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Improved Perioperative Antibiotic Use and Reduced Surgical Wound Infections Through Use of Computer Decision Analysis

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ABSTRACT

A prospective study was performed over a two-year period to determine whether computer-generated reminders of perioperative antibiotic use could improve prescribing habits and reduce postoperative wound infections. During the first year, baseline patterns of antibiotic use and postoperative infection rates were established. During the second year, computer-generated reminders regarding perioperative antibiotic use were placed in the patient's medical record prior to surgery and patterns of antibiotic use and postoperative wound infections monitored.

Hospitalized patients undergoing non-emergency surgery from June to November 1985 (3,263 patients), and from June to November 1986 (3,568) were monitored with respect to indications for perioperative antibiotic use, timing of antibiotic use and postoperative infectious complications. Perioperative antibiotic use was considered advisable for 1,621 (50%) patients in the 1985 sample and for 1,830 (51%) patients in the 1986 sample. Among these patients, antibiotics were given within two hours before the surgical incision in 638 (40%) of the 1985 sample and 1,070 (58%) of the 1986 sample ($p<0.001$). Overall, postoperative wound infections were detected in 28 (1.8%) of 1,621 patients in 1985 compared with 16 (0.9%) of 1,830 such patients in 1986 ($p<0.03$).

We conclude that computer-generated reminders of perioperative antibiotic use improved prescribing habits with a concurrent decline in postoperative wound infections. [*Infect Control Hosp Epidemiol* 1989; 10(7):316-320.]

INTRODUCTION

Postoperative infectious complications are an important cause of morbidity and mortality in the surgical patient. Efforts to reduce these complications include careful attention to surgical technique and perioperative antimicrobial prophylaxis. Prospective randomized controlled clinical trials have established the utility of perioperative antimicrobial prophylaxis in some settings.[1,2] Factors thought to be important to the success of perioperative antimicrobial prophylaxis include: the type of surgical procedure, choice of antimicrobial agent, timing of antimicrobial use, route of administration and dosage necessary to attain efficacious levels of antibiotic in serum and tissue during surgery.[3]

Guidelines for the proper use of perioperative antibiotics have been developed.[4-6] Deviations, however, from these guidelines are frequent.[7] We have developed a computer system to assist in monitoring antimicrobial use, postoperative surveillance of infectious complications and generating physician reminders of proper perioperative antibiotic use based on published guidelines. We report here our experience before and after the hospital-wide introduction of pro-

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spective physician reminders employing computer-generated perioperative antibiotic decision analysis.

METHODS

We developed a series of interactive computer programs to monitor the use and timing of perioperative antimicrobials in hospitalized patients undergoing non-emergency surgery classified as clean or clean-contaminated. These computer programs were added to the Health Evaluation through Logical Processing (HELP) hospital information system, which contains an integrated patient data base from many clinical areas such as the clinical laboratory, pharmacy and surgery.[8,9] This hospital information system is clinically operational at the LDS Hospital, a 520-bed tertiary referral center and teaching facility for the University of Utah School of Medicine. Additional computer programs had been developed to assist in creating the operating room schedule, preparing the surgeon-specific instrument tray, creating patient anesthesia records and monitoring hospitalized patients for nosocomial infection.[10,11]

Guidelines for perioperative antibiotic use were adapted from published recommendations, and antibiotic prophylaxis was deemed advisable or of no proven value for each surgical procedure.[4-6] Timing of the first dose of antibiotic was determined by daily chart review in which the patients' medication and anesthesia records were checked. All times were recorded as written by the nursing or anesthesia staff. Hospital computer surveillance of surgical wound infection was performed as previously described[11,12] and based on the definitions employed for the Study on the Efficacy of Nosocomial Infection Control (SENIC).[13] No changes in the algorithms of surgical wound infection were made between study periods. The diagnosis of a wound infection required the demonstration of purulent material on Gram's stain from the operative site or finding purulent material on reoperation at or near the surgical field of a previous operation. Wound infections were defined as nosocomial if they occurred within 30 days of the operative procedure. Isolation of pathogenic microorganism(s) was not required to establish the diagnosis of a wound infection if antimicrobial therapy had been started prior to obtaining the wound culture. Surgical wound infection surveillance after hospital discharge was not performed. Infections that resulted in rehospitalization within 30 days of the original procedure were included in our surveillance methods. The classification of the surgical procedure as either clean, clean-contaminated, contaminated or dirty was determined by the surgeon at the time of surgery based on generally accepted criteria.[14] Timing of antibiotic prophylaxis was defined as optimal if given within two hours prior to the surgical incision, premature if given more than two hours before and late if given after the recorded surgical incision time.

Baseline observations of postoperative wound infection rates and patterns of antimicrobial use were established from June through November, 1985. In a

ANTIBIOTIC PROPHYLAXIS GUIDELINE

( ) A parenteral prophylactic antibiotic is generally indicated for this patient's surgery. If given, prophylactic antibiotics should be started 1-2 hours before surgery and discontinued within 24 hours after surgery.

( ) Prophylactic antibiotics are generally of unproven benefit for this patient's surgery but may be indicated in the presence of certain risk factors.

PHARMACY/INFECTIOUS DISEASES

Figure. Example of perioperative antibiotic reminder sticker.

Table 1
Study Population

	1985		1986	
	No.	**(%)**	**No.**	**(%)**
Patients Screened	7,422	—	7,605	—
Patients Excluded	4,159	(56)	4,037	(53)
Outpatient surgery	2,242	(54)	2,106	(52)
Emergency surgery	1,222	(29)	1,267	(31)
Hospitalized >48 hours before surgery	344	(8)	353	(9)
More than one operation	293	(7)	241	(6)
Contaminated surgery	37	(1)	57	(1)
Dirty surgery	21	(1)	13	(1)
Final Study Population	3,263	(44)	3,568	(47)
Clean surgery	1,596	(49)	1,839	(52)
Clean-contaminated surgery	1,667	(51)	1,696	(48)*

* *$p<0.02$ for 1986 as compared to 1985, chi-square test*

matching six-month period from June to November, 1986, patients scheduled for non-emergency surgery had an antibiotic reminder sticker placed in their charts if computer decision analysis had determined the planned surgical procedure to be one in which antibiotic use was of value (Figure). Six-month study periods were deemed of sufficient size to detect, with an 80% power, a 50% reduction in inappropriate antibiotic use and a corresponding 50% reduction in surgical wound infection rates. Statistical comparisons employed the chi-square test.

RESULTS

More than 15,000 surgical procedures were performed in the hospital during the two six-month study periods, with more than 300 different kinds of operative procedures involving 241 participating surgeons. Patients were excluded from the final study population for the following reasons: short stay or outpatient surgery, 54%; emergency surgery, 30%; hospitalized for more than 48 hours before the operation, 9%; more than one operation during the same hospitalization, 7%; contaminated surgical procedure, 1%; or dirty surgical procedure, less than 1% (Table 1). Reasons for patient exclusion were similar for the two study periods. The final study populations

Table 2
Characteristics of the Final Study Population

	1985		1986		
	No.	(%)	No.	(%)	p*
Male	1,425	(44)	1,575	(44)	—
Female	1,838	(56)	1,993	(56)	—
Mean Age	51 years		52 years		
Representative Surgical Procedure					
Urologic procedures	263	(8.1)	327	(9.2)	—
Total joint replacement	221	(6.8)	243	(6.8)	—
Abdominal hysterectomy	183	(5.6)	203	(5.7)	—
Laminectomy	159	(4.9)	162	(4.5)	—
Vaginal hysterectomy	138	(4.2)	115	(3.2)	<0.04
Cholecystectomy	135	(4.1)	183	(5.1)	<0.06
Coronary artery bypass	110	(3.4)	135	(3.8)	—
Gastric bypass & cholecystectomy	115	(3.5)	38	(1.1)	<0.001
Gastric bypass	76	(2.3)	134	(3.8)	<0.001
Inguinal hernia repair	118	(3.6)	101	(2.8)	—
Bowel resection	80	(2.5)	79	(2.2)	—
Exploratory laparotomy	78	(2.4)	74	(2.2)	—
Antibiotic Prophylaxis					
Cefazolin	1,257	(60)	1,317	(55)	—
Cefonicid	198	(9)	237	(10)	—
Cefoxitin	157	(8)	209	(9)	—
Cefamandole	135	(6)	111	(5)	—
Cefoperazone	48	(2)	186	(8)	<0.001

**chi-square test*

Table 3
Actual Antibiotic Use Compared to Computer-Generated Antibiotic Decision Analysis

	1985		1986	
Computer Decision Analysis	No.	(%)	No.	(%)
Prophylaxis Generally Indicated	1,621	—	1,830	—
Received antibiotic*	1,276	(79)	1,493	(82)
Premature timing	193	(12)	176	(10)†
Optimal timing	638	(40)	1,070	(58)‡
Late timing	445	(27)	247	(14)‡
Did not receive antibiotic*	345	(21)	337	(18)
Prophylaxis of Unproven Value	1,642	—	1,738	—
Received antibiotic*	822	(50)	893	(51)
Premature timing	72	(4)	79	(5)
Optimal timing	288	(18)	447	(26)‡
Late timing	462	(28)	367	(21)‡
Did not receive antibiotic*	820	(50)	845	(49)
Total	3,263	—	3,568	—

* *On same day as operation*
† *p<0.02, chi-square test*
‡ *p<0.001, chi-square test*

included 3,263 patients in 1985, and 3,568 patients in 1986. Relatively more clean surgical procedures were performed in 1986 than in 1985; 52% versus 49%, respectively ($p<0.02$). The demographics of the two study populations were similar with respect to age, sex and antibiotic selected for perioperative use except for an increase in cefoperazone use in 1986. The observed increase in cefoperazone use was largely restricted to the urologic service. The 12 most common operative procedures accounted for 51.4% of the operative procedures in 1985, and 50.4% in 1986 (Table 2).

Overall, 66% of the study patients received perioperative antibiotic prophylaxis. In 1985, computer decision analysis deemed antibiotic use of value in 1,621 (50%) surgical patients, of which 79% received antibiotics the same day as the operation (Table 3). In 1986, computer decision analysis deemed antibiotic use of value in 1,830 (51%) of patients, of which 82% received antibiotics. There was less agreement when computer decision analysis deemed antibiotic use of unproven value with 1,642 such computer decisions in 1985 and 1,738 such decisions in 1986. Among these latter patients, antibiotics were employed in 50% in 1985, and 51% in 1986.

Errors in timing of perioperative antibiotic use were common in both study periods (Table 3). Optimal timing of antibiotic prophylaxis increased from 40% in 1985 to 58% in 1986 ($p<0.001$). Most of the improved timing resulted from a decrease in the number of patients receiving antibiotics after the surgical incision: 27% to 14% in 1985 and 1986, respectively ($p<0.001$). There were also significantly fewer patients who received premature antibiotics: 12% versus 10% in 1985 and 1986, respectively ($p<0.02$).

Postoperative wound infections were found in 1.1% of the 3,263 patients in 1985, versus 0.7% of the 3,568 patients in the 1986 sample (Table 4). The wound infection rates were similar from 1985 and 1986 when stratified according to indication for antibiotic prophylaxis, the timing of antibiotic prophylaxis and the classification of the surgical procedure (Table 5). However, wound infection was significantly less common among patients undergoing clean surgical procedures who received optimal timing of antibiotic prophylaxis compared with those patients who received premature timing of antibiotic prophylaxis ($p<0.05$). The lowest rates of postoperative wound infection were observed in patients in whom antibiotic prophylaxis was deemed by computer analysis to be of unproven value, among patients who did not receive antibiotic prophylaxis and patients who received optimal timing of antibiotic prophylaxis.

DISCUSSION

Hospital-wide clinical information systems that

Table 4
Postoperative Wound Infections in Relation to Computer-Generated Antibiotic Prophylaxis Decision Analysis and Timing of Antibiotic Use

	1985			1986		
Computer Decision Analysis	Total No.	Wound Infection		Total No.	Wound Infection	
		No.	(%)		No.	(%)
Total	3,263	37	(1.1)	3,568	24	(0.7)
Prophylaxis Generally Indicated	1,621	28	(1.8)	1,830	16	(0.9)†
Received antibiotic*	1,276	24	(1.9)	1,493	14	(0.9)‡
Premature timing	193	7	(3.6)	176	4	(2.3)
Optimal timing	638	5	(0.8)**	1,070	7	(0.7)
Late timing	445	12	(2.7)	247	3	(1.2)
Did not receive antibiotic*	345	4	(1.2)	337	2	(0.6)
Prophylaxis of Unproven Value	1,642	9	(0.6)	1,738	8	(0.5)
Received antibiotic*	822	3	(0.4)	893	4	(0.5)
Premature timing	72	0	(0.0)	79	2	(2.5)
Optimal timing	288	0	(0.0)	447	1	(0.2)
Late timing	462	3	(0.6)	367	1	(0.3)
Did not receive antibiotic*	820	6	(0.7)	845	4	(0.5)

* *On same day as operation*
† $p<0.04$ *for 1985 compared with 1986, chi-square test*
‡ $p<0.05$ *for 1985 compared with 1986, chi-square test*
** $p<0.02$ *for optimal timing compared with late timing of antibiotic prophylaxis, chi-square test*

integrate and create a computerized medical record require substantial commitments of time, computer resources and technical support. Despite the promise of clinical computing, successful adaptation of computer decision analysis to the prospective management of patients has been very limited.[15] Partially, this is the result of the large computer storage space and the technical difficulties in creating the information within a computerized medical record in a format useful to clinical decision analysis.

The decision related to perioperative antibiotic prophylaxis is relatively straightforward for the clinician, although actual clinical practice may deviate substantially from ideal guidelines, as we demonstrated in this study. Before computer decision analysis can be initiated, a complex computerized medical record must be created and combined with computerized medical logic that can monitor patient care concurrently. The elements essential to the computer decision analysis include the patient's name and location, the surgeon and planned surgical procedure, the patient's drug allergy history and drug use during hospitalization, and a list of all surgical procedures with an assessment of the clinical utility of perioperative antibiotic prophylaxis. Computerized infected surveillance gave a uniform definition of wound infection unaffected by observer bias. Once these elements were created and in routine clinical use, we were able to establish the magnitude of misapplication of perioperative antibiotic prophylaxis, to provide a clinical tool (computer-generated physician reminders) to improve its use and to measure the value of clinical computing on patient morbidity.

Three measurements of the clinical impact of computer decision analysis were employed. The first was to evaluate the frequency of perioperative antibiotic use in surgical procedures for which its use is of unproven value. Little impact was observed. No specific surgical specialty or surgeon was readily identifiable as uniformly disagreeing with the computer decision analysis. It is possible that the computer decision analysis was in error with respect to the value of perioperative antibiotic use for some of the surgical procedures. However, the premise that perioperative antibiotic use is of unproven value is based on the very low incidence of postoperative infectious complications in patients undergoing such procedures. Our observed rate of postoperative infectious complications was exceptionally low in those patients in whom the "computer-generated" decision analysis was that antibiotic use was of unproven value, both when antibiotic prophylaxis was used, or not employed. Thus, the overall decision analysis was supported.

The second measure was to evaluate the timing of perioperative antibiotic use. Substantial improvement in the timing of antibiotic use was demonstrated from 1985 to 1986. The educational impact and the discussions surrounding the introduction of the physician reminder stickers undoubtedly contributed to the improved timing of perioperative antibiotic use.

The third measure was the rates of postoperative wound infection. The overall postoperative wound infection rate dropped in 1986 following the introduction of the computer-generated physician reminder stickers. As relatively more clean surgical procedures were performed in 1986 versus 1985, the

Table 5
Postoperative Wound Infections in Relation to Surgical Procedure Classification, Indication for Antibiotic Prophylaxis and Timing of Antibiotic Use

Computer Decision Analysis	1985 Total No.	1985 Wound Infection No.	1985 Wound Infection (%)	1986 Total No.	1986 Wound Infection No.	1986 Wound Infection (%)
Clean Surgery	1,596	10	(0.6)	1,839	12	(0.7)
Prophylaxis Generally Indicated	712	9	(1.3)	849	9	(1.1)
Received antibiotic*	592	8	(1.4)	720	8	(1.1)
Premature timing	117	4	(3.4)	80	3	(3.8)
Optimal timing	271	1	(0.4)†	525	3	(0.6)†
Late timing	204	3	(1.5)	115	2	(1.7)
Did not receive antibiotic	120	1	(0.8)	129	1	(0.8)
Prophylaxis of Unproven Value	884	1	(0.1)	990	3	(0.3)
Clean-Contaminated Surgery	1,667	27	(1.6)	1,696	12	(0.7)
Prophylaxis Generally Indicated	909	19	(2.1)	969	7	(0.7)
Received antibiotic*	684	16	(2.3)	762	6	(0.8)
Premature timing	76	3	(3.9)	96	1	(1.0)
Optimal timing	367	4	(1.1)‡	536	4	(0.8)
Late timing	241	9	(3.7)	130	1	(0.8)**
Did not receive antibiotic	225	3	(1.3)	207	1	(0.5)
Prophylaxis of Unproven Value	758	8	(1.1)	727	5	(0.7)

* *On same day as operation*
† $p<0.05$ *for optimal timing compared with premature timing of antibiotic prophylaxis, chi-square test*
‡ $p<0.05$ *for optimal timing compared with late timing of antibiotic prophylaxis, chi-square test*
** $p<0.03$ *for 1986 compared with 1985, Fisher's exact test of proportions*

overall wound infection rate may not necessarily reflect solely the impact of improved timing of antibiotic prophylaxis. However, surgical wound infection rates were higher among patients whose antibiotic prophylaxis was not optimally timed, and timing of antibiotic prophylaxis was improved. The sole exception was among patients undergoing clean-contaminated surgery who received antibiotic prophylaxis after surgery had begun. Among this small group of patients (130) only one surgical wound infection was found. Even if four or five surgical wound infections had been found (consistent with wound infection rates of 1985 for a similar group of patients), a net reduction in surgical wound infections still would have been observed in 1986. Thus, improvement in the timing of perioperative antibiotic use was proportionally related to the drop in postoperative rates of wound infection. Therefore, two clinically valuable improvements in patient care management were demonstrated and were associated with the implementation of prospective physician reminders based on computer decision analysis.

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