The Environmental Distribution of Staphylococcus Aureus in an Operating Suite *

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AS THE KNOWLEDGE of bacteriologic principles and pathogenesis of infection has become known, surgical technics have been improved and operating rooms have been designed to reduce the contamination of surgical wounds with infectious agents. During the past 15 years antibiotics have been widely employed as prophylactic agents in an attempt to prevent the occurrence of postoperative surgical infections. However, the incidence of infections has not been decreased appreciably, and the most common micro-organism encountered is *Staphylococcus aureus* which is resistant to the antibiotics usually employed. Altemeier [1] has discussed a number of serious problems which have been created by the indiscriminate use of antibiotics.

The early developmental history of modern surgery reveals little data applicable to the incidence of postoperative infections. Colebrook [8] elaborating on Monyihan's observations stated that in 1888 two-thirds of the patients died after opening the peritoneum and infection was probably one of the common causes of death during this period. Brewer [7] reported that when he joined the staff of the Roosevelt Hospital in 1895, approximately 40 per cent of clean operations were followed by septic infections. This figure was reduced to 9 per cent one year later after many changes to improve aseptic technics were made.

Aseptic methods gradually evolved and brought about a concurrent decrease in the incidence of postoperative infections. In 1913, Beckman [3] reviewed 6,825 operations and reported that infections occurred in 117 patients, an incidence of 1.7 per cent, which is as low as that usually reported in the present era. Ninety-six per cent of the positive bacteriological cultures from the patient's wounds contained staphylococci.

Other investigators in the period prior to the antibiotic era disclosed a higher incidence of infections. Brewer [7] in 1912 found that 2.4 per cent of clean surgical cases became infected and with elimination of the possible sources of infection, this figure was reduced to 1.2 per cent. The importance of aseptic technics was well studied in 1925 by Meleney,[25, 26] who reported that 15 per cent of clean wounds became infected. The most common etiologic agent in his study was the hemolytic streptococcus, which could not be isolated from any of the fomites in the operating rooms, but was found in the throat cultures of 33 per cent of the staff. The use of the agglutinin absorption technic revealed that one person was carrying the strain of streptococcus responsible for infections. Later in 1933, Meleney [24] reported that serious wound infections were reduced from 4 per cent to

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1.7 per cent and trivial infections from 10 per cent to 5.4 per cent in a seven-year period at the Presbyterian Hospital in New York by improving aseptic technic. Ives and Hirshfeld [20] in 1938 thought that 5 per cent of all clean wounds became infected. A striking reduction of infection from 15.5 per cent to 1.1 per cent was attributed by McKissock *et al.*,[23] in 1941 to the introduction of improved surgical technics, including procedures for the dressing of surgical wounds.

The incidence of wound infections in the present antibiotic era has increased appreciably at times in some institutions. Sevitt [30] in 1953 reported a case of gas gangrene developing in a postoperative wound due to the introduction of *Cl. welchii* into the operative suites by a faulty ventilation system. Blowers *et al.*[5] reported in 1955 that the infection of wounds with penicillin resistant staphylococci became so frequent in a thoracic surgery suite that it was necessary to close the unit for a time. The high rate of infection was attributed to lack of isolation facilities for infected patients, the use of unsterilized blankets, inefficient ventilation and excessive activity of the staff during operations. The correction of faulty procedures was followed by a reduction in the rate of infection from 11 per cent to 4 per cent and the carrier rate of *Staphylococcus aureus* among patients and staff fell from 74 per cent to 37 per cent.

Howe,[17, 18] in his reports of 1954 and 1956, presented data to show that the incidence of infection of clean wounds after operations at the Massachusetts Memorial Hospital gradually increased over a five-year period despite the prophylactic use of antibiotics. The analysis of the hospital carrier rate and the bacterial flora of infected wounds suggested that the increase in postoperative sepsis was due to the high carrier rate of the penicillin resistant staphylococci in hospital personnel and patients as a result of the widespread use of penicillin. The application of rigid aseptic technics in the operating suites and on the surgical floors reduced the carrier rate of staphylococci in personnel from 99 per cent to 75 per cent and the incidence of penicillin resistant strains of staphylococci from 78.5 per cent in 1953 to 62.7 per cent in 1955. It would have been interesting to note the reduction in carrier rate of the strains which caused the majority of infections. The incidence of major wound infections in Howe's series was reduced from 2.85 per cent in 1953 to 1.54 per cent in 1955. Emphasis was placed on the prevention of postoperative sepsis by meticulous management of wounds, the elimination of cross contamination from patient to personnel and thereby to other patients. Well established aseptic surgical technics were believed to be more important than prophylactic antimicrobial therapy.

The importance of careful aseptic surgical technic is well illustrated by the recent report of Sompolinsky *et al.*,[32] who described a postoperative infection rate of 36 per cent of patients in January 1954. The majority of the physicians and nurses were carriers of *Staphylococcus aureus;* however, only two were carriers of the infecting strain which was bacteriophage type 6/47/53/77. Careful aseptic technic was then instituted and only two infections occurred in the next two years, even though the carriers of the infecting strain remained in the operative suite.

The mode of entry of micro-organisms into clean surgical wounds is unknown. Most wounds are not sterile at the time of surgical closure as was shown by Hunt,[19] who cultured 28 abdominal wounds during surgical operations and found 25 to contain bacteria. Dandy [9] maintained that most wound infections resulted from contamination by gauze sponges and claimed that infections did not occur following prolongation of the sterilizing process. Blowers

et al.[5] in 1955 believed blankets to be an important reservoir of pathogenic organisms.

Since one reservoir of pathogenic staphylococci is considered to be the nose, a profitable approach to the problem of contamination of surgical wounds might be a consideration of human carriers. Miles *et al.*[27] reported that 47 per cent of outpatients carried staphylococci in the nose and 18 per cent carried the organism on their hands. Barber *et al.*[2] showed that the carrier rate of penicillin resistant staphylococci among hospital personnel was 75 per cent, whereas no penicillin resistant strains were obtained from people working outside of hospitals. It was demonstrated by Lepper and his co-workers [22] that members of a hospital staff soon acquired strains of staphylococci which were resistant to an antibiotic after the agent was used in a hospital. Similar studies have been reported by Knight,[21] Rountree,[28, 29] and Wise *et al.*[33] It is probable that the antibiotic resistant strains are selected during antibiotic therapy and are harbored by hospital personnel who spread the bacteria to susceptible patients.

Numerous investigations of the air of operating rooms have been conducted to determine the types and quantity of bacteria present. Many of these investigations were conducted prior to the development of procedures for bacteriophage typing; and, therefore, no conclusive statements could be made regarding the relationship of strains obtained from the air and those isolated from infected wounds. The reports of Hart [15, 16] in 1938 showed that the number of bacteria in the air of a room increases directly with the number of occupants. Duquid and Wallace [11] in 1948 studied the spread of staphylococci from the clothes of human carriers and determined that from 1,000 to 10,000 staphylococci are liberated per minute into the air from the clothes by different degrees of activity. Gould and Allan,[14] however, in 1954 could not relate the staphylococci found in the air of wards and operating rooms to those causing surgical infections because of difference in bacteriophage types. Conversely, Shooter *et al.*[31] in 1956 found that a reduction in the incidence of wound infections occurred by increasing the air pressure in operating rooms and thereby reversing the direction of flow. Girdlestone and Bourdillon [12] found that activity associated with entry of patients into the operating room provoked liberation of large numbers of airborne bacteria with counts up to 100 bacteria per cubic foot. They suggested that the bacterial counts should not exceed ten per cubic foot when tissues of normal resistance to infection were exposed and two per cubic foot when burned tissue, brain, or other highly susceptible tissues were involved.

The bacteriology of surgical gloves was investigated by Devenish and Miles [10] in 1939, who found that 24 per cent of gloves were punctured or torn during surgical operations and postulated that infection occurred due to the leakage of bacteria into the wounds. A similar figure was reported by Girdlestone and Bourdillon,[12] but they reported that the strains of staphylococci isolated from the purulent material of patients were never of the same phage type as those grown from the hands of the surgeons or their assistants.

In July 1956, in cooperation with the members of the Surgical Service at The Jefferson Medical College Hospital, a study was performed in an attempt to determine the presence and extent of contamination by staphylococci in the operating rooms and to detect the source and mode of entry of the pathogenic bacteria into clean surgical wounds.

Method of Investigation

All material for bacteriologic investigation was collected during 71 operative procedures in the operating rooms of The Jef-

TABLE 1. *Type and Number of Specimens Obtained for Bacteriologic Study*

Nose cultures		206
Residents	18	
Nurses	44	
Interns	17	
Students	12	
Staff	33	
Patients	71	
Miscellaneous	11	
Surgical gloves		481
Skin biopsy		64
Instrument water		47
Wound water		54
Talcum powder		44
Sterile packs		11
Air cultures		149
Hall vents	14	
Table	69	
Window ledge	66	
Tubes and drains		6
Rubber band		1
Procaine solutions		11
Skin graft		1
Scrub brushes		8
Antiseptic detergent		10
Postoperative infections		3
Total Specimens		1096

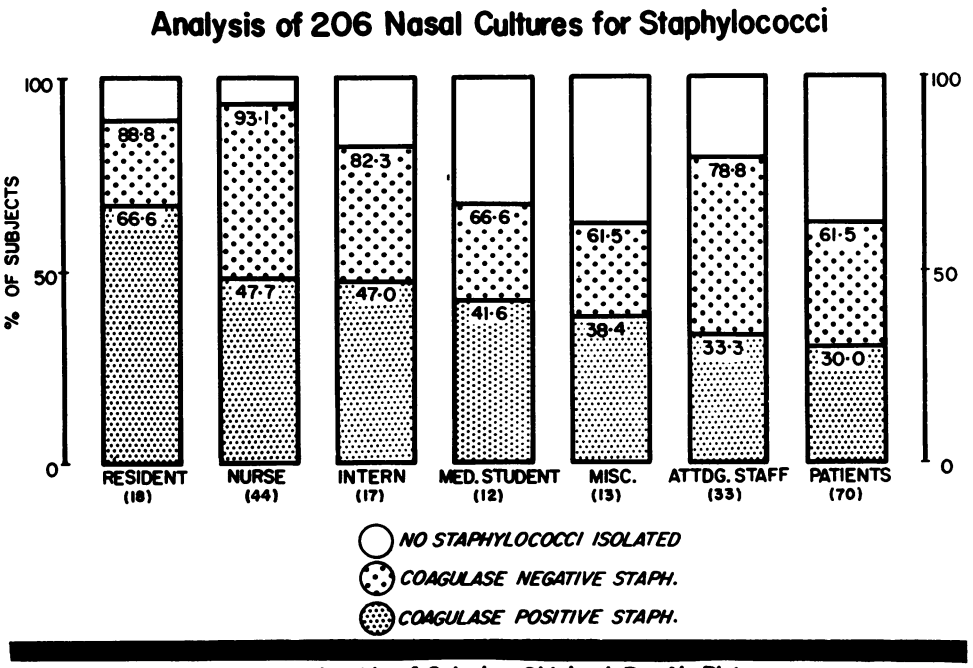
ferson Medical College Hospital from August 13 to August 17, 1956, inclusive. The majority of the surgical procedures were performed on private or semi-private patients. A variety of material was studied in order to detect the possible sources of contamination of the patients during the procedures. A moderator was assigned to each procedure to obtain uniformity in the collection of the specimens.

A swab which was moistened with nutrient broth was introduced into the anterior nares of every person entering the area. All nasal swabs were immediately inoculated to 5 per cent horse blood agar and trypticase soy broth. All surgical gloves were carefully removed from the hands without inversion, and 1 ml. of trypticase soy broth was introduced into each glove. Following complete mixing, 0.1 ml. of the broth was inoculated into a Petri plate which then received trypticase soy agar for quantitative determination of the number of bacteria present. At some time during the operative procedure, a small portion of skin was obtained from the edge of the surgical incision. This was ground with sterile sand in a sterile mortar and cultures were obtained. Five ml. of water, which was used for rinsing instruments during the operative procedure, was obtained for bacteriologic analysis. Prior to closure of the skin the open wound was irrigated with sterile saline solution and 5 ml. were obtained for culture. The paper indicators from surgical packs, as well as tubes, drains, talcum powder and other materials used during operations, were collected in an aseptic manner for study. Sterile blood agar plates remained open near the operative sites, at other parts of the rooms, and near the outlets of air conditioning vents. The clinical courses of all patients were followed and cultures were obtained from all infections that developed during the postoperative period.

All cultures were tested for pathogenicity as indicated by the coagulase technic. Only coagulase positive strains are typeable with the bacteriophages which are presently employed. Each coagulase positive strain was typed with the bacteriophage technic, utilizing 25 different strains of bacteriophage as described by Blair and Carr.[4]

Results

A total of 1,096 cultures were obtained in five days. Table 1 lists the types of material and the number of specimens which were studied. There were 206 nasal cultures. These were divided into seven groups depending upon the nature of hospital duties as seen in Figure 1. The resident group of 18 subjects, who had close contact with infections because they frequently changed dressings of patients with infected wounds, had the highest percentage of positive cultures (67%) for coagulase positive staphylococci. The operating room nurses num-



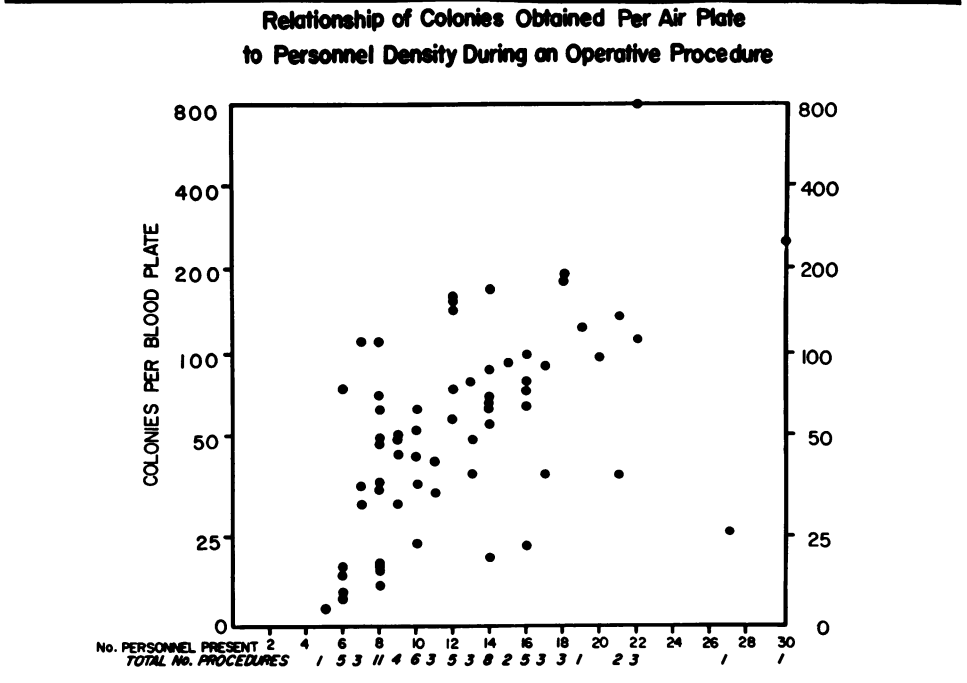


FIGURE 1 (upper)
FIGURE 2 (lower)

bered 44, and 48 per cent of the group harbored coagulase positive staphylococci in their nares. This group had contact with contaminated materials only as was necessary in the operating rooms while assisting at surgery and disposing of sponges, instruments, sheets, etc.

There were 17 interns studied, of which

47 per cent had cultures yielding coagulase positive staphylococci. This group began their internship six weeks prior to the study and had not had as long a contact with infected patients as had most of the resident staff. The medical students were Junior and Senior students who had very little direct contact with infected patients. They had coagulase positive staphylococci in 41 per cent of cases. The miscellaneous group was composed of orderlies, maids, and one clergyman who had limited contact. Coagulase positive staphylococci were carried by 38 per cent of these individuals. It was interesting that the members of the attending surgical staff had a carrier rate of 33 per cent and the patients 30 per cent. The incidence of nasal carriers of coagulase positive staphylococci appeared to be proportional to the degree of contact with infected materials.

It is well known that a large percentage of a hospital staff carry strains of coagulase positive staphylococci in their upper respiratory tracts. Very little attention has been given to the carrier rate of the strains actually incriminated in postoperative infections. As a corollary to this study, cultures were obtained from 16 postoperative infections which occurred at Jefferson Hospital from June 1 to October 31, 1956. This did not include the patients involved in the operating room study. As can be seen in Table 2, eight (50%) of the infections were caused by bacteriophage 52/42B/81/44A, four by type 44A, two by 77/44A and one each by 75/77/42B/VA4 and 79/44A. The percentage of carriage of these types of strains by 136 members of the personnel was 6, 4, 1, 1 and 1 respectively. Approximately 13 per cent of the personnel who entered the operating rooms during the period from August 13, to August 17, 1956, were carrying strains which were known to cause wound infections occurring during the five month period, June 1 to October 31, 1956.

TABLE 2. *The Incidence of Bacteriophage Types of Staphylococci Causing Postoperative Infections and Their Carriage by Hospital Personnel*

Strains Isolated from Postoperative Wound Infections (6/1/56 to 10/31/56)	Sixteen Surgical Infections		Carriers Among 136 Persons	
	No.	Percentage	No.	Percentage
52/42B/81/44A	8	50	8	6
44A	4	25	5	4
77/44A	2	12	2	1
75/77/42B/VA4	1	6	1	1
79/44A	1	6	1	1
			17	13

TABLE 3. *Bacteriologic Analysis of Surgical Gloves*

	No.	Percentage
Total number of gloves	481	
Punctured or torn	50	10
Sterile cultures	11	2
Staphylococci cultured:	433	90
Coagulase negative	370	77
Coagulase positive	68	14
Bacteriophage typeable	0	—
Maximum colonies per glove	180,000	
Minimum colonies per glove	0	
Mean colony count per glove	4,212	

A total of 481 surgical gloves were examined. As can be seen in Table 3, only 2 per cent were sterile. The maximum and minimum numbers of bacteria isolated from gloves were 180,000 and 0 respectively and the mean bacterial count was 4,212. Staphylococci were isolated from 90 per cent; however, 14 per cent of the gloves contained pathogenic staphylococci which were indicated by the coagulase test. None of the coagulase positive staphylococci which were isolated from gloves were typeable with bacteriophages. The incidence of torn or punctured gloves was 10 per cent, which is less than has been reported in other studies.[10, 11] Other bacteria isolated were sarcina, diphtheroids, yeasts and gram negative bacilli.

The preparation of the patient's skin was similar in all cases and consisted of the application and scrubbing with tincture of benzalkonium chloride in a dilution of 1 : 1000. This was allowed to dry and was followed by surgical draping. Unfortunately, the skin from the edge of the incision was not obtained at the beginning of every surgical procedure, but in some cases was obtained just before closure of the wound and in others sometime during the procedure. The bacteriologic results are shown in Table 4. Only 8 per cent of the 64 samples of skin were sterile. Staphylococci were present in 53 per cent of skin samples. Coagulase negative staphylococci were present in 42 per cent and coagulase positive staphylococci in 11 per cent. Only one culture of staphylococcus was typeable with bacteriophage. It was bacteriophage type 7/54.

The rinse water used for cleansing surgical instruments was studied at the conclusion of 47 surgical procedures. As seen in Table 5, 36 per cent were sterile. Staphylococci were present in 43 per cent with coagulase positive and coagulase negative cultures observed in 8 per cent and 34 per cent of the cases respectively. Bacterial counts ranged from 0 to 2,000 bacteria per ml. with a mean bacterial count of 1,009 per ml. None of the staphylococci isolated from rinse water was typeable with bacteriophages.

The water used for rinsing wounds prior to closure was sterile in 20 per cent of 54 patients as seen in Table 6. Staphylococci were present in 59 per cent of wounds. Coagulase positive staphylococci were isolated in 17 per cent. Only one culture was obtained which was typeable with bacteriophage. It was bacteriophage type 79. The degree of contamination of the wounds was quite variable; the bacterial count of the wound rinse water varied from 0 to 11,400 bacteria per ml. The mean bacterial count was 655 per ml.

Results of the cultures of talcum powder used in 44 operative procedures are shown in Table 7. Approximately 80 per cent were sterile. The degree of contamination was relatively small since the maximum bacterial count per gram of powder was 20 and the mean bacterial count was 6 per gram of powder. Staphylococci were the predominating bacteria present and were isolated from 13 per cent of the samples. Coagulase positive staphylococci were present in 7 per cent of the samples and none of the cultures were typeable.

The paper indicators from the center of 11 linen packs were sterile in eight instances or 73 per cent, as indicated in Table 8. Coagulase positive staphylococci, Pseudomonas and a gram negative bacillus were isolated from separate packs. The material for more than one operative procedure was often obtained from a single pack. This may have increased the opportunity

TABLE 4. *Bacteriologic Analysis of Skin Obtained During Sixty-Four Surgical Procedures*

	No.	Percentage
Total samples studied	64	
Sterile	5	8
Staphylococci:	34	53
Coagulase negative	27	42
Coagulase positive	7	11
Bacteriophage typeable	1	2

TABLE 5. *Bacteriology of Samples of Water Used for Rinsing Instruments During Forty-Seven Operations*

	No.	Percentage
Total specimens	47	
Sterile	17	36
Staphylococci:	20	43
Coagulase negative	16	34
Coagulase positive	4	8
Bacteriophage typeable	0	—
Maximum bacterial count per ml.	2,000	
Minimum bacterial count per ml.	0	
Mean bacterial count per ml.	1,009	

for cross contamination. Not all of the packs contained indicators.

All rubber tubes, drains, medicated soap and scrub brushes, as indicated in Table 9, which were tested, were found to be sterile. Eleven samples of procaine hydrochloride were examined and only one contained a coagulase negative staphylococcus. In most instances the solutions of procaine used in the operating rooms were placed in open containers and samples for bacteriologic study were obtained at the conclusion of the surgical procedures. There was possibility of contamination of this material from the air during the time of exposure. A rubber band from an instrument table was obtained during a surgical procedure on a patient with preoperative infection and yielded coagulase positive staphylococci of the same bacteriophage type as obtained from the nose and preoperative infected site of the patient. The band had not been in contact with the patient but was handled by the suture nurse.

Open culture plates were placed as close to the operative field as was technically possible during 69 procedures. In many instances the agar plates were touched by instruments and the surgeons' gloves. Table 10 shows that 43 per cent of the cultures contained staphylococci. Coagulase positive staphylococci were isolated from the air during 10 per cent of the operative procedures. The remainder of the cultures revealed sarcina, yeasts and gram negative bacilli. Culture plates were allowed to stand open in other parts of the room and were subject to varying degrees of contamination from the air as seen in Table 11. Staphylococci predominated and were isolated from 41 per cent of 66 culture plates; however, coagulase positive staphylococci were found during 14 per cent of the operations. The number of bacteria which fell on Petri plates during the time of operations varied from three to 800 colonies. The mean count per air plate was 77 colonies. Blood agar plates were suspended under air conditioning vents in a manner which allowed the air to flow directly on to the agar medium. They revealed strains of staphylococci of which 50 per cent were coagulase positive. In no instance were strains of staphylococci, isolated from the air, susceptible to bacteriophage. Consequently, all were nontypeable.

Figure 2 represents a scattergram which correlates the bacteria in the air of the operating rooms with the number of people present during the operative procedure. The time required for the operations was an important factor but was not recorded. The smallest number of people present during one procedure was five and the maximum number was 30. It can be seen that

TABLE 6. *Analysis of Bacteriology of Fifty-Four Surgical Wounds Prior to Closure*

	No.	Percentage
Total specimens	54	
Sterile	11	20
Staphylococci	32	59
Coagulase positive	9	17
Bacteriophage typeable	1	2
Maximum bacterial count per ml. of rinse water*	11,400	
Minimum bacterial count per ml. of rinse water	0	
Mean bacterial count per ml. of rinse water	655	

* Approximately 5.0 ml. of sterile water was used in rinse.

TABLE 7. *Analysis of Cultures of Forty-Four Samples of Talcum Powder*

	No.	Percentage
Total specimens	44	
Sterile	35	79
Staphylococci:	6	13
Coagulase positive	3	7
Bacteriophage typeable	0	—
Maximum bacterial count per Gm.	20	
Minimum bacterial count per Gm.	0	
Mean bacterial count per Gm.	6	

as the number of people increased in an operating room there was an increase in the number of bacteria in the air.

It was hoped that it would be possible to determine the source and mode of entry of staphylococci into the wounds by bacteriophage typing of the cultures obtained from postoperative infections during the time of the survey. Three (4 per cent) of the 71 patients developed infections during the postoperative period. Staphylococci were isolated from all three patients. One consisted of a superficial infection of a skin graft caused by a staphylococcus of bacteriophage type 79. The other two patients had infections of deep surgical wounds of the abdomen. Unfortunately for the purpose of this investigation, the infections of the two deep surgical wounds were caused by non-typeable strains of staphylococci.

Case 24 consisted of the application of skin grafts to the legs. The grafted areas developed a purulent infection from which was isolated *Staphylococcus aureus,* bacteriophage type 79. The cultures obtained during the operation revealed the following results:

Cultures	*Bacteriophage Type*
Nose cultures:	
Patient	47/53/54/75/77
Surgeon	42B/44A
Assistant surgeon	7
Assistant surgeon	53/77/VA4
Scrub nurse	No staphylococci
Anesthetist	47/54/75/77
Supernumeraries (4)	
(2)	Non-typeable
(1)	No staphylococci
(1)	52/42B/81/44A
Gloves	Non-typeable
Donor skin	Non-typeable
Air plates	Non-typeable
Linen pack indicator	Sterile
Soap	Sterile
Brushes	Sterile

It can be seen that at least six different types of staphylococci were present in the noses of eight people. One supernumerary was carrying type 52/42B/81/44A which was known to be causing 50 per cent of the postoperative infections during the five month period, July 1 to October 31, 1956. Type 79, which was isolated from the postoperative infection, was not isolated from any source in the operating room during the operative procedure. Since the infection was superficial, it is probable that infection occurred outside of the operating room in this patient.

TABLE 8. *Analysis of Cultures from Eleven Surgical Packs*

	No.	Percentage
Total specimens	11	
Sterile	8	73
Coagulase positive staphylococci	1	9
Pseudomonas	1	9
Gram negative bacilli	1	9

The other two patients had deep wound infections. As stated above, in both instances the strains were nontypeable with bacteriophage. Both patients underwent a laparotomy. Case 17 illustrates the difficulty of analysis of bacteriological results in these two patients:

Cultures	*Bacteriophage Type*
Nose cultures:	
Surgeon	Non-typeable
1st assistant	3A/54
2nd assistant	53/77/VA4
Suture nurse	Non-typeable
Anesthetist	No staphylococci
Anesthetist	47/54/75/77
Supernumeraries (8)	
(5)	No staphylococci
(1)	Non-typeable
(1)	55/53/54
(1)	77/VA4
Air plates	Non-typeable
Skin biopsy	Sterile
Drains	Sterile
Talcum powder	Sterile
Instrument water	Sterile
Wound rinse	Non-typeable
Soap	Sterile
Brushes	Sterile
Linen packs	Sterile

In this case the infection of the patient was caused by a nontypeable coagulase positive staphylococcus. At least six different types of staphylococci were present in the operating room. During the procedure four gloves were punctured, of which one contained a nontypeable coagulase positive staphylococcus. Cultures of non-typeable staphylococci, which may or may not have been the same strain causing infection, were isolated from the nose of the surgeon, suture nurse, one supernumerary, the gloves, air plates, and the irrigating solutions from the wound just prior to closure. It is possible that the source of infection was in the operating room, but because of the resistance of the cultures to lysis by bacteriophage, it was impossible to determine the source of the strain or mode of entry.

Discussion

In this investigation there were no attempts to study factors on the ward which may have contributed to infection. It was our opinion that antibiotic resistant pathogenic staphylococci were acquired by hospital personnel during their contacts with purulent materials from infections of the patients. The bacteria may be carried to the operating room and gain access in some manner to the wounds where infection occurs in susceptible patients. By identification of all strains of staphylococci from all possible sources in the operating rooms, it would appear possible to trace the strain from a source to the infected wound. This objective was not accomplished in this investigation because only two patients developed infections of deep wounds and in both instances the etiologic strain of staphylococcus was resistant to lysis by bacteriophage. It was possible that these infections originated in the operating room.

TABLE 9. *Analysis of Miscellaneous Cultures*

	Total	Sterile	Coag. Pos.	Coag. Neg.
Tubes and drains	6	6		
Procaine	11	10		1
Scrub brushes	8	8		
Medicated soap	10	10		
Rubber band	1		1	
Donor skin	1			1

TABLE 10. *Analysis of Sixty-Nine Air Plates Near the Operative Field*

	No.	Percentage
Total samples	69	
Sterile	1	1
Staphylococci:	30	43
Coagulase positive	7	10
Bacteriophage typeable	0	—
Maximum colony count per plate	900	
Minimum colony count per plate	0	
Mean colony count per plate	53	

It was learned that the staphylococci were present and abundant in several different areas. Staphylococci were isolated from 86 per cent of members of the hospital personnel. Coagulase positive cultures were found in 47 per cent; however, strains which were known to cause infections were isolated from the anterior nares of approximately 13 per cent of the personnel. The strains isolated from the interior of surgical gloves were different than those obtained from cultures of anterior nares in that a high percentage of the latter were susceptible to bacteriophage and none of the former were susceptible. This would indicate that staphylococci deposited on the hands by nasal secretions are markedly reduced in number by scrubbing with soap and the bacteria present in the gloves represent different strains which were harbored in the deep structures of the skin and gained access to the surface during the surgical procedures. The pathogenicity of the staphylococci from the gloves is not known and is the subject of further study. It is interesting that gloves were punctured during operations on the three patients who developed infections.

Though bacteria, particularly staphylo-

TABLE 11. *Analysis of Bacteria in Air Near Walls of Operating Rooms During Sixty-Six Surgical Procedures*

	No.	Percentage
Total samples	66	
Sterile	0	—
Staphylococci:	27	41
Coagulase positive	9	14
Bacteriophage typeable	0	—
Maximum colony count per plate	800	
Minimum colony count per plate	3	
Mean colony count per plate	77	

cocci, were isolated from 80 per cent of wounds during the surgical procedures, they caused no infection in 68 of the 71 patients and in the three infected patients there was no proof of their significance. The lack of proof may have been due to the inadequacy of the laboratory methods.

Staphylococci were present in the air of the operating room and the frequency with which they were isolated was proportional to the number of people in the area. This source may have been significant in their isolation from 7 per cent of samples of talcum powder, one sample of procaine and many of the strains isolated from open wounds. Finding bacteria in 27 per cent of surgical packs indicated inefficiency in the sterilization process. None of the strains isolated from the packs was definitely incriminated in the infectious process.

These results indicate that many sources of staphylococci exist in operating rooms and rigid aseptic technique in all phases of operative procedure should be stringently enforced in an attempt to prevent their entry into surgical wounds.

Conclusions

1. An attempt was made to determine the presence and number of staphylococci present in various areas of operating rooms during 71 operations. A total of 1,096 bacteriologic cultures were obtained. Two of the patients developed postoperative infections of deep wounds.

2. The incidence of coagulase positive cultures of staphylococci isolated from the anterior nares of all persons entering the operating rooms was greater in those members of the hospital staff who had close contact with infected patients.

3. The presence of many different bacteriophage types of *Staphylococcus* was detected in the anterior nares of the 136 members of the hospital personnel who entered the operating rooms during the period of five days from August 13 to August 17, 1956. Five of these types of *Staphylococcus* were known to cause postoperative wound infections which occurred during the period from July 1 to October 31, 1956, and were isolated from 13 per cent of the personnel. Other strains were isolated which were not implicated in any infection during the period of five months.

4. Staphylococci were isolated from the interior of 90 per cent of 481 surgical gloves at the conclusion of the surgical procedures. The mean bacterial count was 4,212 per glove. Coagulase positive staphylococci were isolated from 14 per cent of the gloves, but none of the strains from gloves was susceptible to bacteriophage. Approximately 10 per cent of the surgical gloves were punctured or torn during surgery.

5. Coagulase positive staphylococci were isolated from 11 per cent of samples of skin obtained from the edge of incisions, 8 per cent of samples of solution used in rinsing instruments during surgery, and from 17 per cent of surgical incisions which were cultured just prior to closure. These strains, with two exceptions, were not typeable with bacteriophage.

6. Various fomites such as talcum powder, rubber drains, tubes, soaps, brushes and surgical packs were found to have a low incidence of viable bacteria.

7. The air of the operating rooms contained a predominance of staphylococci

mixed with other bacteria. The contamination of the air became greater as the number of people in the room increased. None of the cultures of coagulase positive staphylococci obtained from the air was typeable with bacteriophage.

8. Two of the 71 patients developed infections of deep surgical wounds. In both instances coagulase positive staphylococci were isolated from the infectious processes, but the cultures were not typeable with bacteriophages. It was not possible, therefore, to trace the source of infections in this study.

9. The need for rigid aseptic techniques to prevent the acquisition of carrier states with pathogenic staphylococci by members of hospital personnel and the spread of these bacteria to susceptible hosts is emphasized. It appears reasonable that the use of prophylactic antibiotics cannot be substituted for careful technic, since the strains causing the infections are usually resistant to the action of the commonly used antibiotics.

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