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Endemic infection in surgical wards

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SUMMARY

Endemic infection in male surgical wards has been studied during three periods. There was some infection due to gram-negative bacilli, though *Staphylococcus aureus* remained as the single most important pathogen even in the absence of epidemic spread. Beta haemolytic streptococci were isolated in large numbers from the lesions of four patients with deep wound infection. Changes introduced in the pattern of post-operative care reduced sepsis due to *Staph. aureus*, reduced the severity of wound infection and apparently decreased the need for antibiotic therapy. Patients who became infected were retained in hospital longer than those who escaped clinically apparent infection.

INTRODUCTION

During the 1950s interest was focussed on hospital cross-infection, especially by the so-called hospital strains of *Staph. aureus* (Williams, 1971). After the introduction of antibiotics active against penicillinase-producing staphylococci it appeared that the problem of wound infection had become less important. During the last decade it seemed clear that a high percentage of surgical wound infection was caused by gram-negative bacilli, frequently low grade pathogens (e.g. *Pseudomonas aeruginosa*) and micro-organisms resistant to many commonly used antibiotics (Thoburn, Fekety, Cluff & Melvin, 1968). In contrast to hospital cross-infection with staphylococci, where carriers amongst the medical staff and patients are the sources or vectors, there is no general opinion on the origin of wound infections with gram-negative organisms. Suggested sources are the patient's own gastro-intestinal flora, contaminated therapeutic substances, etc. (Whitby & Rampling, 1972).

The present investigation was initiated after a small epidemic with a highly resistant *Klebsiella* sp. in a surgical ward among 13 patients, two of whom died. The aim of this study was to investigate the prevalence of wound infection in a surgical ward, with reference to 'clean' and 'dirty' wounds, the time of occurrence after surgical intervention and the bacteria causing wound infection in a non-epidemic situation.

MATERIALS AND METHODS

Clinical studies

The investigation was done amongst male patients in a surgical ward of the University Hospital at Leiden. The unit consisted of 52 beds: one room was the so-called intensive care room containing 8 beds in which the patients stayed for 24–48 hr. after operation; the other part of the ward was divided into several rooms; one room with 21 beds, one with 13 beds, one with 4 beds, and 6 single rooms which were also used for isolation. The periods of investigation were: Period I, middle of March until the end of July 1971; Period II, middle of January until the middle of April 1972; Period III, middle of March until the middle of June 1973.

The clinical part of the investigation was carried out by the nurse-epidemiologist of our team (G.A.M.B.) who saw and classified all wounds at the moment the dressing was changed; this was usually between day 6 and day 9 when wound healing had a normal course, or whenever the clinical situation dictated.

The appearance of the wound was classified as follows: 1, Normal; 2, Erythema; 3, Superficial infection; 4, Deep infection. Pus was present in those wounds designated 'infected'. To obtain some uniformity of judging wound infection, during each period of the investigation, a number of wounds were scored by the nurse and a surgeon independently. In general there was excellent agreement.

After discussion with three surgical staff, all operations were classified as 'clean' or 'dirty', the classification relating to the expectation of a bacteria-free surgical field; for instance all gut operations were classified 'dirty'.

During all three periods of the investigation the clinical status of any drainage lesions was also recorded. Between periods II and III the nurse-epidemiologist instructed the nursing and surgical staff in regard to wound dressing techniques and post-operative care. It was expected that during period III, the prevalence of wound infection would decrease as a result of improved techniques.

All information regarding the patient, age, site and type of operation, the duration of the operation, length of incision and the clinical appearance of the lesion was collected on a form. Later the bacteriological results were added. For analysis these results were brought together on an edge-punch card system.

Bacteriological methods

Wounds were sampled using cotton swabs which were first moistened in broth if the wound was dry. These swabs were inoculated within 2 hr. of sampling on blood agar (blood agar base containing 5 % sheep blood) for aerobic and anaerobic incubation, Oxoid McConkey No. 2 and Oxoid C.L.E.D. agar and incubated at 37° C. overnight. Brewer's thioglycollate medium was also inoculated and incubated anaerobically at 37° C. for 4 days. No significant anaerobes were isolated; techniques were not sufficiently stringent for *Bacteroides* spp.

After incubation each colony type was assessed; + + = more than 50 colonies, + = 20–50 colonies, ± = 10–20 colonies and for less than 10 colonies the actual count was recorded. Each colony type was identified at least to the generic

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Table 1. *Factors associated with the appearance of clinical sepsis (periods I, II and III)*

Factor	Total patients: Clean operations	Total patients: Dirty operations	Percentage of patients with clinical wound infection: Clean operations	Percentage of patients with clinical wound infection: Dirty operations	Total patients with a drain	Percentage of patients with clinical infection of drain
Age						
Less than 50 yr.	131	82	10†	39	41	32
More than 50 yr.	175	59	20†	31	56	45
Duration of operation*						
Less than 90 min.	175	70	15·5	33	32	44
More than 90 min.	120	36	19	42	43	35
Length of incision*						
Less than 15 cm.	152	91	14	45	40	43
More than 15 cm.	148	46	17·5	43	54	39
Drain						
Absent	250	102	15	37‡	—	—
Present	56	39	20	62‡	—	—

* Some not known.
† Difference significant at $P < 5\%$ level.
‡ Difference significant at $P < 1\%$ level.
No other pairs reach the 5 % level of significance by χ^2 test.

level and all were stored on agar slopes in screw-cap bottles. *Staphylococcus aureus* strains were phage-typed and other catalase-positive, gram-positive cocci identified by the Baird-Parker (1963) techniques.

RESULTS

Table 1 shows that the same factors identified by others (Public Health Laboratory Service, 1960) were also at work in the patients studied here, at least in patients with 'clean' operations. Age, duration of operation, length of incision and presence of a drain were all factors tending to increase the likelihood of clinically apparent infection. The small numbers of patients generally prevent these differences from being statistically significant. In clean operations, age was the only factor found to be significantly associated with clinical wound infection. In dirty operations the presence of a drain was associated with a significant increase in wound infection.

The striking difference in the risk of infection in relation to the type of operation found previously (Williams *et al.* 1962) was again apparent (Table 2). Infection has here been divided into superficial and deep infection. Operations are listed in order of decreasing risk based on deep infection only. Table 2 also shows the time at which infection appeared after surgery. Most of the wound infections (66/117, 57 %) appeared more than 1 week after operation and 22 (19 %) appeared more than two weeks after operation. There was a suggestion that ward staff

Table 2. *Infection in relation to type of operation (periods I, II and III)*

Operation group	Total patients	Number of patients with post-operative infection appearing after: 1–3 days		4–7 days		8–14 days		≥ 15 days		Percentage with clinical infection of drain	
		Super-ficial	Deep	Superficial	Deep	Superficial	Deep	Superficial	Deep	Superficial	Deep
Liver, spleen, gallbladder (dirty)	9	0	0	1	1	0	2	0	2	11	56
Gut surgery	39	1	1	1	3	2	4	3	4	18	31
Stomach surgery	41	1	1	1	3	2	4	3	4	17	29
Perineal surgery (dirty)	20	2	0	3	1	3	2	2	1	50	20
Nephrectomy	8	0	0	1	1	0	0	0	0	13	13
Appendicectomy	39	0	0	2	3	0	1	0	0	5	10
Thoracic surgery	25	0	1	1	1	2	0	0	0	12	8
Liver, spleen, gallbladder (clean)	27	0	0	0	2	0	0	0	0	0	7
Fractures	60	3	1	2	2	6	1	1	0	20	7
Amputations	21	2	0	1	0	4	1	0	0	33	5
Neck and head	25	0	1	0	0	0	0	0	0	0	4
Herniotomy	121	0	0	5	2	6	3	2	0	11	4
Perineal surgery (clean)	9	0	0	0	0	1	0	0	0	11	0
Osteomyelitis	3	0	0	0	0	0	0	0	0	0	0
Total	447	9	5	18	19	26	18	11	11	14	12

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Table 3. *Expected and observed results for period III*

		Expected	Observed
Infection	Surface	30 patients	31 patients
	Deep	24 patients	16 patients
Antibiotic prescription	Prophylactic penicillin plus streptomycin	29 patients	33 patients
	Methicillin type	15 patients	6 patients
	Other	20 patients	13 patients
Recovery of pathogenic organisms	+ + *Staph. aureus*	19 patients	11 patients
	+ + gram-negative rods	27 patients	26 patients
Mean length of stay in hospital for all patients		15·6 days	15·9 days

Total patients contributing in period III = 196.
+ + indicates heavy growth of the organism.

Table 4. *Increased duration of hospital stay in relation to infection*

	Mean stay (days)	Percentage of patients with a duration of stay					Total patients*
		1 wk	2 wk	3 wk	4 wk	⩾ 5 wk	
Infected	19·2	4	31	31	15	19	52
Uninfected	15·5	15	41	23	8	14	333

* Some not known.

became aware of infection earlier as the study progressed. In period I, 38 % of infections became apparent during the first week; in period III, 51 % of infections was apparent during the first week.

There was no statistically significant evidence that the interval between admission and operation increased the chance of infection, although there was a trend in this direction. For example amongst herniotomy patients there were 84 operated upon within 4 days of admission and 12 % developed some degree of infection; 20 % of the 34 not operated on within 4 days of admission developed infection however.

The main interest in period III was to see whether changes made in the post-operative nursing care might influence the rate of infection. Because of the different balance of operations in each period, the results are presented in terms of an 'expected' versus 'observed' analysis. As seen from table 3, three factors were lower than expected; deep infection, prescription of therapeutic antibiotics and the recovery of heavy growths of *Staphylococcus aureus*. It is tempting to assume that these are related; that is, that the preventive measures reduced the incidence of staphylococcal contamination of the wounds, which reduced the severity of sepsis and necessitated less antibiotic therapy.

Analysis of length of stay in relation to infection presented some difficulties in avoiding bias (table 4). Patients who had clinically apparent infection within

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Table 5. *Duration of hospital stay in relation to infection*

	Period I		Period II		Period III	
	Total patients	Median stay (days)	Total patients	Median stay (days)	Total patients	Median stay (days)
Clean operations						
Infected	11	18 ($P < 0{\cdot}5\,\%$)	15	21 ($P < 0{\cdot}2\,\%$)	27	17 ($P < 0{\cdot}05\,\%$)
Uninfected	57	13	80	15	114	14
Dirty operations						
Infected	16	22 ($P < 0{\cdot}05\,\%$)	27	25 ($P > 5\,\%$)	30	14 ($P > 10\,\%$)
Uninfected	19	11	26	22	25	14

Analysis according to the Wilcoxon test.

Table 6. *Bacteriology of lesions (periods II and III only)*

Appearance of lesion	Total lesions*	Percentage of lesions with a heavy growth of: *Staph. aureus*	*Strep. pyogenes*	*Ps. aerug.*	*Proteus* sp.	*Escherichia*	Micrococcaceae coag. neg.
Normal	175	7	1	1	2	3	47
Erythema	109	11	2	4	3	5	47
Superficial infection	41	12	2	12	10	15	20
Deep infection	26	35	15	12	12	19	15

* Some patients had more than one separate lesion.

Table 7. *Relation of lesion flora to subsequent wound appearance (periods II and III only)*

(All lesions were initially normal or showed erythema only.)

First sample	Second sample: Lesion normal or erythema only	Lesion clinically infected
Percentage with + + pathogenic flora*	17†	42†
Percentage with + + non-pathogenic flora only	26	28
Percentage yielding no bacterial growth	42	30
Total patients	219	36

* Pathogenic bacteria included here are *Staph. aureus*, *Strep. pyogenes*, *Pseudomonas*, *Proteus*, *Escherichia* and *Klebsiella*.

† Significant difference $P < 0{\cdot}1\%$.

+ + Indicates a heavy growth of the organisms.

7 days of operation were compared with those who were free of infection entirely or for at least 3 weeks. Such an analysis omits from the 'infected' group therefore patients who become infected during the course of a long stay in hospital, and reduces the apparent length of stay for infected patients. Nevertheless the mean stay for the infected group was 19·2 days and for the uninfected 15·5 days. The distribution of duration of stay in table 4 is statistically significantly different ($\chi^2 = 17{\cdot}4$, d.f. $= 8$, $1\% > P > 0{\cdot}1\%$).

An alternative method of analysis is given in table 5 where all patients are considered. Patients with clean operations who became infected had a significantly prolonged stay in hospital. This was also true for those with dirty operations in period I but not in period II or III.

Bacteriology

In view of the current interest in the gram-negative rods as invaders, it was a little surprising to find that *Staph. aureus* was the most frequently isolated pathogen (table 6) although there was no evidence from phage typing that any

Table 8. *Lack of protective effect of normal skin flora in wounds*

(Patients with two or more swabs who had no infection at the first swab.)

First swab	Total patients	Second sample: Normal or erythema	Second sample: Deep or superficial infection
+ + micrococcaceae	49	43	6
± or no micrococcaceae but no other pathogen	41	35	6

spread of strains was occurring. It is noteworthy that four (15 %) of the 26 patients with deep wound infection yielded heavy growths of *Streptococcus pyogenes.*

Escherichia coli was isolated in large numbers from five patients with deep infection and *Proteus* and *Pseudomonas* from three such patients. Other gram-negative bacilli included *Acinetobacter anitratus* (two patients with deep infection) and *Klebsiella* and *Citrobacter* (one patient each). Coagulase-negative micrococcaceae were less common in infected lesions than in clinically normal lesions. Differences in the distribution of cocci in surgical lesions are outlined by Bosscher-Zonderman & Smith (1973).

In patients sampled on two or more occasions, a study was made of the clinical status at second swab in relation to microbiological status in the first (table 7). Those who subsequently became clinically infected, more often had heavy growths of potential pathogens in the lesion at the first swab than did those who remained free from infection ($\chi^2 = 13{\cdot}7$, d.f. $= 1$, $P < 0{\cdot}1\,\%$). Perhaps surprisingly, lesions with no aerobic microbial growth were evenly divided; it was expected that these would mostly occur in the non-infected group. Lesions which subsequently became clinically infected, less often had heavy growths of non-pathogens initially (table 8), but this difference is not significant ($P > 50\,\%$). No 'protective effect' of non-pathogens in surgical lesions could be demonstrated.

Prophylactic antibiotics

In the three periods together, prophylactic antibiotics were given before or on the day of operation to 119 patients who experienced 10 deep and 29 surface infections; 206 patients who did not receive any antibiotics experienced 17 deep and 20 surface infections. Thus 33 % of patients given prophylactic antibiotics became infected compared with 18 % of those not given antibiotics, this is statistically significant ($\chi^2 = 9{\cdot}3$, $P < 1\,\%$). There were insufficient patients to make a division into clean and dirty operations valid and insufficient patients received antibiotics after operation to make analysis worth while. It is recognized however that antibiotics may be prescribed before operation because infection is feared. The only significant bacteriological effect of prior antibiotic therapy on the isolation of microorganisms was a reduction in the yield of coagulase-negative cocci ($P < 1\,\%$).

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DISCUSSION

The clinical infection rate was high for a general surgical ward, even if only the deep infections are considered of significance. Much of the infection seemed attributable to post-operative care rather than to infection during or before operation; there was no evidence of any epidemic spread of any microorganism. It is perhaps surprising to find that the results of this study so closely parallel those reported 10 or 20 years ago. A comparison of our results with those reported by the Public Health Laboratory Service (1960) shows that the prevalence of *Staph. aureus* has diminished a little though that of the 'coliforms' has barely increased. It seems most likely, as Williams (1971) suggested, that the interest in infections with gram-negative rods arose, not from an increased prevalence, but from the therapeutic problems which these organisms may pose.

Changes in the nursing routine instituted between period II and period III would appear to have made some difference in the incidence of infection; the incidence of *Staph. aureus* was less than expected in period III and, presumably directly related to this, the incidence of deep infection was also lower than expected. In consequence the prescription of antibiotics for treatment was reduced. Presumably this occurred because most of the useful changes that can be made in a nursing routine are directed at reducing the spread of the more desiccation-resistant gram-positive organisms.

In this respect the value of a nurse-epidemiologist can be assessed in economic as well as clinical terms by the reduction of duration of stay in hospital and of prescription of antibiotics.

The most important points to emerge from this study appear to be that post-operative surgical ward infection is still too frequent and that infection can be reduced by reintroducing the hygienic measures and careful nursing procedures devised by other workers during the peak of studies of hospital infection (Williams, 1971).

It seems to us that the problems of endemic hospital infection are still as great as they ever were. The decline in interest in this sphere is presumably because the 'band wagon' (Williams, 1971) has lost its appeal.

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