a grounded theory approach, transcripts were analyzed for recurrent themes.

Results: Despite having knowledge of guidelines, participants perceived consistent failure in the proper timing of antibiotic administration. Thematic analysis revealed a number of obstacles to the observance of guidelines including: (1) low priority, (2) inconvenience, (3) workflow, (4) organizational communication, and (5) role perception. Workflow and role perception were the dominant obstacles.

Conclusion: This study suggests that proper antibiotic timing is thwarted by significant obstacles. The gap between evidence-based guidelines and practice is populated by individual values, professional conflicts, and organizational conflicts which must be addressed in order to achieve optimal practice in this domain. Using group interviews to reveal these factors to team members and managers may be a first step to resolving the gap and reducing surgical site infections.

In the USA surgical site infections (SSIs) are the second most common nosocomial (hospital acquired) infection after urinary tract infections.[1–4] A modest wound infection rate of less than 4% translates into 500 000–920 000 annual SSIs.[5] An extensive study by the Harvard School of Public Health concluded that SSIs accounted for the second largest number of adverse events, second only to medication errors.[6] In the UK a recent survey reported that, depending on the type of surgery, SSIs occurred in approximately 2–15% of operations.[7]

SSIs occur in susceptible hosts when bacteria are present in a surgical wound,[8] and can result in significant morbidity, mortality,[9–12] and costs.[13] A cohort study concluded that, in the 1990s, patients who developed SSIs spent 60% more time in the intensive care unit, were over five times more likely to be readmitted to hospital, and were twice as likely to die.[14]

Antibiotic prophylaxis is one of the most effective strategies for preventing SSIs,[15–21] especially if administered before surgical incision.[22 23] One large prospective clinical trial further specified the 2 hour pre-incision period as the ideal interval for the delivery of prophylactic antibiotics, as administration after incision resulted in a fourfold increase in SSIs (the incidence of wound infection of patients who received antibiotics within the 2 hour period before incision was 0.6% compared with an incidence of 2.6% when the antibiotics were given after incision).[24]

Despite this evidence, proper timing of prophylactic antibiotics remains problematic. A major 1996 study by the Antibiotic Prophylaxis Study Group (APSG) found that, although 86% of patients received antibiotic prophylaxis for postoperative wound infections, only 61% received these medications within a 2 hour preoperative period.[25] In a Canadian survey of hip fracture patients, only 30% of 352 patients who underwent surgery with insertion of prosthetic foreign material received prophylactic antibiotics within the 2 hour interval before incision.[26] More recently, a study by the National Surgical Infection Prevention (SIP) Project[27 28] in the United States found that prophylactic antibiotics were administered to only 55.7% of patients within 1 hour before incision.[29] This breadth of literature supports many physicians' views that *timing is the most common problem in antibiotic prophylaxis for surgical wound infections*.[8 16 21 25 30]

The compelling evidence for proper antibiotic timing combined with the disappointing influence on clinical practice prompted several national organizations concerned with antibiotic prophylaxis to develop guidelines stipulating its optimal timing.[15 31–35] The majority of guidelines suggested that antibiotics be given within an interval of 30 minutes, rather than 2 hours, before surgical incision.[31–34]

Unfortunately, even the creation of guidelines largely failed to change practice as implementation and clinician compliance remained problematic,[16 25 36–38] a dilemma that has been described in other areas of health care.[39 40] While recent literature on this subject has suggested analyzing the barriers to the incorporation of guidelines,[41] this strategy has not yet been directed towards improving the timing of prophylactic antibiotics for reducing SSIs. Furthermore, a literature review found no studies that systematically explored the barriers to proper prophylactic antibiotic timing as perceived by the key participants involved in its administration. Concurring with Pope *et al* that "*… qualitative research on understanding meanings and experiences makes it particularly useful for quality assessment and for unpacking some of the complex issues inherent to quality improvement*",[42] the present study investigated the views and perspectives of healthcare professionals with key roles in the administration of prophylactic antibiotics at two Canadian teaching hospitals. This approach may provide a useful

Abbreviations: OR, operating room; SSI, surgical site infection

perspective for combating the significant burden of surgical site infections and result in improved patient care.

METHODS

Setting

This study was conducted in two large Canadian university affiliated teaching hospitals. These settings were chosen because the volume and complexity of cases presented a potential environment for antibiotic timing problems to occur. At both hospitals A and B elective surgical patients were prepared for surgery in a designated preoperative area, transferred to a ''holding area'' in anticipation of their surgery, and then brought to the operating room (OR) when the preceding case was completed. In hospital A prophylactic antibiotics were usually administered in the OR. In hospital B antibiotic administration was initiated in preadmission by nurses or in the OR by the anesthesiologist.

Participants

Over a 3 month period beginning in December 2003, semi-structured interviews were conducted with a total of 27 participants: 12 anesthesiologists, 11 surgeons and four perioperative staff (1 nurse, 1 nurse administrator, 1 anesthesia administrator, 1 pharmacist) from the two academic hospitals combined. Preliminary interviews suggested that the roles and responsibilities for prophylactic antibiotic administration rested primarily with surgeons, anesthesiologists and, to a lesser degree, with nurses. Considering the protocol driven organization of patient flow through the OR and the potential impact of that flow on antibiotic timing, it was felt that other perioperative staff would also provide important perspectives as they all have an interest in the care of surgical patients. Anonymity of the participants was guaranteed by a coding system. Surgeons and anesthesiologists from hospital A were labelled SA and AA, respectively, while those from hospital B were designated SB and AB.

Sampling

The research methods were guided by the grounded theory approach to qualitative inquiry.[43] Grounded theory research allows for comprehensive exploration of a topic in an iterative manner, in which data analysis occurs alongside data collection, and data collection is shaped to pursue emergent issues. From an initial convenience sample, theoretical sampling[44] was employed in which participants were recruited and interviewed until no new themes emerged in the data. In addition, criterion sampling[44] was used to select participants with a range of experience to inform the historical aspects of the research problem. Finally, a confirming/disconfirming sampling strategy[44] was employed to probe emerging trends. To facilitate these sampling approaches, data were not collected in institutional ''batches''; rather, participants were drawn from all groups and hospitals at all stages of the interview process.

Data collection

The semi-structured interviews were conducted using questions developed from preliminary interviews and correspondence with key informants from the key professions. Closed and open questions were asked. The closed questions sought to probe the participants' awareness of guidelines and also solicited their estimates of the frequency of compliance to proper timing. The open questions were designed as general questions or prompts. The interviewer was thus afforded the flexibility to explore participants' views and perceptions, often deviating from the interview schedule. With this interview structure, the interviewer was able to pursue emergent themes as they developed through the study period. Conversely, participants had the opportunity to lead the discussion in any direction that they thought was relevant to the topic of prophylactic antibiotic timing. Depending on the interview, not all questions were asked and not all responses were directed to the specific questions. All questions were piloted with four sample participants to resolve any ambiguities and ensure the script's effectiveness in prompting thoughtful responses. Box 1 presents an outline of these questions. Interviews were audio recorded and transcribed with all identifying factors removed.

Box 1 Interview prompts

Background

- Please identify your area of specialization and years of experience as a staff person.

Closed questions

- Do you know of any guidelines that exist regarding prophylactic antibiotics?
- How often would you estimate that they are actually administered at the proper time (within 30 min before incision)?
  - Were outliers before or after incision?

Open questions

Process

- What are some important principles surrounding the delivery of prophylactic antibiotics for the prevention of surgical wound infections?
  - In your experience which, if any, of these principles have been difficult to follow?
- Why do you think that antibiotics are not administered at the proper times?
- Describe the sequence of events before a patient arrives in the operating room.
  - How does this current process affect antibiotic administration?

Roles and responsibilities

- Tell me about the roles of the professionals involved in administering prophylactic antibiotics.
- Whose responsibility is it to ensure the proper timing of prophylactic antibiotic administration? Why?

Data analysis

The responses to closed questions were recorded. The transcribed responses to open questions were analyzed in an iterative and constant comparative process for recurrent themes by two researchers. Discrepancies were addressed by the researchers returning to the data and negotiating the status of the ambiguous themes or by attempting to combine them with other existing ones. A single researcher applied the confirmed coding structure to the entire data set using NVivo qualitative data analysis software,[45] which facilitated the comparison of themes across the two hospital sites and allowed for cross-coding to reveal interrelationships or interdependencies among themes.

Table 1 Demographic characteristics of study subjects

Position	Sex	Years of experience
Hospital A		
Surgeon SA1	M	0–4
Surgeon SA2	M	5–9
Surgeon SA3	M	10–14
Surgeon SA4	M	20–24
Surgeon SA5	F	5–9
Surgeon SA6	M	20–24
Surgeon SA7	F	20–24
Surgeon SA8	M	20–24
Surgeon SA9	M	10–14
Surgeon SA10	M	15–19
Anesthesiologist AA1	M	0–4
Anesthesiologist AA2	M	30–35
Anesthesiologist AA3	F	5–9
Anesthesiologist AA4	M	0–4
Anesthesiologist AA5	F	5–9
Anesthesiologist AA6	M	5–9
Anesthesiologist AA7	M	20–24
Anesthesiologist AA8	F	0–4
Anesthesiologist AA9	M	20–24
Perioperative staff PA1	F	20–24
Hospital B		
Surgeon SB1	M	20–24
Anesthesiologist AB1	M	0–5
Anesthesiologist AB2	M	0–5
Anesthesiologist AB3	M	15–19
Perioperative staff PB1	F	20–24
Perioperative staff PB2	F	0–4
Perioperative staff PB3	F	30–34
Total participants (M:F)	27 (18:9)	
Range of experience		1–36

Box 2 Perceived obstacles identified by participants

Process
- Individual
  - Low priority
  - Inconvenience
- Systemic
  - Workflow
  - Organizational communication

Role perception
- Shared responsibility
- Individual responsibility
  - Acceptance
  - Resignation

RESULTS

All invited participants consented to the study. Their demographic characteristics are shown in table 1.

Closed questions

When participants were asked the closed question ''Do you know that guidelines exist?'', 21 of the 27 participants said ''yes''. In their responses, 23 of the 27 participants added that they knew that the antibiotics should be given before incision, whether or not they were aware of guidelines. Participants were also asked: ''How often do you estimate that antibiotics are given within the proper interval?'' Seventeen of the 27 participants responded that, in their estimation, the antibiotics were given appropriately 75% of the time or less. Furthermore, 15 participants stated that prophylactic antibiotics were erroneously administered *after* surgical incision.

Open questions

Thematic analysis of responses to the open questions revealed two main categories of perceived obstacles to proper antibiotic timing. The first was ''Process'', or how tasks and routines are accomplished at the individual and systemic levels. The second was ''Role perception'', or the various perceptions of roles and their boundaries. Box 2 summarizes these two themes and their subcategories.

Process: individual level

Low priority

Process at the individual level involves the routines or order by which individuals perform their required tasks. The most dominant theme in this category was low priority, as both anesthesiologists and surgeons declared that antibiotics were a low priority among their many responsibilities. Anesthesiologists were more concerned about safely anesthetizing the patient and surgeons agreed that this was a more important task for the anesthesiologist than giving antibiotics. As one anesthesiologist said: ''*… the anesthesiologist … has other things which take absolute priority*'' (AA2). Surgeons were more concerned with ''*stressors in the OR environment*'' (SA1) such as OR delays and missing equipment but, similar to the anesthesiologists, their priority was their own major task—the surgery itself. As one surgeon summarized, ''*… the anesthesiologist is worried about the airway … making sure the patient gets the right drugs, gets oxygen … and the surgeon is worried about … the patient on the floor, this patient, the residents*'' (SB1). Overall, the administration of antibiotics was often deliberately assigned a low priority by team members.

According to anesthesiologists, another reason for the low priority of antibiotics was that the management of SSIs usually occurred beyond their period of contact with patients. As one anesthesiologist said: ''*… we forget sometimes basically because we don't see the immediate benefits of the antibiotics*'' (AB2).

Thus, from the time a patient entered the OR to the moment of incision, both professionals stated that they had more immediate and important tasks to think about or perform.

Inconvenience

Another factor that interrupted task accomplishment at the individual level, often resulting in late antibiotic administration, was the perceived inconvenience of performing this task. Because the most common prophylactic antibiotic, cefazolin, almost always came as a powder which then had to be reconstituted with saline, anesthesiologists reported being deterred from preparing it. As one anesthesiologist from hospital A explained: ''*I want to make sure it's totally dissolved which takes time … it doesn't get administered on time. So if it's mixed already then it … decreases my workload*'' (AA4).

But even when antibiotics arrived premixed in an IV (intravenous) bag, as often occurs in hospital B, the effort to connect it to the main IV line was described as cumbersome. An anesthesiologist from this hospital said: ''*I think the bag is a bit rate limiting … you have to [connect] a secondary line and that's significant effort*'' (AB2).

In both hospitals there was therefore a perception that the inconvenience of administering antibiotics disrupted the anesthesiologist's preoperative routines and, as in the other obstacles from individual processes, would result in the task being postponed until after the recommended interval.

Process: systemic level

Workflow

In contrast to individual processes, systemic processes refer to factors at the organizational level that contribute to improper antibiotic timing. The main obstacle in this category was workflow, defined as routines by which an organization moves from one task to another. Participants discussed three issues: (1) limitations of the current system; (2) unanticipated changes to workflow; and (3) inherent unpredictability of workflow systems.

Participants most commonly complained that limitations of the existing workflow system affected proper timing of antibiotics. At hospital A the standard routine of having IVs inserted in the OR (because anesthesiologists had more expertise than nurses at starting the larger IVs required for major surgery), rather than preoperatively, was commonly cited as a significant obstacle to proper antibiotic timing. Participants stated that the earlier the IV was inserted, the sooner the antibiotics could be given. As one anesthesiologist remarked: ''*… you're not going to have the ability to give antibiotics until you start the IV. So timing depends on having IV access*'' (AA5).

In hospital B, however, where preoperative administration of antibiotics occurred more frequently, this routine was still perceived by participants to be problematic as the task was now vulnerable to unanticipated changes. As an anesthesia administrator at this hospital explained: ''*At times this system falls apart because [a nurse is] unable to start an intravenous on the patient … the antibiotic is sent to the operating room with the patient … the anesthesiologist may not always be aware that an antibiotic was ordered … therefore the timing of the antibiotic may be inappropriate [because] surgery may have already started before the antibiotic is actually administered*'' (PB1).

Finally, participants at both hospitals described a general level of unpredictability inherent to the existing workflow system as a cause for improper antibiotic timing. For example, due to a large variety of surgeries, not all of which require antibiotics (or the same kind), anesthesiologists were unable to develop a consistent routine for antibiotic administration. As one anesthesiologist explained: ''*I think the difficulty is the variety of cases we do. For some cases they're not required so because I'll be rotating through different rooms … with different surgeons and different procedures, it will mean that I have to be aware of every service, every procedure they do and which ones are indicated for prophylactic antibiotics and [that] I keep that kind of database in my head*'' (AB1).

For all participants it was evident that system workflow was a major obstacle to proper antibiotic timing.

Organizational communication

The other category under systemic processes—organizational communication—refers to the protocols and procedures by which members in an institution communicate with each other, either verbally or in writing. Difficulties encountered in this process leading to late antibiotic administration, according to participants, included the lack of verbal transfer of information with respect to antibiotics. As a surgeon described: ''*… communication issues … surround … were they given or not and who was supposed to give them*'' (SA1). Here, a perioperative staff member emphasized the importance of this information exchange: ''*… if the antibiotic isn't given prior to the patient actually entering the operating room then communication needs to occur between the nurse in surgical day care … to the OR nurse and anesthesiologist to ensure that they recognize that prophylactic antibiotics … need to be given …*'' (PB1).

The written medication ordering system for prophylactic antibiotics was also considered to be a source of confusion when nurses were the ones administering antibiotics because the task required two different orders from the surgeon. As a perioperative staff member from hospital B said: ''*… whoever's written the [antibiotic] order hasn't written for an IV to be started so … the nurse won't start the antibiotics … so anesthesia has to … sort everything out …*'' (PB2).

Both of these types of communication lapses were reported to contribute to late antibiotic administration.

Role perception

The second of the two major categories to emerge as an obstacle to proper antibiotic timing was role perception, defined in this paper as the various perceptions of roles and their boundaries. Two main types of role perception were identified: (1) shared responsibility for antibiotics; and (2) individual responsibility for antibiotics. Individual responsibility was further divided into (a) attitude of acceptance and (b) attitude of resignation. Because all participants declared that it was the surgeon's responsibility to order antibiotics, the differences in role perceptions centred on the responsibility of administering the antibiotics.

Shared responsibility

At both hospitals four surgeons, seven anesthesiologists, and two perioperative staff in combination stated that antibiotics should be administered not by a specific professional but by whoever was most convenient. For example, since antibiotic delivery was dependent on IV access, surgeons stated that whoever started the IV could administer the antibiotic. As one surgeon stated: ''*… it should be given on the wards by the nurses when the patient is called for the OR if the patient has an IV and it's ordered … if it is policy to have IVs in the holding area … it should be given there by the nursing staff … failing that, it should be given by the anesthesiologist as soon as the IV is inserted in the OR*'' (SA1).

A perioperative staff member agreed: ''*… multiple team members should be able to start IVs so part of it is having within your team some redundancy …*'' (PA1).

In the OR, however, shared responsibility meant that the surgeon requested the antibiotic and the anesthesiologist administered it. As one anesthesiologist explained, ''*… there's certainly a responsibility on both parts to one, ensure that antibiotics have been ordered … then two, from the anesthesiologist's perspective, to make sure they've been given*'' (AA5).

Thus, certain healthcare team members expressed a sense of cooperation regarding responsibility for administering antibiotics.

Individual responsibility: acceptance

Three surgeons and three anesthesiologists asserted that a single profession—usually anesthesia or nursing—was responsible for administering antibiotic prophylaxis. The recurrent rationale was that one person should be responsible for giving the drug and that the anesthesiologist, considering the circumstances, was the ideal person to fulfil this role. As one anesthesiologist explained: ''*… I think that the person who's best placed [to administer the antibiotic], because of their proximity to the patient at the appropriate time, is the anaesthesiologist*'' (AA3).

Individual responsibility: resignation

The dominant attitude revealed by anesthesiologists *and* surgeons was that of being resigned to a situation that neither was particularly comfortable with. Seven surgeons, seven anesthesiologists, and one perioperative staff member agreed that, while anesthesiologists usually administered antibiotics, it really should not be that physician's responsibility. Participants expressed a sense of resignation about the status quo, conceding to it because it seemed the ''most efficient way'' due to factors such as ''IV started in OR'' and ''the surgeon's scrubbed for surgery''. As one surgeon stated:

''… my expectation of anesthesiologists administering antibiotics in the OR is probably an excessive expectation above and beyond what they should be doing. This is based on previous frustrations with relying on nursing staff, either on the ward or in the holding area … so it's been a fall back'' (SA4).

Surgeons and anesthesiologists responded to this less than ideal situation in different ways. Surgeons reported that they regretted that anesthesiologists were usually the ones to administer antibiotics. As one surgeon remarked: *''I have … trouble with the concept that the anesthesiologist should be responsible for giving the antibiotics …''* (SA10). For their part, anesthesiologists expressed resentment at their role as they believed that antibiotics fell outside their central scope of practice. There was also a sense of resentment that the conventionally equal status between physicians became unbalanced when they were placed in the position of carrying out a drug order requested by a surgeon. As one anesthesiologist explained: *''… we are essentially administering a drug that another surgeon, another physician has asked for …''* (AB2). Another anesthesiologist declared: *''… to some anesthesiologists it's insulting to have the surgeon say give the Ancef [antibiotic]''* (AB3).

Thus, both surgeons and anesthesiologists expressed a sense of tension regarding the current practice of implicitly assigning responsibility for antibiotic administration to anesthesia. Surgeons expressed regret that they often needed to make such a request to another physician while anesthesiologists conveyed resentment towards performing the task.

DISCUSSION

This study is one example of the well described difficulty of transferring evidence-based guidelines into practice.[16 25 36 37 46 47] Exploring key participants' perceptions of the obstacles to properly timed prophylactic antibiotics for SSIs provides insight into the evolving nature of antibiotic administration in the OR. In particular, issues of workflow and role perception require careful attention.

The issue of workflow appears to have a central role in its contribution to improperly timed antibiotic administration. Further insight into the problem may be gained by analyzing the general evolution of changes in workflow experienced by hospitals. For example, in the past, studies reporting antibiotic timing problems have suggested that antibiotics were given too *early* (that is, before incision).[21 48] These errors contrast with the perceptions of participants in the current study who largely reported *late* delivery of antibiotics. These studies, however, were conducted at a time when it was usual for patients to be admitted to hospital the night before surgery. Improperly timed antibiotic delivery was often attributed to the concept of ''on call'' drug administration—a protocol by which antibiotics were to be given by the floor nurse when the patient was ''called'' to the operating room.[21 48] This system of workflow was particularly vulnerable to unexpected delays in the OR resulting in administration before the recommended interval.[8 16 48 49] Many authors and infection control organizations therefore condemned this protocol[15 16 25 48 50 51] and subsequent interventions were designed to move antibiotic administration closer to the time of surgery.[52–54]

However, such measures have the potential to result in the opposite timing problem—that is, late administration—which has also been shown to contribute to poor antibiotic coverage.[16 24 55] The perceptions of participants in the current study, that antibiotics were being delivered too late, supports the influence of this shift in workflow.

Improper timing may also be influenced by the economically driven trend from patients being admitted the night before surgery to the system of ''same day admissions''[56] whereby patients come to hospital on the day of their surgery rather than the night before. On the one hand, in addition to financial benefits, this change would be predicted to improve antibiotic timing since IVs (required for antibiotic insertion) must now be inserted closer to the time of surgery, a practice consistent with experts' recommendations (above). On the other hand, an unintended consequence of this workflow shift may be that healthcare professionals now have limited time to prepare patients for their surgeries.

Participant responses from this study appear to support this concern. Respondents indicated that this change in patient flow created a narrow window of time for IV insertion resulting in inconsistencies regarding where the procedure takes place—that is, just before compared with inside the OR. Since the environment and personnel outside the OR are completely different from those inside, respondents reported that confusion often arose regarding who had administered or who should administer the antibiotics. Late timing would occur, for example, when the anesthesiologist assumed that the antibiotic was given before the OR and did not realize until later (usually after incision) that the drug was not given. Thus, shifts in hospital workflow may have had a negative impact on the timing of prophylactic antibiotics and may also have the potential to compromise other quality standards within the hospital system. These findings may therefore be relevant to hospitals currently moving to same-day admissions or otherwise altering existing admission protocols.

In addition to systems based obstacles, professional relationships in the form of role perception emerged as another major obstacle to proper antibiotic timing. This obstacle arises from a sense of tension between healthcare professionals regarding team roles in the administration of antibiotics. This tension may arise from the unique context of the OR where some traditional team roles and hierarchies are interestingly realigned due to the circumstance of two physicians working simultaneously on a single patient.[57] For example, both surgeons and anesthesiologists expressed a sense of frustration and awkwardness that the responsibility of antibiotic administration was implicitly assigned to an anesthesiologist (that is, another physician) rather than to a nurse in the traditional manner. Surgeons' reluctance to directly request such a ''favour'' and anesthesiologists' resentment of this duty may stem in part from a perceived violation of the usual medical hierarchy. Surgeons may therefore only indirectly communicate about antibiotics, or resist even this indirect communication until it is urgently needed, or even delay the request until it is too late—all scenarios which have the potential to lead to antibiotic administration after incision. A recent study of communication lapses in the OR suggested that the most common communication failure—''occasion''—referred to suboptimal (or late timing) of verbal exchanges. These late exchanges often involved the delivery of antibiotic prophylaxis.[58] Thus, tension between physicians in the current study may be manifest as communication lapses with potential critical implications for the timing of antibiotics.

Perceived tension between healthcare professionals has also been studied from the perspectives of both organization theory and aviation safety. Research on individual and organizational stress in the human services suggests that, when conventional hierarchies within institutions shift, conflicts may arise between members of the organization at the interpersonal level.[59] One proposal from this literature is to ''blur the boundaries'' between different professions in order to improve patient care[60]—a suggestion consistent with the sub-theme of shared responsibility in this study. Similarly, studies in the domain of patient safety have suggested that pilots and OR doctors display comparable

interpersonal conflicts but, while the aviation industry has addressed this lack of teamwork through crew management training, this kind of preparation is underdeveloped in medicine.[61] The role tensions that arise as a function of the power relations between professions may therefore prove to be a formidable force and require focused attention as they may have an overall negative impact on quality of care delivered in team settings.

The main themes of ''Process'' and ''Role perception'', together with their sub-themes, parallel the literature aiming to improve the transfer of guidelines into practice. This literature describes barriers to evidence-based practice from the perspective of individual, team, and organizational levels,[39 42 62] and this classification can be applied to the results of the current study. At the individual level the findings suggest that it is not clear how antibiotics are prioritized in individual routines during surgical procedures; at the team level there is tension surrounding the responsibility for antibiotic administration; and, at the organizational level, workflow changes have appeared to negatively affect the timing of antibiotics.

Obstacles at these various levels may also be related to one another. For example, role tensions at the team level may contribute to low priority at the individual level. It would not be surprising that, if an individual were resentful of a task, it would be assigned a lower priority. Such relationships suggest that, because these obstacles do not necessarily exist in isolation, any efforts to eliminate them should consider addressing multiple rather than single targets.[39 63]

The findings of this study may present the groundwork for interventional strategies. For example, to address workflow obstacles, an institution might rule that antibiotic administration consistently be performed in the OR. To simultaneously bypass the low priority of antibiotics among physicians and their role perception conflicts, the circulating nurse (present in all ORs) can be assigned the duty of attending to the antibiotics. In this scenario the anesthesiologist no longer needs to prioritize the administration of antibiotics among higher priority tasks, and the restoration of the traditional hierarchical arrangement in the OR may reduce the role tension between the physicians. Of course, any such change will create a ripple effect requiring consideration of where antibiotics might be placed on the circulating nurse's priority list and whether team members will accept such a shift in duties. Multiple interventions that acknowledge and engage the sociological realities of a clinical culture are likely to be required to improve the implementation of guidelines into practice.

Certain design decisions may have affected this study. Firstly, the sampling method may have captured only participants more interested in, or informed about, prophylactic antibiotics. The range of interest and knowledge evident in study participants, however, reduces this likelihood. Secondly, two academic hospitals were studied. Exploring transferability of these results—that is, their ability to assist our understanding of the antibiotic timing phenomenon in other contexts—requires further research to refine the factors we have described toward a sophisticated and fully elaborated theory of the socio-organizational dimensions of antibiotic timing across a variety of institutional settings. Thirdly, individual interviews were the chosen data collection method. It may be that focus groups combining surgeons and anesthesiologists would provide additional insight into issues such as roles and responsibilities, particularly where points of view are in conflict.

The proper timing of prophylactic antibiotics for the prevention of SSIs remains problematic. Eliciting the views and perspectives of key participants has indicated that obstacles to this transfer from evidence-based guidelines to clinical practice exist at multiple levels—institutional, healthcare team, and individual.

The semi-structured interview approach used in this study should encourage other qualitative methods of inquiry such as focus groups and ethnographic studies. Focus groups combining surgeons and anesthesiologists would provide additional insight into issues such as roles and responsibilities, particularly where points of view are in conflict. Ethnographic work would locate a researcher throughout the entire perioperative environment and allow more dynamic observation of the obstacles identified in this study. Yet another direction for research would be to assess the transferability of this study's findings to other similar contexts, such as community hospitals or hospitals transitioning towards a system of same-day admissions.

In conclusion, this study has the potential to initiate methods of research that address not only the improper timing of prophylactic antibiotics for SSIs, but also the continuing general dilemma of successful transfer of evidence-based guidelines to clinical practice.

Key messages

- Evidence suggests that proper timing of prophylactic antibiotics reduces the incidence of surgical site infections, but guidelines have remained ineffective at implementing this practice.
- Anesthesiologists, surgeons, nurses, and perioperative personnel perceived a number of obstacles to the successful transfer of these guidelines into practice.
- Inherent limitations of workflow processes and unanticipated changes to workflow were identified as a major obstacle to the ideal timing of antibiotics.
- Conflicts regarding responsibility for antibiotic administration were also perceived as problematic.
- Obstacles were uncovered at the individual, team, and systemic levels.
- This exploration of obstacles to proper antibiotic timing may lead to interventions designed to promote evidence-based practice and decrease the number of surgical site infections.

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