Studies on the Epidemiology of Postoperative Infection of Clean Operative Wounds *

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The determination of the sources and mechanisms of transport of the contaminating bacteria which result in postoperative infection of clean elective surgical wounds should indicate the means of shielding these wounds from significant contamination. Aseptic and antiseptic technics in the performance of operative procedures have been designed to reduce the possibility of *exogenous* bacterial infection by direct contact of the wound by contaminated personnel or materials. When properly applied, these technics should accomplish that purpose. *Endogenous* contact infection of clean operative wounds may occur as the result of transection of organs or tissues containing viable microorganisms.

Bacteria may reach operative wounds in other ways, however, to produce infections. One of the possibilities frequently mentioned is the environmental air of the operating rooms, which contain large numbers of bacteria, some of which may be of pathogenic types. Previous studies by other investigators [1-6] have shown that these microorganisms are constantly being deposited upon all surfaces of the walls, floors, tables, and other exposed surfaces.

Other studies [7-9] have demonstrated that the immediate vicinity of the operative wound is exposed to larger numbers of bacteria when the personnel of the surgical team talk, sneeze, or cough, even though accepted methods of wearing masks, caps and gowns are enforced at the time. Part of this bacterial pollution may be in the form of aerosol droplets of moisture containing many bacteria in each droplet. A clean operative wound may, in this way, become contaminated by a large initial dose of micro-organisms at a single point.

Another possible source of infection of clean operative wounds may exist. In patients who have septicemia, the production of a *locus minoris resistentiae* will often result in the development of an abscess at that site. Such decreased local resistance in these patients may be caused by a minor injury. It has been contended that certain diagnostic procedures such as bronchoscopy and esophagoscopy may result in transient bacteremia, and it is theoretically possible that a similar bacteremia could occur during or following major operative procedures permitting hematogenous bacterial contamination of the clean operative wound.

Materials and Methods

The present study was undertaken to explore the possible origins of infection occurring in clean operative wounds and to attempt to explain by epidemiological means the reasons for the development of such lesions.

All patients on the General Surgical Service of the Cincinnati General Hospital who were operated upon in the period of

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TABLE 1. *Epidemiologic Studies of Wound Infections, Cincinnati General Hospital. Clean Operative Wounds*

No.	Age	Operation		Surgeon	1st Asst.	2nd Asst.	Scrub Nurse	Anes.	Sedimentation Plate	Wound Operative Culture	Wound Infection Culture
		Type	Duration								
1	72	Cholecystectomy	1 hr. 20 min.	HSA	Neg.	Neg.	—	HSA	Micrococcus	Not done	HSA (UNT)
2	47	Radical neck dissection	5 hrs. 15 min.	Neg.	Neg.	Neg.	Neg.	HSA (UNT)	Bacillus, Gaffkya, micrococcus	Sterile	Paracolon bacillus, HSA (53/77)
3	66	Herniorrhaphy	2 hrs. 10 min.	Neg.	BHS	—	BHS	HSA (UNT)	No plates	Proteus mirabilis	Esch. coli, Proteus mirabilis
4	71	Exploratory laparotomy; lysis of adhesions	3 hrs. 35 min.	Neg.	—	—	Neg.	—	Diphtheroid, Gaffkya, bacillus, micrococcus, sarcina	Esch. coli, non-hemo. strept.	Esch. coli, non-hemo. strept.
5	25	Radical inguinal node dissection	3 hrs. 25 min.	HSA	Neg.		HSA	Neg.	Sterile	Bacillus, sarcina	Gaffkya S. ein., HSA (UNT)
6	68	Radical mastectomy	4 hrs.	Neg.	—	Neg.	Neg.	Neg.	Sterile	HSA (UNT)	Non-hemo. strept. bacillus

HSA = Hemolytic *Staphylococcus aureus.*
Neg. = Nonhemolytic *Staphylococcus* or no pathogenic bacteria.
BHS = Beta hemolytic *Streptococcus.*

14 months between December 1, 1959 and February 1, 1961 were included in this study. The patients were placed into four categories, being classified as having *clean, clean-contaminated, contaminated,* or *dirty,* on the basis of the type of disease present, operation performed, or inevitable or obvious contamination.

A wound was considered to be a *clean* operative wound when the procedure had been performed under aseptic circumstances without a major break in technic, and was an operation which did not transect the gastro-enteric, genito-urinary or tracheal-bronchial systems and was not performed in the vicinity of any apparent inflammatory reaction. A wound was considered *clean-contaminated* when all of these characteristics were true except that opening or transection of viscera known to contain bacteria occurred. It was classified as *contaminated* when it was the result of violence, or associated with gross spillage at time of transection of a hollow viscus, or was complicated by a major break in aseptic technic. *Dirty* wounds were those in which there was continuing contamination by fecal, tracheo-bronchial, or genito-urinary discharges, or through which drainage of purulent material was effected.

Cultures of the flora of the anterior nares of the personnel active in the operating rooms were taken every two weeks and incubated for isolation and identification of *staphylococci, streptococci,* or other pathogenic bacteria. Blood agar culture plates were placed in a uniform position as near as practical to the operative field and were permitted to receive the sedimentation of dust and bacteria for a period of one hour during each operation. These plates were cultured and the number of colonies and the type of bacteria recovered were carefully studied and analyzed.

To determine the bacterial contamination of the wound itself, cultures were taken just after the closure of the fascia

and prior to the closure of the skin. This was accomplished by the instillation of 30 cc. of sterile saline solution into the partially closed wound and the aspiration of 10 cc. of this fluid for immediate inoculation into tubes of deep meat media. Detailed identification of the organisms was subsequently done. In all wounds which became infected, careful bacteriologic characterization of the organisms present in the wound discharge was made.

Results

In this study, 1,161 specimens of the flora of the nares of the personnel, were obtained, and 1,093 showed the presence of *staphylococci or streptococci.* In the 825 plates which were exposed to the environmental air of the operating room, sedimentation of bacteria occurred with an average colony count of 8.4 colonies per plate. In some instances, during emergency operative procedures, sedimentation plates were not exposed. It was, however, possible to obtain cultures of the operative wounds in 838 patients. Bacteria were cultured in 263 of these with an average of 1.2 species per wound. It is noteworthy that the hemolytic *Staphylococcus aureus* was isolated from 23 wounds and that the beta *Streptococcus hemolyticus* was isolated from nine wounds at time of completion of the surgical procedure.

In the 14-month period prior to February 1, 1961, 817 operations were performed on patients who were classified as having *clean* operative wounds. Of these 817 patients, six developed wound infections—an incidence of 0.7 per cent. Table 1 indicates the characteristics of the patients, the type of operation performed and the bacterial data in the four parameters studied.

In the patients with infections occurring in wounds classified as *clean,* the age varied from 25 to 72 years. No two operations were of the same type and the duration of the surgical procedure varied from one hour and 20 minutes to five hours and 15 minutes. Cultures of the personnel attendant at the operations in this group indicate that in six instances representatives carried the hemolytic *Staphylococcus aureus* in their upper respiratory tract.

One infection was monomicrobic and the remaining five were polymicrobic. The hemolytic *Staphylococcus aureus* and the colon and paracolon bacilli were recovered in three each of the infected wounds.

There is a striking lack of correlation between infecting bacteria and those recovered from the nasal flora of the operating personnel or the environmental air. It is interesting to note that the bacteria recovered from the wound at the end of the operation in two instances were the same as those recovered from the subsequent wound infection.

Unfortunately, cultures were not obtained from the hands or gloves of the operating personnel or from the patients' skin or excised tissues such as gallbladder or lymph nodes.

A similar analysis was done of the 333 patients who were classified as having *clean-contaminated* operative wounds, during the same period. Seventeen of these became infected, giving an incidence of 5.1 per cent. The pertinent data are reported in Table 2.

In the group of 17 patients who had infections occurring in wounds classified as *clean-contaminated,* the ages varied from 14 to 75, and the length of the operation ranged from 30 minutes to six hours.

Fourteen of the 17 patients had operations which included resection of, or entry into, organs of the digestive system. In four of these the operation was cholecystectomy. In the remaining nine, the surgical procedure involved the colon in six instances, the esophagus in one instance, the small intestine in two, and the appendix in one.

The infections were monomicrobic in seven infected patients and polymicrobic in nine, one being reported as having a negative culture.

TABLE 2. *Epidemiologic Studies of Wound Infections, Cincinnati General Hospital. Clean-Contaminated Wounds*

No.	Age	Operation		Surgeon	1st Asst.	2nd Asst.	Scrub Nurse	Anes.	Sedimentation Plate	Wound Operative Culture	Wound Infection Culture
		Type	Duration								
1	65	Cholecystectomy; resection of fistula	1 hr. 37 min.	Neg.	Neg.		BHS	Neg.	Bacillus	Paracolon intermedium	Micrococcus, bacillus paracolon aerogenoides
2	70	Cholecystectomy; appendectomy	1 hr. 50 min.		Neg.	HSA (UNT)	Neg.	Neg.	Diphtheroid, micrococcus, Gaffkya sarcina, Neisseria, BHS, N. H. strept.	Sterile	Gaffkya, E. intermedium
3	67	Cholecystectomy; appendectomy	2 hrs. 35 min.	Neg.		Neg.	HSA (81)		Micrococcus, diphtheroid	A. aerogenes	HSA (UNT), proteus mirabilis
4	67	Exploratory laparatomy and colostomy	57 min.	HSA (UNT)	Neg.	Neg.	Neg.	Neg.	—	Not done	Paracolon coliforme BHS
5	39	Ileo-transverse colostomy	2 hrs. 35 min.	Neg.			Neg.		Bacillus	Sterile	E. Coli
6	14	Appendectomy	30 min.		Neg.	Neg.	Neg.			E. coli	E. coli
7	48	Cholecystectomy; acute cholecystitis	2 hrs.	HSA (80/81)	Neg.	Neg.	Neg.	Neg.	Bacillus, Gaffkya, sarcina, diphtheroid	N. H. strept. HSA (UNT)	Bacillus, HSA (UNT)
8	69	Anterior colon resection	4 hrs.	BHS			Neg.		Sterile	HSA (UNT)	HSA (UNT)
9	46	Anterior colon resection	2 hrs. 10 min.		Neg.	HSA (UNT) BHS	BHS		Bacillus, diphtheroid, Gaffyka, micrococcus	Sterile	Gaffkya, N. H. strept., HSA (UNT)
10	60	Anterior colon resection	1 hr. 35 min.	Neg.	Neg.	HSA (UNT)	BHS		Bacillus, micrococcus, Gaffkya, sarcina, BHS, N. H. strept.	Diphtheroid	Sarcina, Gaffkya, HSA (UNT)
11	55	Pneumonectomy	4 hrs.	Neg.	Neg.		HSA (UNT)	Neg.	Bacillus, micrococcus, N. H. strept. diphtheroid	N. H. strept.	HSA (UNT)
12	64	Resection of jejunum	3 hrs.	HSA (UNT)	Neg.		Neg.		Micrococcus	HSA (UNT)	HSA (UNT)
13	53	Radical neck dissection	5 hrs. 48 min.	HSA (UNT)	Neg.		Neg.		Micrococcus, bacillus, sarcina	HSA (80/81)	Pseudomonas aeruginosa, HSA (80/81)
14	59	Esophagectomy	6 hrs.	BHS	Neg.	Neg.	BHS	BHS	Micrococcus, Gaffkya	Micrococcus, sarcina, BHS	HSA (80/81)
15	18	Exploratory laparotomy and cecostomy	2 hrs.	Neg.	Neg.	—	Neg.		Micrococcus, bacillus	Sterile	BHS, proteus mirabilis
16	73	Leg amputation	2 hrs. 10 min.	HSA	HSA	HSA			Micrococcus	Not done	Steriie
17	75	Exploratory laparotomy and enterotomy	1 hr. 20 min.	Neg.	Neg.	Neg.			Bacillus, sarcina, Gaffkya, micrococcus	Not done	HSA (UNT)

HSA = Hemolytic *Staphylococcus aureus.*
Neg. = Nonhemolytic *staphylococcus* or no pathogenic bacteria.
BHS = Beta hemolytic *Streptococcus.*

The *Staphylococcus aureus* was found in 10 of the infected wounds, being of the bacteriophage type 80/81 in two cases, but being untypable in the remaining eight. Various types of gram negative intestinal bacilli were also noted in 10. The beta *Streptococcus hemolyticus* was found in two. The source of the 80/81 type Staphylococcal infections was not apparent since none of the operating room personnel concerned harbored this organism then. In the case of the untypable strains of *Staphylococcus aureus,* there was a suggestive correlation between the nasal flora of the surgical team and the infected wound. There was no evidence of significant bacterial infection from aerial spread as monitored by the sedimentation plates.

In six patients the operative wound culture revealed a type similar to that responsible for the subsequent wound infection. These two patients developed wound infections caused primarily by the hemolytic *Staphylococcus aureus,* bacteriophage type 80/81, which is most commonly encountered in the hospital environment and which is responsible for most of the epidemics of hospital acquired staphylococcal infections. This particular causative organism could not be found in the nasopharynx of the operating personnel or in the general sedimentation from the air of the operating room concerned with the operations on these two patients. It is particularly interesting to note that at least three of the operating personnel concerned with Case 14 were carriers of the beta *Streptococcus hemolyticus* in their nasopharynx, and that the wound operative culture at the completion of the operation showed the presence of this same organism. The subsequent infection which developed, however, was not caused by *Streptococcus hemolyticus,* but by completely different organism. This suggests the possibility that the bacteria reached the patient's wound by the hematogenous route.

In Cases 15, 16 and 17, the available information is so inadequate that no speculation can be made concerning the sources of the infecting organism.

Summary

Wound infections occurring in clean operative wounds may result from contamination by bacteria in several ways. These include direct contact from exogenous sources, direct contact from endogenous sources, sedimentation from environmental air or from endogenous bacteremic sources.

In this study, the comparison of the sources and mechanisms resulting in infection of the *clean* operative wounds with the same factors relating to *clean-contaminated* operative wounds strongly suggests that contamination by direct contact is responsible for the majority of these infections.

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