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Surgical Wound Infections

A 5-Year Prospective Study of 20,193 Wounds at the Minneapolis VA Medical Center

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This report describes a 5-year prospective study of postoperative wound sepsis utilizing a careful program of wound surveillance. Surgical wounds following 20,193 operations on all surgical services were surveyed by a trained nurse epidemiologist. Daily examination of wounds, culture of all suspicious wounds, and 30-day outpatient clinic follow-up were performed. Results were disseminated at monthly intervals to all involved surgeons and operating room personnel. Prospective and ongoing analysis of results facilitated identification and rectification of specific problem areas. Wound infection rates demonstrated a steady decline over the course of the study, overall rates dropping from 4.2% to 1.9% ($p < 0.05$). This reduction in incidence of postoperative wound sepsis of 55% is estimated to have saved 2740 inhospital days and nearly $750,000.

IN SPITE OF MODERN STANDARDS of preoperative preparation, antibiotic prophylaxis, and refinements in anesthetic and operative technique, postoperative wound infections remain a serious problem. In addition to patient discomfort and morbidity associated with established wound sepsis, there are consequences of such infections that are more easily identified and quantitated, namely time and money. Estimates of prolongation of hospital stay for individual patients due to surgical wound infections range from 6 to 14 days.[1-5] Translation of these figures into dollars and cents places estimated increase in hospitalization costs (based on data published in the mid-1970s) from $5,000 to $7,000/patient.[1,2] Overall wound infection rates of 4% to 7% of all operations, considered quite acceptable,[1,2] provide a better vantage point on the serious nature of this problem.

There is, however, considerable variation in rate of wound infection from hospital to hospital. In order to accurately assess success in infection prophylaxis, a standard "acceptable" wound infection rate must be established at each institution. Continual monitoring in the form of wound surveillance can then allow each hospital to identify and immediately correct specific problem areas. This report represents a 5-year prospective wound surveillance program initiated in February 1977 at the Minneapolis VA Medical Center, an 860-bed teaching hospital with ten operating rooms. Over the 5-year period spanned by this study, there was a significant decline in overall wound infection rate from 4.2% to 1.9%. The various possible factors that may account for this trend will be discussed.

Method

Over 22,000 operations were performed at the Minneapolis VA Medical Center between February 1, 1977 and February 1, 1982. All operations were included except those of dental surgery and transurethral prostatic resec-

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tions. Initially, all transurethral resections of the prostate were included;[6] however, since infections are detected as urinary tract infections and not true wound sepsis, they have been removed from the present study. Ninety per cent of operations were performed with residents as operating surgeons under direct staff supervision, the remainder being performed with staff as operating surgeon. A total of 20,193 wounds were observed by a nurse epidemiologist (MO) on a daily basis until discharge from the hospital, and were observed at variable intervals during follow-up clinic visits. Gram smears and aerobic and anaerobic cultures were performed on any wound that appeared inflamed and demonstrated drainage of any type within 30 days of operation. A wound was considered clearly infected if pus discharged. Wounds with serous or nonpurulent drainage and negative cultures were considered infected only if significant physical signs of sepsis were present concurrently (warmth, erythema, induration, and pain) and the physician diagnosis was infection. Wounds with cellulitis and no drainage and suture abscesses were not considered an infection.

Operations were classified into clean, clean-contaminated, and contaminated categories according to the criteria established by the Committee on Control of Surgical Infections of the American College of Surgeons.[7] The initial classification was done by operating room personnel and verified by the nurse epidemiologist.

Class I, Clean Wound

This is a nontraumatic wound in which no inflammation was encountered, no break in technique occurred, and the respiratory, alimentary, and genitourinary tracts were not entered.

Class II, Clean-Contaminated Wound

This is a nontraumatic wound in which a minor break in technique occurred or in which the gastrointestinal, genitourinary, or respiratory tracts were entered without significant spillage. This category includes transection of the appendix or cystic duct in the absence of acute inflammation and entrance into the biliary or genitourinary tracts in the absence of infected bile or urine.

Class III, Contaminated Wound

This is a fresh, traumatic wound from a relatively clean source or an operative wound in which there is a major break in technique, gross spillage from the gastrointestinal tract, or entrance into the genitourinary or biliary tracts in the presence of infected urine or bile. This includes incisions encountering acute nonpurulent inflammation. Also included in this contaminated category are dirty wounds, such as traumatic wounds from a dirty source or with delayed treatment, fecal contamination, foreign bodies, a devitalized viscus, or pus from any source that is encountered.

Monthly infection reports listing infection rates and organisms cultured for each wound classification and by surgical service were compiled and distributed to all involved surgeons and the Infection Control Committee. In addition, this information was discussed at Surgical Complications Meetings each month.

Data Analysis

Statistically significant differences in yearly infection rates were sought using chi squared analysis. All wound infection rates were compared to baseline rates determined in 1977, the first year of the study.

Estimates of cost per wound infection were calculated using an average increase of ten hospital days/patient with infection[1] and Minnesota Hospital Association estimates of cost/day (1978 $185/day, 1979 $257/day, 1980 $292/day, and 1981 $365/day). Estimated savings/year were then calculated as the difference between cost for expected and observed numbers of wound infections.

Results

Rates of Infection

Over the 5-year study period, there were 574 wound infections in 20,193 wounds for an overall infection rate of 2.8% (see Table 1). For the first year of wound surveillance, there were 188 wound infections in 4476 operations for an incidence of 4.2%. During the surveillance, overall Clean (Class I) wound infection rate was 1.8%, the Clean-Contaminated (Class II) wound infection rate was 2.9%, and the Contaminated (Class III) wound infection rate was 9.9%. Overall wound infection rates for each of the surgical services are listed in Table 2.

Wound infection rates for each year and for each type of wound classification are listed in Table 3. Overall infection rates were significantly lower ($p < 0.05$) in each year from 1978 to 1981 when compared to 1977. Clean wound infection rates were 2.2% or less for each year in the study with a trend toward a decrease, and were significantly lower ($p < 0.05$) in 1981 compared to 1977. Clean-Contaminated wound infection rates were significantly lower in 1978, 1979, 1980, and 1981 compared to 1977 ($p < 0.05$). Contaminated wound infection rates were significantly lower ($p < 0.05$) in 1979. Figure 1 illustrates downward trends in wound infection rates for Clean and Clean-Contaminated wounds, while no trend could be identified for the Contaminated wound category.

Infection rates for specific, commonly performed surgical procedures are listed in Table 4 and compared to rates for the same procedures at comparable hospitals

TABLE 1. *Incidence of Wound Infection (1977–1981)*

Wound Classification	Total Number	Number Infected	Per cent
Clean	12,503	209	1.8
Clean-Contaminated	5685	167	2.9
Contaminated	2005	198	9.9
Total	20,193	574	2.8

TABLE 3. *Wound Infection Rates by Year and Wound Classification*

Year	Clean	Clean-Contaminated	Contaminated	Overall
1977	2.2%	5.6%	12.8%	4.2%
1978	1.7%	3.0%*	8.8%	2.8%*
1979	1.8%	1.9%*	8.5%*	2.4%*
1980	1.6%	2.4%*	9.0%	2.7%*
1981	0.8%*	1.3%*	10.2%	1.9%*

* $p < 0.05$ by chi squared compared to 1977.

across the country. Table 5 shows the three most frequently cultured organisms for each year of the study in order of decreasing frequency from left to right. *Staphylococcus aureus* was the organism most commonly encountered, with *Enterococcus* and *Pseudomonas* the next most frequently causative organisms. Table 6 illustrates estimated savings for each year of the study based on calculated decrease in infection rates compared to 1977. For the 5-year study period, a total savings of $769,000 is estimated.

Factors Contributing to Observed Decline in Wound Infection Rates

During the study period, wound surveillance was utilized to identify trends in rates of wound infection, thus allowing immediate correction of techniques or procedures. The following are two specific instances where techniques were modified in Class I (Clean wounds) with favorable results. While individually they do not account for major alterations of infection rates, such instances may have a cumulative positive effect. In 1977, a transient rise in vascular surgical wound infection rates to 6% led to examination of preoperative preparations. Simply postponing skin shaves until the morning of the day of surgery resulted in a decline in wound infection rate to 1.9% over the next 6 months. Similarly, an increase in wound infection in patients undergoing carpel tunnel release led to a standardization of preoperative preparation to three 10-minute scrubs the evening before surgery.

TABLE 2. *Wound Infection Rates by Surgical Service (1977–1981)*

Surgical Service	Wound Infection Rate (%) Overall	Clean
General surgery	3.4	1.5
Vascular	5.3	4.2
Thoracic	1.5	1.7
Head and neck	4.5	2.1
Urology	3.4	2.6
Otolaryngology	2.4	0.5
Neurosurgery	1.4	1.3
Ophthalmology	0.3	0.2
Transplant	2.3	1.3
Orthopedics	3.8	2.1

This resulted in an immediate decrease in rate of infection from 9% to 0% for the subsequent 2 years.

Examination of the greatly improved results in Class II Clean-Contaminated wounds demonstrates the advantages of the appropriate use of prophylactic antibiotics. Patients undergoing partial gastrectomy had a wound infection rate of 16.6% in 1977, and 50% of the patients with resulting wound infections had not received prophylactic antibiotics. The vagotomy and pyloroplasty infection rate was 16% in 1977, and 71% of these patients had not received prophylaxis. Omission of preoperative antibiotics was noted in 71% of patients undergoing cholecystectomy whose wounds later became infected (6.9%) and in 75% of patients undergoing gastrostomy whose wounds became infected (16.2%). A reduction in Clean-Contaminated wound infection rates of 71% was noted over the time period spanned by the study. It was speculated by the surgeons that this reduction in Class II wound infections was the result of a more consistent and appropriate use of preoperative antibiotics. A second example of the impact of surveillance on Class II Clean-Contaminated wound infection rates is illustrated by experience with elective colon resections. Beginning in 1977, this hospital participated in the Condon Bowel Prep

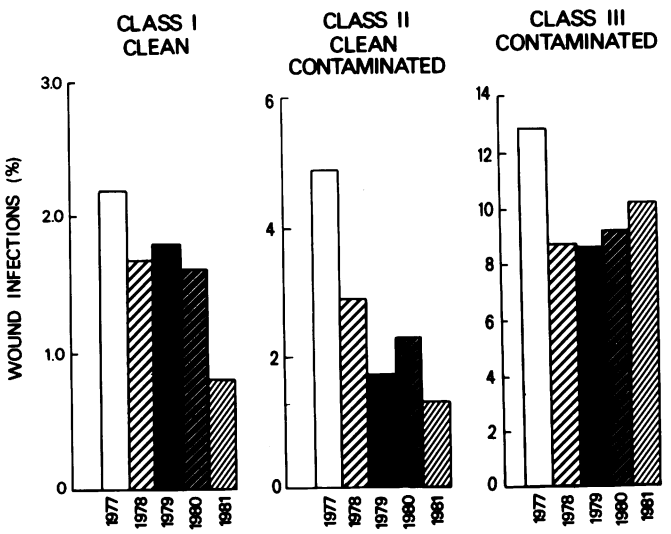

FIG. 1. Wound infection rates by category of infection over 5 years.

TABLE 4. *Infection Rates for Specific, Common Surgical Procedures*

Operative Procedure	38 Virginia Hospitals[8]			National Research Council[9]			Foothills Hospital Canada[10]			University of Virginia[11]			VA Medical Center Minneapolis, Minnesota		
	No. of Wounds	Infections		No. of Wounds	Infections		No. of Wounds	Infections		No. of Wounds	Infections		No. of Wounds	Infections	
		No.	(%)		No.	(%)		No.	(%)		No.	(%)		No.	(%)
Partial gastrectomy				288	29	10	194	26	13				102	8	7.8
Vagotomy and pyloroplasty							687	41	6.5				148	7	4.7
Appendectomy	5522	266	5	551	63	11	1821	180	10	382	23	6	131	8	6.1
Ruptured	511	135	26							40	6	15	47	5	10.6
Nonruptured	4085	11	3							206	9	4	84	3	3.6
Colon resection	1661	199	12							151	15	10	524	30	5.7
Partial colectomy with anastomosis				220	22	10	312	54	17						
A-P resection				190	22	12	101	25	25				59	10	17
Cholecystectomy	6343	200	3	756	52	7	3129	93	3	342	20	6	482	13	2.7
Herniorrhaphy	6778	95	1							444	12	3	1448	26	1.8
Inguinal				1312	25	2	2360	11	0.5				1222	14	1.2
Ventral				314	12	4	239	10	4				104	5	4.8
Umbilical													76	4	5.3
Splenectomy	232	9	4				141	1	0.7				49	0	0
Nephrectomy	325	15	5	127	22	17	164	6 (unilat)	3.6				158	0	0
							79	5 (bilat)	6						
Below-knee amputation	398	44	11							74	11	15	306	42	13.7
Above-knee amputation	409	45	11	101	18	18							187	19	10.2
Negative laporatomy				321	25	8	159	8	5				49	0	0
Radical neck dissection	142	18	13							47	10	21	121	20	16.5
Exploratory thoracotomy				137	8	6	61	3	5				68	2	3
Lobectomy, segmental resection				131	9	7	155	6	4				238	3	1.3
Fem-pop bypass	434	23	5				369	25	7	69	6	9	80	12	15
Aortoiliac bypass							246	10	4				11	0	0
Aorto-fem bypass	261	12	5										48	2	4.2
Aneurysm repair													170	2	1.2
Coronary artery bypass										134	8	6	421	9	2.1

Valve replacement			120	5	4				160	11	7	167	5	3
Craniotomy-tumor						269	1	0.4				101	1	1
Craniotomy-aneurysm						104	3	3				8	0	0
Total craniotomy									141	2	1.4	177	4	2.3
Laminectomy	3299	61	2			228	5	2	416	10	2.4	387	6	1.6
Suprapubic or retropubic prostatectomy				19	11							136	8	13.2
Total hip replacement	748	12	2			238	10	4	264	7	3	254	4	1.6
Total knee replacement	417	18	4						72	1	1.4	150	1	0.6
Menisectomy	2232	11	0.5			993	4	0.4	467	3	0.6	114	0	0
Open reduction: plate, screw, nail				6	4							644	17	2.6
Open reduction and nailing of fractured femur				144		194	13	6.7				41	3	7.3
Open reduction of fractured tibia						83	7	9				19	0	0
Fractured hip						655	32	5				363	10	2.8
Bunionectomy						853	7	0.8				47	4	8.5

Study,[12] in which a number of patients received intravenous cephalothin and no oral antibiotic as a preoperative medication before surgery. This study came to a conclusion after 1 year, when a 30% wound infection rate was found in this patient randomization. Over the subsequent 4 years, with the addition of oral neomycin and erythromycin, the wound infection rate fell to 4%.[13]

Review of 53 Class III Contaminated wound infections in 1978 revealed that 27 of 53 (51%) were general surgery patients who had primary closures at the time of surgery. Distribution of information to all resident staff surgeons was followed by a decline in use of primary closure and an overall drop in Class III infection from 12.8% to 8.8%. Contaminated wounds were again investigated when the infection rate rose from 9% in 1980 to 10.2% in 1981. It was found that 22% of the contaminated wound infections (8/37) were given no preoperative antibiotics. These wounds were known to be contaminated before surgery and the omission occurred due to lack of a physician's order or lack of administration during the busy time of anesthesia induction. Steps were subsequently taken to correct these errors.

Several factors that potentially have altered results in all classes of wounds may be ruled out: residents were operating surgeons in 90% of the cases throughout the study period; no major changes were made in operating room technique; and finally, there were equivalent relative proportions of clean and contaminated cases during each year of the study. Data regarding duration of preoperative hospitalization, incidence of severe systemic illness, incidence of extreme obesity, or frequency of infections at remote sites are not available.

Discussion

The overall wound infection rate for a total of 574 infections in 20,193 wounds at the Minneapolis VA Medical Center for the entire study period (1977–1981) was 2.8%. By wound classification, a Clean wound infection rate of 1.8%, Clean-Contaminated rate of 2.9%, and Contaminated rate of 9.9% were determined. These rates compare favorably with those reported by Cruse[1] and the National Research Multi-institutional Council[9] (Table 7). Overall, Class II and Class III wound infection rates at this institution were lower than those reported by either of these authors. Clean wound infection rates for this institution were slightly higher than those at the Foothills Hospital, reported by Cruse. Over the 5-year span of the study, yearly wound infection rates decreased by 55% (from 4.2% in 1977 to 1.9% in 1981). Class I wounds were reduced by 64%, Class II wounds by 77%, and Class III wounds had a 20% reduction when compared to 1977.

Specific factors that are known to contribute to the incidence of postoperative wound infection rates may be divided into two categories: factors related to bacterial

TABLE 5. *Organisms Most Commonly Involved in Surgical Wound Infections (Relative Frequency)*

Year	First	Second	Third
1977	*Staphlococcus aureus*	Enterococcus	*Pseudomonas*
1978	*S. aureus*	Enterococcus	*Proteus*
1979	*S. aureus*	Enterococcus	*Pseudomonas*
1980	*Pseudomonas*	*S. aureus*	Enterococcus
1981	*S. aureus*	Enterococcus	*Pseudomonas*

contamination and factors that promote the growth of bacteria once they have been introduced into the potentially infected wound. Factors determining the degree and potential severity of bacterial contamination include: size of inoculum; whether or not major organ tracts containing bacteria are entered at the time of operation (gastrointestinal, respiratory, genitourinary), *i.e.*, class of wound; virulence of organisms introduced; duration of preoperative hospitalization; duration of operation; antibiotic therapy; and the presence of remote infection or use of medical devices (catheters). Factors that may predispose to wound infection that are related to the ability of inoculated bacteria to thrive include: ischemia; endotoxic shock and hypovolemic shock; presence of foreign body or dead tissue; careless surgical technique; age and debility; obesity; malignancy; steroid therapy; radiation therapy, and diabetes mellitus.[1,2,14,15]

A variety of techniques are used to attempt to minimize contamination and decrease bacterial growth, including: preoperative skin preparation; draping, preoperative respiratory tract toilet; mechanical and antibiotic bowel preparation for colon operations; preoperative systemic antibiotics; careful aseptic technique; and careful operative technique with minimal tension, no dead space, and maintenance of good blood supply to tissues.[1,15]

Organized direct surveillance of healing operative wounds is a relatively new technique of infection detection and prophylaxis. Gardner[16] published the first report advocating the use of an "Infection Control Sister," outlining her responsibilities as: "collecting and preparation of adequate records; prompt recognition and disposal of patients; improvement of the liaison between Matron and Ward doctors; checking performance of Ward techniques; compilation of infection records; routine checks of staphylococcal carrier rates; assessment of environmental contamination; and efficiency of preventive measures."[16] More recent literature supports the use of wound surveillance as an effective means of decreasing the incidence of postoperative wound infection.[2,6,11,16-19] Mulholland,[20] on the other hand, who clearly advocates the use of wound surveillance by a nurse epidemiologist, reported that there was a direct correlation between time spent in surveillance with an increased wound infection rate. He concluded that increased efficiency of detection of wound infections by the nurse epidemiologist (as compared to physician reporting) resulted in more accurate *and* higher rates of wound sepsis.

Examination of wound infection data at the Minneapolis VA Medical Center on a continuing basis allowed

TABLE 6. *Savings in Dollars Since 1977*

Year	Number of Wounds	Projected Wound Infections	Actual Wound Infections	Difference	Cost Per Day*	Additional Hospital Days[1]	Savings
1977	4476		188				
1978	4335	182	120	62	$185	620	$114,700
1979	3969	167	97	70	$257	700	$179,900
1980	3808	160	101	59	$292	590	$172,280
1981	3605	151	68	83	$365	830	$302,950
				Total Savings Since 1977			$769,830

* Minnesota Hospital Association Estimator and Blue Cross and Blue Shield, Minnesota.

TABLE 7. *Wound Infection Rate for All Surgical Procedures*

Author	No PT	Inf Rate Class I	No PT	Inf Rate Class II	No PT	Inf Rate Class III	Total No PT	Inf Rate Overall
Cruse[1] Foothills Hospital 1980	47,054 (80%)	1.5%	9370 (16%)	7.7%	442* (0.8%)	15.2%	62,939	4.7%
National[9] Research Council 1964	11,690 (75%)	5.1%	2589 (17%)	10.8%	681* (4%)	16.3%	15,541	7.4%
Olson VAMC MPLS 1981	12,503 (62%)	1.8%	5685 (28%)	2.9%	2005 (10%)	9.9%	20,193	2.8%

* This number includes only contaminated cases while VAMC includes some which may be referred to as Class IV or dirty cases.

for early identification of problem areas. Two instances of improper preoperative skin preparation, which were identified in our Class I (Clean) wounds, were noted to be directly correlated with a transient rise in wound infection rates and were subsequently corrected. A decline in infection rates for Class II (Clean-Contaminated) wounds corresponds temporally to a more uniform and appropriate usage of preoperative antibiotics. Finally, a surveillance of postoperative wounds led to the increased usage of delayed secondary wound closure in Class III Contaminated cases. There does not, however, appear as yet to be a significant decline in Class III wound infection rates (range 8.5%–12.8%) with a rate of 10.2% reported for the last year of the study. These data indicate that continued investigation needs to be done.

One further advantage of a well-defined wound surveillance program is the process of accurate, objective collection of detailed information regarding infection rates for specific standardized operative procedures.[21] This process allows comparison of infection rates from one institution to the next, with appropriate assumptions of comparable patient populations regarding age and associated systemic illnesses. Table 4 lists wound infection rates reported by five major institutions during a comparable time period for comparison with results at the Minneapolis VA Medical Center. Wound infection rates for the following operations were less than those reported for at least three of the five major institutions cited: partial gastrectomy, vagotomy and pyloroplasty, colon resection, cholecystectomy, splenectomy, nephrectomy, above-knee amputation, thoracotomy, lobectomy, laminectomy, total hip replacement, and menisectomy. While specific factors responsible for these low infection rates are difficult to identify with certainty, the utilization of a strict wound surveillance program may well be significant.

In summary, we have presented data from a 5-year prospective wound surveillance study at the Minneapolis VA Medical Center. Over the course of 5 years, overall wound infection rates have decreased significantly. Infection rates for Class I and Class II wounds showed a downward direction. We feel that these decreases in wound infection rates are, for the most part, related to the institution of careful surveillance of all surgical wounds, with consequent early detection of trends. The early potential for wound management and modification of preoperative preparatory methods have allowed for considerable savings of inhospital time and money spent as a result of wound infections.

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