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The bacteriology of primary wound sepsis in potentially contaminated abdominal operations: the effect of irrigation, povidone-iodine and cephaloridine on the sepsis rate assessed in a clinical trial

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SUMMARY

Two hundred and nine potentially contaminated abdominal operations were randomly allocated to prophylaxis with a single dose of 1 g cephaloridine intra-incisionally, irrigation of the wound at the end of the operation with saline or spraying of the wound with povidone-iodine. In high risk operations (ileocolorectal or those in obese patients) the rate of major wound sepsis in those protected by cephaloridine was 3·8 per cent compared with 13·2 per cent in the irrigation and 16·7 per cent in the povidone-iodine groups. In low risk operations no significant differences in sepsis rates were found.

Bacteriological studies of incised organs, subcutaneous fat and pus showed that the majority of wound infections arose from endogenous sources. The outstanding problem remains that of prevention of contamination of the abdominal wall during surgery.

WOUND irrigation either with water alone or, more usually, diluted with wine or other antiseptic has an ancient lineage:

> . . . a certain Samaritan . . . went to him, and bound up his wounds, pouring in oil and wine . . . .
>
> St Luke 10 : 33–34.

In the latter half of the nineteenth century wound irrigation was firmly established in surgical practice, although Lister (1909), in an assessment of aseptic operating techniques, concluded that:

> . . . the irrigation of the wound by antiseptic irrigation and washing may therefore now be avoided, and Nature left quite undisturbed to carry out her best methods of repair . . . .

Fleming (1919–20) demonstrated the ill effects of antiseptics on leucocyte function. Halsted, however (Dunphy, 1975), had made a practice of washing out surgical wounds with normal saline and his disciples continue this practice in many centres.

It has been shown that povidone-iodine sprayed into potentially contaminated laparotomy incisions reduces the wound sepsis rate below that found in untreated controls (Gilmore and Sanderson, 1975) and single dose intra-incisional cephaloridine prophylaxis (Pollock et al., 1977) has emerged as a significant factor in the reduction of the sepsis rate in such wounds.

By far the greater proportion of wound sepsis in general surgery arises from endogenous rather than exogenous sources. This study was undertaken to correlate organ, subcutaneous and pus bacteriology and to test the relative efficacy of saline irrigation, povidone-iodine spray and single dose intra-incisional cephaloridine.

Patients and methods

During an 8-month period in 1976, 218 consecutive patients undergoing potentially contaminated abdominal operations entered the trial. The following were excluded: patients with purulent peritonitis, including that due to perforated appendicitis for which the appropriate treatment was a systemic antibiotic; patients receiving preoperative antibiotics, except those used for bowel preparation in elective colorectal surgery; patients undergoing prostatectomy, who were in another trial; perineal and perianal wounds and those for the drainage of abscesses.

Twenty-seven of the 42 patients undergoing elective ileocolorectal surgery were prepared for 2 or 3 days with aperients, bowel washouts and phthalylsulphathiazole 2 g, neomycin 500 mg and tetracycline 500 mg, all three times daily. The remaining 15 had only aperients and washouts. The 4 emergency ileocolorectal cases had no preparation.

The methods of disinfection of the skin, of randomization and of double-blind assessment were standardized (Pollock et al., 1977). Fragments of the lining of the organ incised, and of the subcutaneous tissue after peritoneal suture, were placed in Robertson's cooked meat broth and transported to the bacteriology department for overnight incubation. Stuart's transport medium was used for duplicate specimens on 34 occasions. Aerobic subcultures were made on Oxoid no. 2 7 per cent horse blood agar and Oxoid cystine-lactose electrolyte-deficient media, and anaerobic cultures were made on Oxoid no. 2 blood agar with 100 μg/ml of neomycin sulphate in evacuated containers with GasPak (BBL) hydrogen-carbon dioxide generators.

When instructions stated that a patient was to receive cephaloridine prophylaxis, 1 g was dissolved in 2 ml of water and placed in the wound before skin closure or into the subcutaneous tissue between the skin sutures.

When patients were allocated to receive povidone-iodine (Disadine DP), it was sprayed for 8 s on to the subcutaneous tissues before skin closure from an aerosol can held at a distance of about 25 cm. After the skin had been sutured the wound edges were sprayed in the same way.

In the irrigation group, 200 ml of sterile 0·9 per cent sodium chloride solution were squirted forcibly with a 50-ml syringe into the wound after suture of the musculoaponeurotic layers and then aspirated; the wound was then dried with swabs.

Following appendicectomy patients normally left hospital after 2 or 3 days (mean 3·03 days), whereas after major laparotomies they went home or to a convalescent hospital after about a week. Wounds were inspected before the seventh postoperative day and aspirated if there was any tenderness, swelling or oedema. Any fluid recovered was inoculated into cooked meat broth bottles for transport to the bacteriology department where aerobic and anaerobic subcultures were made. If the aspirated fluid was obviously pus, a skin suture was removed and the wound opened for a short distance to allow drainage.

All patients were seen 4 weeks after operation and questioned about wound healing. Any reported discharge after leaving hospital was regarded as primary sepsis, although it was not possible to study it bacteriologically.

Definitions of primary, secondary, major and minor sepsis and of obesity remained as in previous reports (Pollock and Evans, 1975).

Statistical assessments were made by the χ^2 test with Yates's correction.

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Results

Two hundred and eighteen consecutive patients were entered in the trial. Nine died within a month of operation without wound sepsis and were rejected from analysis, leaving 209 operations, 12 (5·7 per cent) of which were complicated by major and 44 (21·1 per cent) by minor wound sepsis. There were, in addition, 6 examples of minor secondary sepsis, 1 due to a urinary fistula and 5 following discharge of sterile haematomas.

The three prophylaxis groups were comparable (*Table I*) except for the chance excess of positive subcutaneous cultures in the irrigation group.

Of the high risk patients (the obese and those undergoing ileocolorectal operations) the cephaloridine group fared better than those receiving povidone-iodine or irrigation, but the difference was only statistically significant between the cephaloridine and irrigation groups. Among low risk patients (all others) there were no significant differences between any of the groups (*Table II*).

In 44 of the 56 cases of wound sepsis cultures were obtained both during operation and from the subsequent pus (*Tables III, IV*). Eleven infections did not appear until after the patients had been discharged from hospital and the pus was not cultured; in the remaining patient the organ culture was omitted. In 34 (77·3 per cent) of the 44 patients, cultures from pus had at least one species in common with those from the incised organ or the subcutaneous tissues, whereas in the other 10 patients pus cultures yielded organisms

Table I: COMPARABILITY OF THE THREE GROUPS IN THE TRIAL

	Irrigation	Povidone-iodine	Cephaloridine
Total	74	65	70
Male	36	33	30
Age 65+	25	17	16
Obese	24	13	18
Organ culture positive	59	52	52
Subcutaneous culture positive	51	27	33
Appendicectomy	26	31	29
Ileocolorectal operation	21	11	14
Gastroduodenal operation	9	11	7
Biliary operation	15	10	17
Miscellaneous operation	3	2	3

Table II: WOUND SEPSIS RATES

	High risk				Low risk			
	Total wounds	Number septic (%) Minor	Major	Total	Total wounds	Number septic (%) Minor	Major	Total
Irrigation	38	15* (39·5)	5 (13·2)	20** (52·6)	36	5 (13·9)	1 (2·8)	6 (16·7)
Povidone-iodine	18	4 (22·2)	3 (16·7)	7 (38·9)	47	8 (17·0)	2 (4·3)	10 (21·3)
Cephaloridine	26	5* (19·2)	1 (3·8)	6** (24·0)	44	7 (15·9)	0 (0)	7 (15·9)

High risk, Ileocolorectal operations and operations in obese patients; low risk, other operations.
* $P<0·05$; ** $P<0·02$.

Table III: MAJOR WOUND SEPSIS

Sex	Age (yr)	Obese	Organ incised	Organ culture	Subcutaneous culture	Pus culture
Cephaloridine prophylaxis						
F	64	Yes	Colon	*Bacteroides* spp.	Sterile	*Bacteroides* spp.
Povidone-iodine prophylaxis						
F	47	Yes	Ileum	*Proteus* spp. *Clostridium* spp.	*E. coli*	*Proteus* spp. *Clostridium* spp.
F	27	Yes	Ileum	*E. coli* *Klebsiella* spp.	*S. epidermidis*	*E. coli* *S. aureus*
M	61	No	Stomach and duodenum	Haemolytic streptococci	*S. epidermidis*	*S. aureus*
M	50	No	Stomach and oesophagus	*S. faecalis*	Sterile	*S. faecalis* *S. aureus*
F	79	Yes	Appendix	*E. coli* *Clostridium* spp.	*E. coli* *Clostridium* spp.	*E. coli* *Bacteroides* spp.
Irrigation prophylaxis						
F	84	No	Colon	*Proteus* spp. *E. coli*	*Proteus* spp.	*Proteus* spp.
F	63	Yes	Colon	*E. coli*	*E. coli* *Bacteroides* spp.	*E. coli* *Bacteroides* spp. *Proteus* spp.
M	64	No	Colon	*E. coli* *Bacteroides* spp.	*E. coli* *Bacteroides* spp.	*E. coli* *Bacteroides* spp.
M	72	No	Stomach and appendix	*E. coli*	Sterile	*S. aureus*
F	82	Yes	Stomach and duodenum	*Klebsiella* spp. *E. coli*	*Klebsiella* spp.	*Klebsiella* spp. *S. pneumoniae*
M	37	No	Stomach and duodenum	*E. coli* *Klebsiella* spp. *S. aureus*	*S. faecalis* *S. epidermidis*	*S. faecalis* *S. aureus* *S. pneumoniae*

Table IV: MINOR WOUND SEPSIS

Sex	Age (yr)	Obese	Organ incised	Organ culture	Subcutaneous culture	Pus culture
Cephaloridine prophylaxis						
M	58	Yes	Ileum	NT	Sterile	*E. coli* *S. faecalis* *Clostridium* spp.
M	46	Yes	Ileum	*Clostridium* spp.	Sterile	*S. aureus*
F	57	Yes	Colon	*S. faecalis*	*S. faecalis*	Anaerobic streptococci
F	70	Yes	Colon	*E. coli*	*E. coli*	*E. coli*
M	50	No	Gallbladder	*S. epidermidis*	*Proteus* spp.	NT
M	66	No	Gallbladder and duct	*E. coli*	*E. coli*	*E. coli* *Enterobacter* spp.
M	54	No	Gallbladder and appendix	*E. coli* *Bacteroides* spp.	*E. coli*	*Bacteroides* spp.
F	30	Yes	Gallbladder	Sterile	*S. faecalis*	NT
M	44	No	Appendix	*E. coli*	*E. coli*	NT
F	9	No	Appendix	*E. coli*	Sterile	NT
F	9	No	Appendix	*E. coli* *Bacteroides* spp.	*E. coli* *Bacteroides* spp.	NT
F	10	No	Appendix	*E. coli* *Clostridium* spp. *S. faecalis*	*E. coli* *Clostridium* spp.	NT
Povidone-iodine prophylaxis						
F	42	Yes	Ileum	*Streptococcus* spp.	*Streptococcus* spp.	*S. faecalis* *S. epidermidis*
M	71	No	Colon	*S. faecalis*	*S. faecalis*	*S. faecalis* *Pseudomonas* spp.
M	33	No	Gallbladder and appendix	*E. coli*	Sterile	*E. coli* *Bacteroides* spp.
F	20	Yes	Gallbladder and appendix	*S. aureus*	*S. aureus*	*S. aureus* *Bacteroides* spp.
M	73	No	Gallbladder	*E. coli*	*E. coli*	*S. epidermidis*
M	50	No	Stomach and jejunum	Haemolytic streptococci *S. epidermidis*	Haemolytic streptococci	Haemolytic streptococci
M	67	Yes	Stomach and jejunum	NT	*S. epidermidis*	*S. epidermidis*
M	8	No	Appendix	*E. coli* *Clostridium* spp.	Sterile	NT
M	13	No	Appendix	*E. coli*	*S. epidermidis*	NT
F	16	No	Appendix	*E. coli* *Clostridium* spp. *Pseudomonas* spp.	*S. faecalis* *Clostridium* spp. *Pseudomonas* spp.	*E. coli* *Clostridium* spp. *Bacteroides* spp.
M	10	No	Appendix	*E. coli*	*E. coli* *S. faecalis*	NT
F	39	No	Appendix	*Klebsiella* spp.	*S. epidermidis*	NT
Irrigation prophylaxis						
F	40	Yes	Ileum	*E. coli*	*S. epidermidis*	NT
M	57	No	Ileum	*Klebsiella* spp.	*Klebsiella* spp.	*Klebsiella* spp. *Bacteroides* spp.
F	65	No	Colon	*E. coli* *Proteus* spp. *Klebsiella* spp. *Bacteroides* spp.	*E. coli* *Proteus* spp. *Klebsiella* spp. *Bacteroides* spp.	*Proteus* spp. *Klebsiella* spp. *Bacteroides* spp.
M	70	No	Colon	*Proteus* spp. *Klebsiella* spp. *Bacteroides* spp.	*Proteus* spp. *Klebsiella* spp. *Bacteroides* spp.	*Proteus* spp. *Klebsiella* spp. *Bacteroides* spp.
F	70	Yes	Colon	*E. coli* *S. faecalis*	*E. coli* *S. faecalis*	*E. coli* *S. faecalis*
M	77	No	Colon	*E. coli* *Pseudomonas* spp.	*E. coli* *Pseudomonas* spp.	*E. coli* *Pseudomonas* spp.
M	62	Yes	Colon	*E. coli*	*Bacteroides* spp.	*S. faecalis* *S. epidermidis*
M	61	No	Colon	*S. faecalis*	*S. faecalis*	*S. faecalis*
F	65	No	Colon	*E. coli* *Klebsiella* spp. *S. epidermidis*	*S. aureus*	*S. aureus* *Bacteroides* spp.
F	75	Yes	Colon	*S. faecalis*	*S. faecalis*	*S. faecalis* *S. epidermidis*
M	58	Yes	Stomach and duodenum	*S. epidermidis*	*S. epidermidis*	*S. epidermidis*
M	76	No	Gallbladder	*Klebsiella* spp.	*Klebsiella* spp.	*E. coli*
F	42	No	Gallbladder	Sterile	*S. epidermidis*	*S. aureus*

Table IV: MINOR WOUND SEPSIS (*Cont.*)

Sex	Age (yr)	Obese	Organ incised	Organ culture	Subcutaneous culture	Pus culture
F	62	Yes	Gallbladder and appendix	*E. coli* *S. faecalis* *Klebsiella* spp.	*S. epidermidis*	*E. coli*
F	48	Yes	Gallbladder and appendix	*E. coli* *S. faecalis*	*E. coli* *S. faecalis*	*E. coli* *Bacteroides* spp.
F	71	Yes	Gallbladder and appendix	*E. coli*	*E. coli*	*E. coli*
M	62	No	Kidney	*E. coli*	*E. coli*	*E. coli*
F	18	No	Appendix	*E. coli* *Clostridium spp.*	*E. coli* *Bacteroides* spp.	*E. coli*
M	29	Yes	Appendix	*E. coli* *Proteus* spp.	*E. coli*	*Bacteroides* spp.
M	9	No	Appendix	*S. aureus* *Bacteroides* spp.	*S. aureus* *Bacteroides* spp.	*S. aureus* *Bacteroides* spp. Anaerobic streptococci

NT, Not tested.

Table V: ORGANISMS ISOLATED

	Organ cultures		Subcutaneous cultures	
	Pure	Mixed	Pure	Mixed
E. coli	55 (25·5)	53 (35·8)	26 (38·5)	16 (56·3)
S. faecalis	21 (23·8)	10 (40·0)	17 (29·4)	7 (57·1)
Clostridium spp.	2 (50·0)	23 (26·1)	0 (0)	4 (75·0)
Bacteroides spp.	2 (50·0)	15 (40·0)	2 (50·0)	10 (70·0)
Proteus spp.	2 (0)	8 (62·5)	4 (50·0)	4 (50·0)
Klebsiella spp.	4 (75·0)	9 (77·8)	3 (100·0)	2 (100·0)
Pseudomonas spp.	1 (0)	6 (33·3)	0 (0)	4 (50·0)
Streptococcus spp.	5 (40·0)	4 (50·0)	3 (33·3)	2 (50·0)
S. epidermidis	12 (16·7)	5 (40·0)	28 (32·1)	4 (50·0)
S. aureus	1 (100·0)	2 (100·0)	6 (33·3)	2 (50·0)
Total wounds	105 (27·6)	58 (39·7)	89 (37·1)	25 (60·0)

Figures in brackets are the percentage subsequently developing sepsis.

different from those found during operation: these were *Staphylococcus aureus* (4), *Streptococcus faecalis* (2), *Staphylococcus epidermidis* (1), *Escherichia coli* (1), anaerobic streptococcus (1) and *Bacteroides fragilis* (1).

Two harvesting methods (swabs in Stuart's transport medium and fragments in Robertson's broth) were compared in 24 operations (organ cultures) and 10 operations (subcutaneous cultures) respectively. In 13 of these 34, cultures from the swab and the fragment of tissue were identical, but in 17 the swab was sterile whereas the fragment was not. In 4 further cases the tissue fragment yielded more species than the swab.

The incidence of wound sepsis was directly associated with the amount of endogenous contamination of the abdominal wall during operation (*Tables V, VI*). When both organ and subcutaneous tissue were sterile (24 patients) there was no wound sepsis. When subcutaneous culture was positive (111 patients) there were 47 instances of major or minor sepsis (42·3 per cent). When the organ was infected but the subcutaneous tissue was sterile (63 patients) there were 7 instances of wound sepsis (11·1 per cent).

The differences between the wound sepsis rates in patients with positive subcutaneous cultures and those in each of the other two categories are significant ($\chi^2 = 15{\cdot}59$ and $18{\cdot}32$, $P < 0{\cdot}001$).

A mixed subcutaneous infection was more likely ($\chi^2 = 5{\cdot}94$, $P < 0{\cdot}02$) to cause wound sepsis than infection due to a single organism (*Table V*).

Table VI: SEPSIS RATES AND SUBCUTANEOUS CONTAMINATION

	Organ and subcutaneous culture sterile		Subcutaneous culture positive		Organ culture positive, subcutaneous sterile	
	No.	Septic (%)	No.	Septic (%)	No.	Septic (%)
Irrigation	6	0	51	49·0	18	5·6
Povidone-iodine	6	0	27	51·9	24	12·5
Cephaloridine	12	0	33	24·2*	21	14·3
Total	24	0	111	42·3	63	11·1

* The sepsis rate with cephaloridine in this group is significantly lower than with either of the other two methods of prophylaxis ($P < 0{\cdot}05$).

The bacteriological findings were reflected in the higher incidence of major and minor wound sepsis in patients undergoing ileocolorectal surgery. Such operations were followed by major sepsis in 1 (3·7 per cent) and minor sepsis in 6 (22·2 per cent) out of 27 patients who had received both mechanical and antimicrobial bowel preparation. Of 19 patients to whom no antimicrobial preparation had been given, 5 developed major (26·3 per cent) and 10 minor (52·6 per cent) wound sepsis. The higher sepsis rate in unprepared patients is significant ($\chi^2 = 12{\cdot}56$, $P < 0{\cdot}001$).

The wound sepsis rate in the 56 obese patients was 42·9 per cent compared with 20·9 per cent in 153 patients who were not obese ($\chi^2 = 10{\cdot}06$, $P < 0{\cdot}01$).

During the 8 months of this trial, settle plates in the operating theatres yielded from 0 to 37 colonies of *S. epidermidis*, diphtheroids and micrococcus species and, occasionally, up to 6 colonies of *S. aureus*.

Discussion

Madden et al. (1971) compared low pressure syringe with high pressure jet irrigation and found that only the latter effectively reduced the sepsis rate in experimental wounds contaminated with *S. aureus* or *E. coli*. Our own results suggest that low pressure wound irrigation is of little value in abdominal surgery.

We have contrasted the effects of spraying potentially contaminated surgical wounds with a chemical disinfectant and of irrigating them with saline with a control group given a single dose of cephaloridine intra-incisionally. The incidence of wound sepsis was lower among patients in the control group than in either of the other two.

Fragments of the lining of potentially contaminated organs and of subcutaneous tissues transported in Robertson's cooked meat broth and subcultured aerobically and anaerobically give a higher yield of organisms than cotton-wool swabs from the same tissues transported in Stuart's medium. Some of these organisms, particularly *S. epidermidis*, may have little pathogenicity, although we have isolated this organism from pus in 6 patients with primary wound sepsis, in 3 of whom it was in pure culture.

One of the difficulties in assessing the bacteriology of wound sepsis is the secondary infection of a discharging wound from the patient himself or from his environment. This is obviated by aspirating pus from wounds before there has been any discharge. It is now routine practice to inspect all wounds before the seventh day and to aspirate if there is any swelling, tenderness or oedema. This policy has resulted in a high rate of correlation of the bacteriology of incised organs, subcutaneous tissues and pus.

S. aureus was identified in cultures from organs in 3 cases (1 in pure and 2 in mixed culture), subcutaneous tissue in 8 (6 pure and 2 mixed) and pus in 10 (4 pure and 6 mixed). Some of these infections may be endogenous but in the 4 examples of wound sepsis in which the pus grew nothing but a *S. aureus* (which was not present in either organ or subcutaneous tissue at operation) we can only conclude that the infections were of exogenous origin. Their presence emphasizes once more the continued necessity for strict asepsis in the operating theatre.

The role of antimicrobial bowel preparation for elective ileocolorectal operations is clearly demonstrated by the much higher rate of wound sepsis among those patients who, for various reasons, did not receive this prophylaxis.

The control of surgical wound sepsis must be based on long-established aseptic principles, together with measures to reduce contamination of the abdominal wall whenever a potentially contaminated organ is incised. The place of such procedures as the changing of gloves and instruments before abdominal wall suture has not been established and the use of a wound protector, though shown by Raahave (1976) to reduce subcutaneous contamination, has not yet been proved to be clinically effective.

At present, accepting the fact that we cannot prevent subcutaneous contamination during certain abdominal operations, we continue to advocate the prophylactic use of a single dose of cephaloridine instilled into the incision before closure.

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References

DUNPHY J. E. (1975) Wound irrigation versus wound débridement. *Ann. Surg.* **181**, 12A.

FLEMING A. (1919–20) The action of chemical and physiological antiseptics in a septic wound. *Br. J. Surg.* **7**, 99–129.

GILMORE O. J. A. and SANDERSON P. J. (1975) Prophylactic interparietal povidone-iodine in abdominal surgery. *Br. J. Surg.* **62**, 792–799.

LISTER J. (1909) *Collected Papers*, vol. 2. Oxford, Clarendon Press, p. 500.

MADDEN J., EDLICH R. F., SCHAUERHAMER R. et al. (1971) Application of principles of fluid dynamics to surgical wound irrigation. *Curr. Top. Surg. Res.* **3**, 85–93.

POLLOCK A. V. and EVANS M. (1975) The prophylaxis of surgical wound sepsis with cephaloridine—experiences in 2491 general surgical operations and reporting a controlled clinical trial against framycetin. *J. Antimicrob. Chemother.* **1**, Suppl., 71–83.

POLLOCK A. V., LEAPER D. J. and EVANS M. (1977) Single dose intra-incisional antibiotic prophylaxis of surgical wound sepsis: a controlled trial of cephaloridine and ampicillin. *Br. J. Surg.* **64**, 322–325.

RAAHAVE D. (1976) Effect of plastic skin and wound drapes on the density of bacteria in operation wounds. *Br. J. Surg.* **63**, 421–426.

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