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The predictive value of bacterial contamination at operation in post-operative wound sepsis

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Summary

Wounds of 53 surgical patients were studied prospectively both clinically and bacteriologically. There were 26 males and 27 females with a mean age of 38.3 yr. Culture of fascia-deep wound swabs at closure of wound at the end of operation was related to culture if post-operative wound infection occurred. Overall wound infection rate was 15.1% with an infection rate for clean wounds of 3.7% being lowest and the dirty wound infection rate of 60% being highest. Pathogenic organisms in seven of eight infected wounds had been isolated at wound closure while in one instance they were different from organisms in the wound at closure. Risk of development of subsequent infection was significant if enteric organisms rather than *Staphylococcus* were isolated from the wound at closure. Wounds that had negative culture at the end of operation had no post-operative infection.

The study underlines the importance of bacteriological analysis of wounds at the end of operation in identifying those at risk of post-operative infection and the probable causative pathogenic organisms. This will be useful in the choice of prophylactic antibiotics for treatment of high-risk patients.

Résumé

Une étude prospective des 53 plaies chirurgicales a été faite sur des paramètres cliniques et microbiologiques. Il y a eu 26 hommes et 27 femmes avec un âge moyen de 38.3 ans. Nous avons comparé des cultures à la fermeture des plaies avec celles survenant post opératoire s'il y en a eu d'infection. En général il y a eu 15.1% d'incidence d'infection avec 3.7% chez les malades porteurs des plaies propres tandis que les plaies souillées éprouvaient 60% d'incidence d'infection. Dans sept cas sur huit les pathogènes isolées des infections ont été de mêmes espèces que celles isolées à la fermeture des plaies tandis qu'au huitième elles ont été causées par une pathogène différente. Le risque de développer une infection post opératoire était significatif avec les enterobactéries, le risque était moins avec le staphylocoque. Il n y avait pas eu d'infection post opératoire si la plaie n'était pas infectée a la fermeture.

Cette étude a démontré l'importance de surveillance microbiologique des plaies chirurgicales, afin de permettre d'instituer une chémoprophylaxie appropriée chez des malades à grand risque d'infection post opératoire.

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Introduction

Post-operative wound infection occurs when the bacteria present within a surgical wound multiply and excite a local reaction with or without a systemic response from the host. It includes any local manifestations of inflammation with heat, redness, swelling, pain and purulent discharge. While wound infection has been observed to be the most common post-operative complication in most centres, the incidence varies from one centre to the other [1,2]. This is because many of the investigations are probably carried out under different situations. In well-controlled co-operative studies in Europe and North America during the last 15 years the overall post-operative wound infection rate has been between 7% and 8% [1,3]. However, in Nigeria, reports from the University College Hospital Ibadan indicate a lower rate, being 4% in 1978 and 4.3% in 1979 [4].

The development of wound infection depends primarily on host and bacterial factors. Other factors such as the pre-operative hospitalization and operative factors such as type and duration of the surgical operation are related to wound infection by influencing the host and bacterial factors.

The systemic, and more particularly, the local host defence mechanisms prevent any bacterial contaminant in the wound from reaching the critical level of growth necessary for infection. The general host resistance is influenced by the patient's age, nutritional status and the presence or absence of intercurrent diseases such as malignancy, concurrent infection and immuno-suppression.

The bacterial factors involved in wound infection are the virulence and the size of the initial bacterial inoculum in the wound. Studies on the pathogenesis of post-operative wound infections have highlighted the importance of bacteria contamination [1]. The bacteria contamination of a surgical wound can be exogenous or endogenous.

In most instances the ground work for succeeding wound infection is laid by contamination of the surgical wound intra-operatively [5]. It thus seems that since intra-operative contamination is a prime factor influencing post-operative wound infection, the risk of subsequent wound infection could therefore be determined by an assessment of the degree of intra-operative contamination.

This paper reports a study designed to investigate the bacteriological status of the wound at operation and the bacteriology of the wound if and when infection occurs. This will enable us to determine the bacterial flora of surgical wounds in our hospital and at the same time define the relationship between the degree of wound contamination at the end of the operation and the risk of the development of subsequent wound infection.

Materials and methods

The study involved 53 consecutive wounds of patients undergoing surgical operations at the Obafemi Awolowo University Teaching Hospitals between 1 January 1986 and 31 December 1986. The personal data including the age and sex of the patients were recorded.

At the end of the surgical procedure the wounds were classified into four categories: clean, potentially contaminated, contaminated and dirty, based upon the degree of contamination present using the guidelines established by the National Research Council in 1964 [1]. Wounds that were contaminated or dirty were left open. All the wounds in the clean and potentially contaminated categories were closed primarily. Intraperitoneal drains, when necessary, were brought out through a separate stab wound.

Parenteral antibiotics were used perioperatively in the potentially contaminated, contaminated and dirty categories. Both mechanical and antibiotic bowel preparation were used for patients undergoing elective colorectal operation.

A deep wound swab was taken at operation after fascial closure in all cases. Each specimen was placed in Robertson's cooked-meat transport medium for subsequent delivery to the laboratory.

In the laboratory each specimen was cultured on to blood and MacConkey agar and incubated for 48 h both aerobically and anaerobically. Identification of micro-organisms was done using routine laboratory methods.

For the purpose of this study, wound infection was defined as any wound in which a purulent discharge occurred during a month of observation after the operation. Swabs were taken from all infected wounds and these were also treated as described above.

Statistical analysis of the results was carried out using a chi-square test with Yates' correction for continuity since cell observations were small. The level of significance was at one degree of freedom.

Results

Fifty-three patients made up of 27 females and 26 males were recruited into this study. Their age ranged from 3 to 75 yr with a mean of 38.3 yr.

The number of patients with wounds in each of the four groups of (i) clean, (ii) potentially contaminated, (iii) contaminated and (iv) dirty are as shown in Table 1. Tables 2–5 show the types of surgical operations carried out on patients with wounds in each of the four groups.

Table 1. Classification of surgical wounds and the accompanying frequency of wound infection in 53 surgical patients

Type of wound	Number of patients	Number of patients with infected wounds	Percentage of infected wounds (15.1%)
Clean	27	1	3.7
Potentially contaminated	11	1	9.0
Contaminated	10	3	30
Dirty	5	3	60
Total	53	8	15.1

Table 2. Types of surgical operations in 27 patients with clean wounds

Type of operation	Number of patients
Hernia repairs	
Inguinal herniorrhaphy	7
Epigastric herniorrhaphy	1
Incisional herniorrhaphy	1
Excision of fibroadenoma of breast	11
Simple mastectomy	1
Subtotal thyroidectomy	3
Exploratory laparotomy with lymph node biopsy	1
Excision of cystic lymphangioma (hygroma)	1
Excision of lipoma	1
Total	27

Table 3. Types of surgical operations in 11 patients with potentially contaminated wounds

Type of operation	Number of patients
Gastrojejunostomy	1
Gastrostomy	1
Release of intestinal adhesion bands	1
Splenectomy	1
Repair of liver laceration	1
Left hemicolectomy	1
Repair of obstructed hernia	4
Appendectomy	1
Total	11

Table 4. Types of surgical operations in 10 patients with contaminated wounds

Type of operation	Number of patients
Abdomino perineal resection of rectum	[illegible]
Toilet mastectomy	1
Appendectomy for perforated gangrenous appendix with peritonitis	[illegible]
Small bowel resection (for gangrenous bowel)	[illegible]
Partial gastrectomy	[illegible]
Total	10

Table 5. Types of surgical operations on five patients with dirty wounds

Type of operation	Number of patients
Closure of intestinal perforation	3
Bowel resection	1
Drainage of intra-abdominal abscess	1
Total	5

Eight patients developed wound infection in this series, giving a wound infection rate of 15.1% for this study. This varied from 3.7% for the clean wounds to 60% for the dirty wounds (Table 1).

Culture of wound swabs taken at the closure of the 53 wounds showed no growth in 17 cases

(Table 6): 13 of these wounds were clean, three were potentially contaminated and one was contaminated. None of these wounds were subsequently infected.

Of the 36 wounds swabs that showed bacterial growth many showed mixed growths (Table 6). Table 7 shows the results of the bacteriological study in the eight infected wounds in this series both at closure of wound at the end of operation and after wound infection had occurred. *Staphylococcus aureus* was responsible for the infections in the clean and potentially contaminated wounds. There were two such cases. The remaining six wound infections were due to enteric organisms and these occurred frequently as mixed growths. There was a strong relationship between the bacteriological analysis of the wounds at operation and the analysis when wounds became infected.

In the two cases of infected wounds in which *S. aureus* was isolated the organism had been isolated in the same wounds at operation. Similarly, in 83% of infected wounds in which enteric organisms were the aetiological agents, the micro-organisms had been present in the same wounds at operation (Table 7). In one

Table 6. Bacteria isolated in wounds at closure of 53 wounds of different categories

Micro-organisms	Clean	Potentially contaminated	Contaminated	Dirty	Frequency of isolation
Staphylococcus albus	4	0	0	0	4
S. aureus	7 + (1)*	3 + (1)	0 + (1)	0	13
Pseudomonas	1	0	0	0 + (1)	2
Coliform	0 + (1)	0	1	1	3
Klebsiella	0	2	2 + (2)	1	7
Escherichia coli	1	1 + (1)	1	2 + (1)	7
Bacillus	0	1	0	0	1
Proteus	0	0	2 + (1)	0 + (1)	4
Streptococcus faecalis	0	0	1	0	11
No growth	13	3	1	0	17

*The figures in parentheses are frequencies of mixed cultures.

Table 7. Relationship of bacterial flora at closure to bacterial flora of infected wound

Category of operation	Number of infected wounds	Closure flora of wound	Infection flora of same wound
Clean	1	(1) *S. aureus* and Coliform	(1) *S. aureus*
Potentially contaminated	1	(1) *S. aureus*	(1) *S. aureus*
Contaminated	3	(1) Klebsiella (2) Coliform (3) Klebsiella	(1) Klebsiella and Proteus (2) Coliform (3) *E. coli* and *S. albus*
Dirty	3	(1) Pseudomonas, Proteus and *E. coli* (2) Coliform (3) *E. coli*	(1) Proteus and Pseudomonas (2) Coliform (3) *E. coli*

case, however, organisms other than the ones isolated at closure caused the wound infection. This was a wound in the contaminated category in which *Klebsiella* was isolated at closure of wound but *Escherichia coli* and *S. albus* were identified as causing the wound infection.

The frequency of isolation of *S. aureus* at closure of the wound was 25% (Table 6). However, the risk of subsequent wound infection of 15.4%, together with the relative risk of wound infection of one when the organism was isolated at wound closure, was low and not statistically significant (Table 8).

When considered together, the enteric bacteria were seen very frequently in wounds at closure and were associated with significant risks of subsequent wound infection. Alone, the Coliform organisms had a 67% risk of subsequent wound infection and a relative risk of infection of 5.6% ($P < 0.065$) even when it was seen relatively less frequently at closure of wounds. Pseudomonas showed a similar trend.

S. albus and Bacillus species on their own caused no infection and had no relative risk of wound infection but were merely contaminants.

Discussion

The risk of infection developing in a surgical wound is a function of many different factors. The main factors are the bacterial contamination, systemic host resistance and local wound environment. The bacterial contamination, especially at the time of operation, is necessary for the development of post-operative wound sepsis while the host's resistance served as the modulator. Therefore, the study of the influence of bacterial contamination is crucial to the understanding of post-operative wound infection. In addition, the degree of bacterial contamination can easily be accessed.

In considering a representative spectrum of general surgical procedures as in this study, the variation in the nature of operations is substantial. The classification of operations based on the degree of contamination of wounds at operation reduces this variation.

The clean wound infection rate of 3.7% found in this study was similar to those ot other reports [6,7]. The infection rates in the contaminated and dirty categories were eight and 20 times higher respectively than the clean wound infection rate. The overall wound infection rate was 15.1%. This is much higher than the 4.8% reported by Cruse and Foord [7]. However, the population size of 53 in this study is much less than the 23,649 of Cruse and Foord [7]. Furthermore, 28% of the total number of wounds in this study were in the heavily contaminated category. These have accounted for the high overall infection rate.

Table 8. Micro-organisms in 53 operative wounds as predictors of subsequent wound infection

		Subsequent infection rate (%)			
Bacteria at closure	Number isolated (%)	Isolated at closure (A)	Not isolated at closure (B)	Relative rate*	*P*-value†
Staphylococcus albus	4 (7.5)	0.0	16.3	0.00	n.s.
S. aureus	13 (24.5)	15.4	15.0	1.03	n.s.
Pseudomonas	2 (3.8)	50.0	13.7	3.64	n.s.
Coliform	3 (5.7)	67.0	12.0	5.56	0.065
Klebsiella	7 (13.2)	28.6	13.0	2.19	n.s.
Escherichia coli	7 (13.2)	28.6	13.0	2.19	n.s.
Bacillus	1 (1.9)	0.0	15.4	0.00	n.s.
Proteus	4 (7.5)	25.0	14.3	1.75	n.s.
Streptococcus faecalis	1 (1.9)	0.0	15.4	0.00	n.s.

*Relative risk, calculated by dividing the figure in column A by that in column B.

†*P*, the level of significance at one degree of freedom of the calculated relative risk as determined by chi-square analysis with Yates' correction.

This study showed that there was a significant correlation ($P < 0.0001$) between the degree of intra-operative contamination using the operation types, and the risk of post-operative wound infection rate (Table 1). This agrees with the findings of other studies [1,8]. Also, there was a strong relationship between positive culture at operation and the high infection rate. Correlation was also established between organisms found in over 80% of the septic wounds and those present at operation (Table 7). There was also an absence of subsequent wound infection when there was a negative culture at operation.

These findings indicate that organisms which were seeded at operation caused post-operative sepsis and that post-operative contamination had been minimal. The main determinant of sepsis in this study therefore was intra-operative contamination.

The analysis of bacterial flora in wound sepsis showed that the enteric organisms were the most frequently isolated aetiological agents while *S. aureus* had a frequency rate of 25% in this study. This finding is at variance with the finding of some studies in which *S. aureus* is the commonest pathogen in post-operative infected wounds. However, it is in keeping with the result obtained by Dineen [9]. There are a relatively high number of gastrointestinal operations in this study with an attending contamination by endogenous intestinal organisms. This in part may explain the difference in finding from that of Howe [10].

Enteric organisms were noticed to have a high relative risk of infection and a high frequency of isolation in the study. On the other hand, *S. aureus* had a lower frequency of isolation (25%), and a relative risk of infection which was not statistically significant.

These findings show that the presence of enteric organisms in the wound at operation was associated with a high risk of subsequent wound sepsis. Gorbach and Barlett [11] and Kelly and Warren [12] reported similar findings. The findings in this study indicate that the enteric organisms are important determinants of wound infection. Furthermore the findings are indicative of the usefulness of bacteriological analysis of operative wound swab in the prediction of subsequent sepsis, as noted by Kelly and Warren [12]. Also, the calculation of the relative risk of subsequent wound infection after the isolation of specific organisms or groups enabled the relative pathogenicity of the organisms to be determined. This is useful in determining the virulent organisms in situations where bacterial mixed cultures occur, especially in wounds of abdominal operations.

S. aureus was isolated pure in infected wounds whereas the enteric organisms were frequently isolated in a mixture. Howe [10] reported a similar finding. The relative risk of wound infection calculated for individual enteric organisms in this study did not achieve significance except in the case of the Coliform organisms. However, when taken together, the relative risk of infection is high for all enteric organisms; these findings could be explained by the synergistic interaction among enteric organisms. Synergy between enteric organisms, especially facultative and anaerobic organisms has been proposed as part of the pathogenesis of sepsis involving these organisms.

It is striking in this study that anaerobes were not isolated given the high number of gastrointestinal operations in the study group. This is at variance with the findings of Hoffman and Gierhake [13]. Considerable technical difficulties are associated with anaerobic cultivation, especially of the fastidious anaerobes. The finding in this study may have been due to such technical problems.

The frequency of isolation [13] of *S. aureus* in the minimally contaminated wounds at operation associated with two wound infections, i.e. a risk of infection of 17% (Tables 7 & 8), is striking. Also, the isolation of enteric organism in minimally contaminated wounds at operation is similarly associated with a low risk of infection. These findings indicate the significance of the size of a bacterial inoculum and the importance of the host resistance. Small numbers of bacteria which occur in minimally contaminated wounds can effectively be dealt with by the host. In these circumstances the organisms must have occurred in small quantities and were removed by the host immune systems.

In conclusion, this study has established that intra-operative wound contamination, being the main determinant, adequately predicts the risk of subsequent post-operative wound infection in general surgical procedures. The findings in the study also present the identification of the pathogens and the categories of operations that must be the target of appropriate prophylaxis at the time of operation or in the very early post-operative period.

As bacteria cannot be completely eliminated from surgical wounds, measures taken to prevent post-operative infection must include intra-operative bacteriological identification of bacteria seeded at operation in the high-risk groups. Where rapid slide techniques are available, appropriate antibiotics can be given as soon as organisms associated with high relative risk of infection are identified. However, where no such facilities are available the results of simple, effective and inexpensive deep wound swabs in the high-risk group will be useful in changing antibiotics prescribed earlier to ones more appropriate to the sensitivities of the pathogens.

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