Postoperative Wound Infection:

A Controlled Study of the Increased Duration of Hospital Stay and Direct Cost of Hospitalization

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The increased hospital stay and direct cost of hospitalization that resulted from a postoperative wound infection (presence of pus at the incision site) after each of 6 common operations were evaluated. With the aid of the hospital computer, matched controls were obtained with respect to patient age, sex, exact operation performed, clinical service performing operation, pathologic finding, and underlying disease process which might alter the patient's predisposition toward infection. Several of the operations (appendectomy, cholecystectomy, total abdominal hysterectomy, and coronary artery bypass graft) were subtyped in order to obtain equivalence between controls and infected patients. In general, an infection doubles the postoperative stay and significantly increases the hospital expense.

IT IS WIDELY ACCEPTED that postoperative wound (POW) infections lead to increased hospital stay and direct cost of hospitalization.[1,4,7] However, no prior study has employed matched controls to quantitate this increase accurately. With the advent of computer banking of hospital data, it is now possible to find procedure- and diagnosis-matched controls for each patient with a POW infection. In this paper we report the differences in duration of hospital stay and hospital bill in patients who acquired a POW infection compared to closely matched patients undergoing the same operation without subsequent POW infection.

Methods

Hospital. The University of Virginia Hospital is a 560 bed hospital with an average daily census of 490 and a monthly admission rate of approximately 1400 patients. The hospital serves the City of Charlottesville with a population of approximately 40,000 and is a referral hospital for most of the western half of the State of Virginia and surrounding areas. The hospital is the main teaching hospital for the University of Virginia School of Medicine.

Selection of Patients. Data were reviewed from all surgical patients at the University of Virginia Hospital who developed a POW infection (from September 1973 through May 1975) after the following 6 operations: 1) appendectomy, 2) cholecystectomy, 3) bowel resection, 4) total abdominal hysterectomy, 5) Caesarean section, or 6) coronary artery bypass graft. This information was obtained from the files of the hospital epidemiologist.[8] An operative wound was considered infected when there was the presence of pus at the incision site (stitch abscesses were excluded).

Selection of controls. A list of all patients undergoing one of the above 6 operations at the University of Virginia hospital between January 1973 and December 1974 was obtained from the Hospital Computer Center. Information concerning the patients' age and sex was also included. The name of the patient with the POW infection was located on the list, and the chart of the patient of the next nearest age and the same sex was then selected and reviewed. If this did not produce a suitable control with respect to the specific procedure or underlying disease, the process was repeated until a suitable one was found. A total of 412 charts were reviewed to produce suitable controls for 51 patients, or an average of 8.1 charts/control.

Factors controlled. In addition to sex, patient age (46/51 [90%] ±5 years and none >10 years difference), and date of surgery (±2 years), the following factors were also matched: the exact operation, the clinical service performing the operation, and any underlying disease process which might alter the patient's predisposition toward infection. Although race and operative team (staff or private) were not always controlled, they were noted for comparison.

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TABLE 1. *Comparison of Length of Stay and Cost of Hospitalization of Infected Patients and Controls After Appendectomy*

Patients with POW Infections									Controls							
Patient	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost
1	10	F	B	S	0	13	1°10″	$1228.80	10	F	W	S	0	2	25″	$ 299.00
2	13	F	W	S	0	10	45″	869.15	13	F	B	S	0	3	35″	286.50
3	21	M	W	S	0	10	1°	977.35	21	M	W	S	0	5	1°	703.75
4	22	M	W	S	1	13	1°25″	1218.50	22	M	W	P	0	5	50″	584.80
5	70	F	W	P	1	22	50″	2977.20	65	F	W	S	0	6	1° 7″	646.00
*	27.2				.4	13.6	1° 2″	$1454.20	26.2				0	4.2	47″	$ 504.01
6	13	M	B	S	0	9	50″	1308.00	12	M	W	S	0	8	36″	779.50
7	19	M	W	S	1	9	1°15″	1223.50	19	M	W	S	1	16	1°48″	1799.15
8	51	M	W	S	0	11	1°42″	1359.72	47	M	W	P	0	6	1°46″	600.40
*	27.7				.3	9.7	1°19″	$1297.07	26.0				.3	10	1°23″	$1066.35
9	17	M	W	S	0	19	1° 5″	2129.07	18	M	W	P	0	4	45″	513.00
10	10	M	W	S	0	7	40″	652.80	8	M	B	S	0	8	23″	823.00
Total (Mean)	24.6				.3	12.3†	1° 4″	$1394.48‡	23.5				.1	6.3†	55″	$ 705.51‡

* Subtotal (mean value).

† $P < 0.01$, Student t-test.

‡ $P < 0.02$, Student t-test.

Note: #1–5 were appendectomy with acute appendicitis; #6–8 were appendectomy with perforated appendix; #9 was appendectomy without pathology found in appendix; #10 was appendectomy with acute gangrenous appendicitis.

Study plan. Pertinent data obtained for each patient included the following: 1) the total number of hospital days, 2) the number of hospital days prior to operation, 3) the number of days after operation prior to the presence of infection, and 4) the number of postoperative days before discharge. In addition, the patient's hospital bill was obtained from the Hospital Business Office. It should be noted that this bill did not include any fees for professional services.

Refinement of Operative Procedures. Four of the six types of operations were subdivided for better refinement. Under appendectomy, patients were classified according to pathological tissue diagnosis, and controls matched for the following: 1) appendectomy with no pathologic change noted, 2) with acute appendicitis, 3) with gangrenous appendicitis, and 4) with ruptured appendix. Categories under cholecystectomy included: 1) common duct exploration (CDE) and a pathologic diagnosis of chronic cholecystitis, 2) no CDE but with a pathologic diagnosis of chronic cholecystitis, 3) CDE and a pathologic diagnosis of acute cholecystitis, and 4) no CDE but with pathologic diagnosis of acute cholecystitis. It should be noted that combinations of "acute and chronic" were matched with control patients with "acute and chronic" changes. The other two operations which were subtyped were separated as follows: coronary artery bypass graft with or without ventricular aneurysmectomy (all the POW infections were sternal wound infections; and all the grafts were matched for equal number grafts, or the controls had more) and total abdominal hysterectomy with or without a Marshall-Marchetti Krantz Urethrocystopexy (MMKU) also performed. With the bowel resection the amount of intestine resected was closely matched as well as the underlying disorder necessitating the operation. The Caesarean sections were easily matched, with all being low transverse cervical Caesarean sections.

Results

The mean duration of postoperative hospital stay for patients with infection following appendectomy (Table 1) was 12.3 days as compared to 6.3 days for the controls ($P < 0.01$). The average hospital bill was $1394.48 for patients with a POW infection compared to $705.51 for uninfected patients ($P < 0.02$). Significant differences were not observed between infected and uninfected patients with a diagnosis of "perforated appendicitis."

Patients having a POW infection after cholecystectomy (Table 2) remained in the hospital for a mean of 18.5 postoperative days compared to controls with 11.4 postoperative days ($P < 0.001$). The average hospital bill in the infected patients was $2582.13 compared to $2139.12 in controls ($P < 0.30$). It was noted that the average preoperative stay of the controls was longer than for those becoming infected (4.2 days vs. 2.2 days, $P < 0.20$) which would tend to increase their total hospital bill.

In the patients undergoing colon resection (Table 3), there was a mean increase in postoperative hospital stay from 12.2 days for controls to 26.0 days for POW infection patients ($P < 0.30$) and a mean increase in hospital bill from $2823.58 for controls to $4414.77 for POW infection patients ($P < 0.50$). This group also had controls with an average of more than double the number of preoperative days

TABLE 2. *Comparison of Length of Stay and Cost of Hospitalization of Infected Patients and Controls After Cholecystectomy*

Patients with POW Infections									Controls							
Patient	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost
11	56	F	W	S	1	18	2°53″	$2337.08	57	F	W	S	4	11	3°10″	$1725.40
12	69	M	W	S	6	17	2°22″	2559.30	66	M	W	P	8	17	2°47″	3366.12
13	74	F	B	S	2	18	4°20″	1991.23	82	F	W	P	6	16	2° 2″	2056.38
14	77	F	W	P	2	18	1°50″	1954.72	82	F	W	S	8	11	4°35″	2812.00
*	69.0				2.8	17.8	2°51″	$2210.58	71.8				6.5	13.8	3° 9″	$2489.98
15	33	F	W	P	0	24	1°35″	3575.47	34	F	B	S	0	6	1°36″	763.56
16	64	M	B	S	3	26	2°35″	3138.50	72	M	W	S	2	14	2°25″	3025.35
*	48.5				1.5	25.0	2° 5″	$3356.99	56.0				1.0	10	2° 1″	$1894.45
17	60	F	W	S	1	10	2°45″	1339.64	56	F	W	S	2	12	1°50″	2020.91
18	63	M	W	S	4	11	2°50″	2041.59	64	M	W	P	10	11	2°13″	2385.36
19	72	M	W	S	1	19	1°52″	2800.05	71	M	W	P	3	11	2°21″	2800.05
20	76	M	W	S	0	24	3°	4357.85	79	M	W	P	2	10	5° 5″	1499.73
*	67.8				1.5	16	2°37″	$2634.78	67.5				4.3	11	2°52″	$2176.51
21	71	F	W	P	5	18	1°52″	2307.82	72	F	B	S	1	6	1°38″	1075.43
Total (Mean)	65				2.2	18.5†	2°32″	$2582.13‡	66.8				4.2	11.4†	2°42″	$2139.12‡

* Subtotal (mean values).

† $P < 0.001$, Student t-test.

‡ $P < 0.30$, Student t-test.

Note: #11–14 were Cholecystectomy with CDE with chronic cholecystitis; #15–16 were Cholecystectomy without CDE with acute cholecystitis; #17–20 were Cholecystectomy with CDE with acute and chronic cholecystitis; #21 was Cholecystectomy without CDE with chronic cholecystitis; #12 and 18 both control and infected patient also had sphincterotomy and duodenotomy. #13 control also had choledocholithotomy while infected patient had duodenotomy.

than infected patients (10.6 days to 5.0 days, $P < 0.20$).

Women undergoing total abdominal hysterectomy who developed a POW infection (Table 4) had a mean postoperative hospital stay of 13.3 days compared to 6.8 days in uninfected control patients ($P < 0.001$). The hospital bill was correspondingly increased from a mean of $1096.44 for controls to $1885.29 in those with infection ($P < 0.005$). Except for a slight increase in both length of stay and in hospital bill, there was no significant difference between controls with or without a Marshall-Marchetti Krantz urethrocystopexy nor between POW infection patients with or without MMKU.

In women undergoing a Caesarean section (Table 5), a mean increase from 5.7 days to 11.5 days was noted in patients with a POW infection as compared to controls ($P < 0.025$). The hospital bill was increased from a mean of $775.30 for controls to $1302.80 ($P < 0.005$).

In patients undergoing coronary artery bypass graft procedure (Table 6), the postoperative hospital stay in the POW infected group was a mean of 26.0 days and for controls was 12.2 days ($P < 0.05$); and the hospital bill was increased from a mean of $4939.82 for controls to $7542.50 for infected patients ($P < 0.05$). The difference was more pronounced for patients without concomitant ventricular aneurysmectomy than in those with aneurysmectomy.

It should be noted that there was no mortality among any of the patients in this study.

TABLE 3. *Comparison of Length of Stay and Cost of Hospitalization of Infected Patients and Controls After Colon Resection*

Patients with POW Infections									Controls							
Patient	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost
22	78	M	B	S	6	23	3°40″	$3356.57	79	M	B	S	15	7	3°	$2714.77
23	19	F	W	S	4	66	4°	11767.05	15	F	W	P	20	10	3°33″	4212.42
24	26	F	W	P	2	14	3°47″	2433.12	27	F	W	P	13	14	3°15″	2951.47
25	56	F	B	S	5	12	3°41″	2236.20	55	F	W	S	1	18	2°19″	1929.06
26	44	M	W	P	8	15	2° 4″	2280.91	47	M	W	P	4	12	3° 8″	2310.20
Total (Mean)	44.6				5	26*	3°26″	$4414.77†	44.6				10.6*	12.2	3° 3″	$2823.58†

* $P < 0.30$, Student t-test.

† $P < 0.50$, Student t-test.

Note: #22 control had anterior rectum resection while infected patient had sigmoid colectomy both for adenocarcinoma; #23 both had total proctocolectomy for ulcerative colitis; #24 both had total proctocolectomy—control for transmural colitis while infected patient for ulcerative colitis; #25 both had anterior resection of sigmoid colon for adenocarcinoma; #26 control had left colectomy while infected patient had sigmoid colectomy both for adenocarcinoma.

TABLE 4. *Comparison of Length of Stay and Cost of Hospitalization of Infected Patients and Controls After Total Abdominal Hysterectomy*

	Patients with POW Infections								Controls							
Patient	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost
27	32	F	B	S	1	12	2°35″	$1714.25	35	F	W	S	1	6	3°15″	$1062.97
28	36	F	B	S	2	15	3°	1830.61	34	F	B	S	1	5	2°10″	833.10
29	38	F	B	S	1	19	2°39″	2282.25	35	F	B	S	0	5	2°15″	799.05
30	48	F	B	S	1	8	2°15″	1107.30	46	F	B	S	4	5	2°41″	1153.85
31	51	F	W	P	2	12	2°33″	2087.71	50	F	W	P	1	7	1°55″	1175.49
32	51	F	B	P	1	11	2°10″	1280.34	51	F	W	P	1	7	3°22″	868.80
33	67	F	W	P	20	15	3°15″	3121.54	72	F	W	P	6	8	1°50″	1436.56
34	43	F	W	P	1	7	2° 5″	1005.10	45	F	W	P	1	8	2°15″	980.00
*	45.8				3.6	12.4	2°34″	$1803.64	46				1.9	6.4	2°28″	$1038.73
35	35	F	W	S	2	15	3°45″	1656.35	45	F	W	S	2	6	2°40″	1078.90
36	44	F	W	P	2	23	2°33″	2963.18	46	F	W	P	2	10	2°12″	1403.45
37	42	F	W	S	6	13	4°10″	2232.78	44	F	W	S	2	9	4°50″	1579.74
38	46	F	B	S	1	9	2°40″	1342.10	47	F	W	S	1	5	4°15″	785.35
*	41.8				2.75	15†	3°17″	$2048.45‡	45.5				1.75	7.5†	3°29″	$1211.86‡
Total (Mean)	44.4				3.3	13.3	2°48″	$1885.29	45.8				1.8	6.8	2°48″	$1096.44

* Subtotal (mean values).
† $P < 0.001$, Student t-test.
‡ $P < 0.005$, Student t-test.
Note: #27–34 Total Abdominal Hysterectomy without MMKU; #35–38 Total Abdominal Hysterectomy with MMKU.

Discussion

With the increasing interest in medical-legal aspects and in cost-effectiveness of hospital care, true estimates of the morbidity and economics of POW infections are of growing importance. Although most surgeons have their own estimate, nowhere in the literature is this convincingly substantiated. Cruse, in following 40,662 consecutive operations prospectively, claimed that a POW infection added 9.1 days to his patients' stay and estimated that this resulted in an added hospital expense of $910. No mention was made of how the figures were obtained.[3]

By comparing the length of hospital stay of a patient developing a POW infection with the average of *all* other patients undergoing the same type of operation, Clarke reported that the POW infection added 8.1 days to the hospitalization.[2] Loewenthal performed a similar study and reported that a POW infection added 7.3 days to the hospital stay.[6] Patients' age, sex, and underlying disease processes were not controlled in these studies.

The Public Health Laboratory Study took a unique approach and had the surgeon predict his patient's length of hospital stay based on the type of surgery.[5] The prediction was then compared with the actual stay which resulted, and it was observed that those who subsequently developed a POW infection outstayed the predicted value by 7.3 days.

At the University of Virginia Hospital, Swartz reviewed the POW infections on the Surgical Service between March 1968 and February 1969 and compared the 48 patients who had POW infections with the other 1115 surgical cases and found that the POW infection patients stayed in the hospital an average of 23.87 extra days.* He estimated that the POW infection

* Swartz, L. B., Unpublished manuscript.

TABLE 5. *Comparison of Length of Stay and Cost of Hospitalization of Infected Patients and Controls After Low Transverse Caesarean Section*

	Patients with POW Infections								Controls							
Patient	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost
39	14	F	B	S	0	8	1°22″	$1083.25	14	F	B	S	0	5	1°11″	$687.80
40	15	F	W	S	0	20	1°42″	1797.00	15	F	B	S	0	5	1°21″	714.05
41	17	F	B	S	0	7	1°55″	1125.05	18	F	B	S	0	5	50″	804.00
42	24	F	B	S	1	12	1°17″	1589.50	24	F	W	P	0	6	1° 5″	790.75
43	28	F	B	S	0	9	1°27″	952.75	27	F	W	P	0	7	1°25″	813.50
44	28	F	B	P	0	13	1°15″	1269.23	30	F	W	S	0	6	1° 5″	841.67
Total (Mean)	21				.2	11.5*	1°30″	$1302.80†	21.3				0	5.7*	1°10″	$775.30†

* $P < 0.025$, Student t-test.
† $P < 0.005$, Student t-test.
Note: #39–44 Low Transverse Caesarean Section.

TABLE 6. *Comparison of Length of Stay and Cost of Hospitalization of Infected Patients and Controls After Coronary Artery Bypass Graft*

Patients with POW Infections									Controls							
Patient	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost	Age	Sex	Race	Status	Preop Days	Postop Days	Operative Time	Cost
45	41	M	W	P	3	11	3°20″	$4662.20	35	M	W	P	6	14	2°15″	$5855.22
46	43	M	W	P	4	21	3°13″	5060.03	43	M	W	P	3	12	5°33″	3350.86
47	62	M	W	P	1	42	3°50″	9556.41	69	M	W	P	11	26	5°	7579.46
*	48.7				2.7	24.7	3°28″	$6426.21	49				6.7	17.3	4°16″	$5595.18
48	48	M	W	S	3	23	4°15″	6943.86	47	M	W	P	13	14	3°59″	4843.47
49	48	M	W	P	4	19	3°58″	6297.79	49	M	W	P	3	12	4°16″	3861.44
50	51	M	W	P	7	44	4°25″	11695.65	51	M	W	P	1	11	3°55″	4551.27
51	66	M	W	P	16	22	2°55″	8581.57	63	M	W	P	5	13	6°42″	4536.99
*	53.3				7.5	27	3°53″	$8379.72	52.5				5.5	12.5	4°43″	$4448.29
Total (Mean)	51.3				5.4	26†	3°42″	$7542.50‡	51				6.1	14.6†	4°31″	$4939.82‡

* Subtotal.
† $P < 0.05$, Student t-test.
‡ $P < 0.05$, Student t-test.
Note: #45–47 Coronary Artery Bypass Graft with aneurystectomy; #48–51 Coronary Artery Bypass Graft without aneurystectomy.

cost the patient between $6700 to $9477. However, matched controls were not sought for each operation.

The Ad Hoc Committee of the National Academy of Sciences—National Research Council has clearly stated that patients who develop a POW infection are statistically different from other patients as regard to age and type of operation.[7] Only by finding matched controls for patients who develop a POW can this bias be overcome. The value of the computer in the endeavor makes it a valuable tool in this study.

In our opinion, unless certain of the operations we studied were subtyped, as described earlier, the equivalence we sought with our controls could not be obtained. The 6 operations studied were selected because they were frequent enough to provide a large sample of infected patients and matched controls. Nevertheless, an average of greater than 8 charts had to be reviewed after age, sex, and procedure matching in order to find each control—an expenditure of a considerable amount of time.

Limitations of this study include the small size of the groups and its retrospective approach. Thus, it represents a pilot study as far as testing the feasibility for using the computer to find matched controls. The next step would be to organize a long range, prospective study. Practically speaking, it would entail programming additional information on the patient's computer data base (e.g., tissue diagnosis for appendectomy or cholecystectomy) in order to decrease the time expended in finding controls.

The results of this study lead us to conclude that by defining a POW infection as the presence of pus at the incision site one can document that such an infection leads to an increase in the duration of hospital stay and in the direct cost to the surgical patient. Although it is different for each type of operation, generally such an infection doubles the postoperative stay and significantly increases the hospital expense in each of the 6 operations studied. Additionally, the use of the computer to find matched patients for controls as opposed to using consecutive admissions is necessary to derive meaningful data.

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References

1. Altemeier, W. A.: Current Infection Problems in Surgery. *In* Proceedings of the International Conference on Nosocomial Infections, Baltimore, Waverly Press, Inc., 1971; pp. 82–87.
2. Clarke, S. K. R.: Sepsis in Surgical Wounds with Particular Reference to *Staphylococcus aureus*. Br. J. Surg., 44:592–596, 1957.
3. Cruse, P. J. E.: Incidence of Wound Infection on the Surgical Services. Surg. Clin. North Am., 55:1269–1275, 1975.
4. Cruse, P. J. E.: Surgical Wound Sepsis. Can. Med. Assoc. J., 102:251–258, 1970.
5. "Incidence of Surgical Wound Infection in England and Wales." A Report of the Public Health Laboratory Service. Lancet, 2: 659–665, 1960.
6. Loewenthal, J.: Sources and Sequelae of Surgical Sepsis., Br. Med. J., 1:1437–1440, 1962.
7. Post-operative Wound Infections: The influence of ultraviolet irradiation of the Operating Room and of Various other Factors. Suppl. Ann. Surg., 160:1–192, 1964.
8. Wenzel, R. P., Osterman, C. A., Hunting, K. J., et al.: Hospital-Acquired Infections. I. Surveillance in a University Hospital. Am. J. Epid., 103:251–260, 1976.