NOSOCOMIAL INFECTIONS

MILTON B. ROSENBLATT
Attending Physician

FRANK ZIZZA
Clinical Pathologist

IRENE BECK
Record Room Librarian

Doctor's Hospital
New York, N. Y.

THE emergence of antibiotic-resistant strains of staphylococci and Gram-negative bacilli has resulted in significant morbidity in hospitalized patients. During the past decade a multitude of measures has been implemented for the prevention, control, and surveillance of hospital-acquired infection, but the hazard has not been eliminated. The nature of the hospital environment and the exposure and susceptibility of patients to cross infection are factors that constantly predispose to the development of nosocomial disease. There is little likelihood that the problem will diminish in the near future because of the increasing age of the hospital population, the increased prevalence of chronic debilitating diseases, and the expansion of interest in complex surgical techniques and ancillary procedures that provide avenues of infection.

A considerable literature[1-10] has accumulated in recent years dealing with particular aspects of hospital-acquired infections, but relatively few studies[11, 12] have been reported that depict the over-all occurrence of these complications in a general hospital. The problem of nosocomial infection has been intensively studied at Doctors Hospital in New York City, and an anti-infection program has been in effect since 1958. A manual of regulations was prepared, to advise all departments of their respective responsibilities, and specific instructions on aseptic techniques were promulgated. In general the basic procedures designed to prevent cross infection included: 1) effective cleansing of all areas of the hospital, 2) transfer of staphylococcal carriers from nurseries and operating rooms, 3) isolation of infected patients, and 4) ancillary measures

Individual Patient Reporting Form

INFECTION REPORT

1. Does patient have any infection? Yes ( ) No ( )
2. Did infection develop after admission? Yes ( ) No ( )

Date infection developed_____

A. Type of infection:

Respiratory Postoperative wound Urinary
Gastrointestinal Blood Eye Skin
Other_____

B. Predominant organism (s)_____

C. Discharge diagnosis:

D. Discharge date:

Form 532

involving disposal of laundry, dishwashing, personnel contact, and preparation of rooms after discharge of infected patients.

Many early regulations, particularly those involving personnel who are carriers, have been revised or eliminated, and the program has been made steadily more practicable. Our current system of surveillance has been in effect since the latter part of 1965. It was thought that the results would be of general interest inasmuch as nosocomial disease is a constant source of anxiety in all hospitals.

Method of Surveillance

In the early years of the program the chief sources of data concerning infection were the routine monthly institutional bacteriologic cultures and those obtained from patients and personnel. The scope of the studies among patients was therefore limited by the extent of the material submitted to the laboratory. The next step in the establishment of the surveillance program was the appointment of an infection control officer, whose duties included daily visits to each floor of the hospital to record the instances of nosocomial infection. This measure resulted in an increased yield of reported cases but did not consistently reflect the extent of infection in the hospital when checked against culture

data from the bacteriology department. It was then decided to include in each clinical chart a special infection sheet (see form on page 11) to be completed by the attending physician at the time of the patient's discharge. Cooperation of the attending staff was assured by the device of considering charts as incomplete until the infection sheets contained all the appropriate data.

The items tabulated for each nosocomial case were recorded in an infection book in which the patients were listed according to floor occupied in the hospital. The data were processed daily as each patient was discharged, and monthly summaries were prepared by the chief librarian and reviewed by the committee on infections.* Comparison of the infection sheets with the monthly culture reports from the bacteriology department provided a check against the possible omission of data.

Evaluation of the extent of infection in the hospital on a current basis was made available by daily reports from the nurse in charge of each floor to the nursing supervisor. These reports listed both new and old cases of infection and provided a continuous summary of the prevalence of infection throughout the hospital. The cooperation of the clinical pathologist in promptly alerting the nurses in charge to the positive findings in material submitted for culture added greatly to the accuracy of the daily reports.

Results

Doctors Hospital is a general hospital with accommodations for approximately 240 patients in private rooms and 30 in semiprivate rooms; there are no wards. The average annual number of patients treated exceeds 9,000, of whom more than 4,000 are surgical. The present survey included a total of 18,357 patients discharged between January 1, 1966, and December 31, 1967.

The total number of nosocomial infections in the two-year period was 343, of which 306 (89.2 per cent) occurred in postoperative wounds, the urinary tract, or the respiratory tract. In 37 instances (10.8 per cent) the infections involved the gastrointestinal tract, uterus, eye, or skin. The total incidence of nosocomial infections was 1.9 per cent. The total number of operations was 8,649, and the incidence of wound infections was 1.3 per cent.

*The committee includes one representative from each hospital division: administration, laboratories, nursing department, and operating room.

TABLE I. INCIDENCE AND DISTRIBUTION OF NOSOCOMIAL INFECTIONS: 1966

Month	Patients discharged	Types of Infections								Number of operations	Incidence of wound infections
		Resp.	Urinary	G.I.	Gyn.	Eye	Skin	P.O. Wound	Total		
Jan.	751	1	4	0	0	0	0	6	11 (1.5%)	325	1.8%
Feb.	734	2	6	0	1	0	0	3	12 (1.6%)	361	0.9%
Mar.	897	3	4	1	2	0	2	5	17 (1.9%)	395	1.3%
April	860	5	3	0	1	0	1	7	17 (2.0%)	377	2.7%
May	914	5	8	0	0	0	0	9	22 (2.4%)	401	1.4%
June	849	6	4	1	1	1	1	5	19 (2.2%)	414	1.2%
July	786	1	3	1	1	0	1	5	12 (1.5%)	346	1.4%
Aug.	660	2	5	0	0	0	0	5	12 (1.8%)	309	1.6%
Sept.	678	4	4	2	1	2	0	3	16 (2.4%)	311	1.0%
Oct.	765	2	6	2	0	1	0	7	18 (2.3%)	374	1.9%
Nov.	809	1	7	0	0	0	0	5	13 (1.6%)	356	1.4%
Dec.	797	8	4	0	2	1	0	3	18 (2.3%)	372	0.8%
Total	9,500	40	58	7	9	5	5	63	187 (2.0%)	4,341	1.4%

TABLE II. INCIDENCE AND DISTRIBUTION OF NOSOCOMIAL INFECTIONS: 1967

Month	Patients discharged	Types of infections								Number of operations	Incidence of wound infections
		Resp.	Urinary	G.I.	Gyn.	Eye	Skin	P.O. wound	Total		
Jan.	709	1	5	0	1	0	1	3	11 (1.4%)	393	0.80%
Feb.	679	1	4	1	0	0	0	9	15 (2.2%)	338	2.60%
Mar.	810	5	2	0	0	0	1	4	12 (1.5%)	432	0.90%
April	799	4	3	0	0	0	0	5	12 (1.5%)	372	1.30%
May	764	8	6	0	0	1	5	7	27 (3.5%)	392	1.80%
June	820	3	1	0	0	0	2	5	11 (1.3%)	386	1.30%
July	745	0	6	0	0	1	2	3	12 (1.6%)	329	0.91%
Aug.	646	5	3	0	0	0	1	0	9 (1.5%)	303	0
Sept.	626	3	1	0	0	0	0	1	5 (0.8%)	309	0.32%
Oct.	734	1	3	0	1	0	1	5	11 (1.5%)	370	1.30%
Nov.	739	4	5	0	1	0	1	7	18 (2.4%)	375	1.90%
Dec.	786	2	7	0	1	0	0	3	13 (1.6%)	309	1.30%
Total	8,857	37	46	1	4	2	14	52	156 (1.76%)	4,308	1.21%

The incidence and distribution of nosocomial infections in each calendar month of the study is shown in Tables I and II. The extent of nosocomial infection apparently had no direct relation to the degree of hospital activity. In 1966 the highest incidences of infection were found in the months of May (2.4 per cent), September (2.4 per cent), and October (2.3 per cent), in which the number of hospital discharges were respectively 914, 678, and 765. The lowest incidences of infection were found in January (1.5 per cent), February (1.6 per cent), July (1.5 per cent), and November (1.6 per cent), in which the number of hospital discharges were respectively 751, 734, 786, and 809. Similar lack of relation was noted for 1967, in which the highest incidence occurred in February (2.2 per cent), May (3.5 per cent), and November (2.4 per cent), with respective discharges of 679, 764, and 739. The lowest incidences occurred in January (1.4 per cent), June (1.3 per cent), and September (0.8 per cent), with respective discharges of 709, 820, and 626.

In 1966 the average number of operations performed each month was 360; the smallest number, 309, occurred in August; the largest number, 414, in June. The incidence of postoperative wound infections ranged between 0.8 per cent in December (372 operations) and 2.7 per cent in April (377 operations). The average number of operations per month was 359 in 1967; the smallest number, 303, in August, and the largest number, 432, in March. The highest incidence of wound infections occurred in February (2.6 per cent) and the lowest in August (0). Comparison of the monthly incidence of postoperative wound infections in 1966 and 1967 revealed no evidence of fluctuations based on seasonal variations.

Bacteriology of Nosocomial Infections

The organisms identified etiologically with the major nosocomial infections are shown in Table III. Postoperative wound infections occurred in 115 cases and comprised 33.5 per cent of the total infections. In 113 of the cases, pathogenic organisms were cultured. The predominant pathogens were *Escherichia coli*, which occurred in 36 per cent of the wound infections; *Staphylococcus*, which occurred in 34 per cent; and *Proteus*, which occurred in 10 per cent. These organisms were found in 80 per cent of the isolations. In the remaining 20 per cent the pathogens cultured were *Klebsiella-Aerobacter*, *Enterococcus*,

TABLE III. BACTERIOLOGY OF NOSOCOMIAL INFECTIONS

Infection site	*Number of infections*	*Number of isolations*	*E. coli*	**Proteus*	*Staph.*	*K. Aerobacter*	*Enterococcus*	*Pseudomonas A.*	*Pneumococcus*	***Strep.*
Postoperative wounds	115	113	41	11	39	7	7	3	0	5
Urinary tract	104	88	41	20	12	6	8	0	0	1
Respiratory tract	77	47	8	4	15	5	0	0	5	10
Skin	19	6	0	0	4	0	0	0	0	2
Uterine	13	3	1	1	0	0	0	0	0	1
Eye	7	6	0	0	5	0	0	1	0	0

**Proteus* species.
***Includes alpha, beta hemolytic (Group A), and unclassified.

TABLE IV. PREDOMINANT PATHOGENS ISOLATED FROM POSTOPERATIVE WOUND INFECTIONS IN SELECTED OPERATIONS

Surgical procedure	*Number of operations*	*Number of infections*	*Infection rate*	*E. coli*	*Staph.*	**Proteus*	*Enterococcus*	*K. aero.*	***Strep.*
Cholecystectomy	156	10	6.4%	3	4	0	0	3	0
Resection of colon	70	11	15.7%	8	2	0	0	1	0
Resection of small intestine	23	7	30.4%	3	0	3	1	0	0
Gastrectomy	36	5	14.0%	2	2	0	1	0	0
Abdominal hysterectomy	211	10	4.7%	4	5	0	1	0	0
Herniorrhaphy	385	6	1.6%	0	5	1	0	0	0
Appendectomy	195	5	2.6%	3	1	1	0	0	0
Radical mastectomy	490	3	0.6%	0	2	1	0	0	0
Lymph node dissection	45	4	9.0%	0	4	0	0	0	0
Operation for hip fracture	82	5	6.1%	0	3	0	0	0	2
Cesarian section	268	3	1.1%	2	1	0	0	0	0

**Proteus* species.
***Includes alpha, beta hemolytic (Group A), and unclassified.

Pseudomonas aeruginosa, *Pneumococcus*, and *Streptococcus*. The high degree of correlation between the number of infections in postoperative wounds and the number of isolations suggests the possibility that a positive culture report was an important consideration in establishing the diagnosis of such infections.

Infections of the urinary tract were reported in 104 cases and constituted 30 per cent of all nosocomial infections. In 88 of the cases pathogens were cultured from the urine. The predominant organism was *Escherichia coli*, which was found in almost 50 per cent of the cultures. *Proteus* and *Staphylococcus* were next in frequency, occurring respectively in 23 per cent and 14 per cent of the isolations. The other organisms found in urinary infections were *Enterococcus*, *Klebsiella-Aerobacter* and *Streptococcus*. In the tabulation of nosocomial urinary infections the criteria excluded patients with asymptomatic bacilluria and those admitted with genitourinary disease and possible antecedent infection.

The diagnosis of respiratory infection was based largely on clinical considerations. Of the 343 nosocomial infections there were 77 cases (22 per cent) in which the symptoms, signs, and laboratory findings were compatible with the diagnosis of infection in the upper or lower respiratory tract. In 20 cases the diagnosis of penumonia was confirmed by x-ray examination; pathogenic organisms were isolated from the sputum in 47 cases. *Staphylococcus* was the predominant pathogen with *Streptococcus* and *Escherichia coli* next in frequency. The other organisms cultured were *Klebsiella-Aerobacter*, *Pneumococcus*, and *Proteus*.

Infections of the skin occurred in 19 cases (5.5 per cent); in six of these, pathogens were isolated. *Staphylococcus* was cultured from the skin lesion in four cases and *Streptococcus* in two cases. Of the 19 nosocomial infections of the skin 15 occurred in adults and four occurred in neonates. Cultures from the lesions in the newborn showed *Staphylococcus* in two cases and *Streptococcus* in two cases.

There were 13 cases of nosocomial endometritis but pathogens were isolated in only three cases. The organisms cultured were *Escherichia coli*, *Proteus*, and *Streptococcus*, respectively. There were seven patients who developed eye infections; in six of them pathogens were isolated. *Staphylococcus* was cultured in five of the cases and *Pseudomonas aeruginosa* in one case. Of the seven cases of eye infection, four occurred in neonates and were caused by *Staphylococcus*.

Postoperative Wound Infections

During the two-year period of study 8,649 operations were performed. Wound infections appeared in 115 cases (1.3 per cent), occurring with greatest frequency in operations on the gastrointestinal tract in which endogenous contamination presented a hazard. The other factors which contributed to the high infection rates in these procedures were the extent and duration of the operation and the nature of the primary disease, often a malignancy. The 488 surgical procedures involving the gastrointestinal tract included cholecystectomy, gastrectomy, resection of the small intestine, colectomy, abdominoperineal resection, and resection of the pancreas. Although this group represented only 6 per cent of all operations, it accounted for 40 per cent of all wound infections. The infection rate among the various procedures ranged from 100 per cent in five cases of abdominoperineal resection to 2.6 per cent in 195 cases of appendectomy. There were 156 cases of cholecystectomy with 10 wound infections (6.4 per cent) and 36 cases of gastrectomy with 5 wound infections (14.0 per cent). Resections of the colon, partial or complete, were performed in 70 cases with 11 wound infections (15.7 per cent). There were 23 resections of the small intestine with seven wound infections (30.4 per cent) of which six occurred in emergency operations for intestinal obstruction.

The remaining 60 per cent of the wound infections were distributed among 8,161 operations that represented a variety of major and minor procedures. There were 490 radical mastectomies with three wound infections (0.6 per cent), 211 abdominal hysterectomies with 10 wound infections (4.7 per cent), 385 herniorrhaphies with six wound infections (1.6 per cent), 82 operations for hip fracture with five wound infections (6.1 per cent), 268 cesarian sections with three wound infections (1.1 per cent), and 45 lymph node dissections with four wound infections (9.0 per cent). In the remaining operations only one wound infection was reported for each procedure.

The predominant pathogens isolated from the wound infections in selected surgical procedures are shown in Table IV. Of the 10 wound infections following cholecystectomy, four were caused by *Staphylococcus* and three each by *Escherichia coli* and *Klebsiella-Aerobacter*. There were 11 infections complicating resection of the colon (caecum, ascending colon, transverse colon, sigmoid) of which eight were caused by *Escherichia coli*, two by *Staphylococcus* and one by *Kleb-*

siella-Aerobacter. Among the seven wound infections following resection of the small intestine, three were caused by *Escherichia coli*, three by *Proteus*, and one by *Enterococcus*. There were five wound infections following gastrectomy with isolation of *Escherichia coli* and *Staphylococcus* in two cases each, and *Enterococcus* in one case. From the five wound infections following appendectomy, *Escherichia coli* was cultured in three cases, and *Staphylococcus* and *Proteus* in one case each.

Among the surgical procedures not involving the intestinal tract there was no predominance of Gram-negative organisms. There were 10 wound infections after abdominal hysterectomy. *Staphylococcus* was isolated in five cases, *Escherichia coli* in four cases, and *Enterococcus* in one case. Of the six wound infections complicating herniorrhaphy, there were five cases in which *Staphylococcus* was the predominant pathogen and one case in which *Proteus* was isolated. From the three infections following mastectomy, *Staphylococcus* was cultured in two cases and *Proteus* in one case. There were four wound infections following lymph node dissection (axillary or groin) and in all four cases *Staphylococcus* was the etiologic agent. Among the five infections complicating operations for fracture of the hip, *Staphylococcus* was isolated in three cases and *Streptococcus* in two cases. There were three wound infections following cesarian section with isolation of *Escherichia coli* in two cases and *Staphylococcus* in one case.

Discussion

The continuous surveillance of nosocomial infection presents many problems in implementation but it is a responsibility that each hospital must assume for the welfare of the patients entrusted to its care. Techniques for surveillance may differ among various institutions depending on their size and complexity but the basic principles are universally applicable. A method of reporting must be established which reveals with reasonable accuracy the extent of hospital-acquired infection on a current basis. This requires constant vigilance and close cooperation of the attending staff, bacteriology department, nursing department, and hospital administration. The techniques used at Doctor's Hospital include: 1) filing of infection sheets by the attending staff immediately after patients' discharge; 2) daily written reports of infections on each floor by charge nurse; 3) verbal and written reports from

bacteriology department to charge nurses and attending staff; and 4) monthly tabulation of infection data.

Concomitant with the surveillance of infection among patients should be the surveillance of the hospital environment. This has been accomplished at Doctors Hospital by regular monthly cultures from the operating, delivery, and recovery rooms, and from the nurseries. The cultures are taken at random from equipment, supply shelves, fixtures, and furnishings in these areas and also from instruments and autoclaved material. In addition there are spot checks on dishes and utensils from the various floor kitchens to test the efficiency of the dishwashing procedures. Multiple cultures are taken from rooms after discharge of patients with infections.

The surveillance studies provide a constant source of reference for the prevention of cross-infection. When infection has occurred, the immediate objective, other than appropriate treatment, is containment. Regulations for isolation of infected patients should be applicable to all contacts including nurses, doctors, and cleaning and serving personnel. Laundry and dishes should be disposed of in a prescribed manner. Rooms should not be occupied again until cultures for the specific pathogens are negative. Surgical dressing trays should be left in patients' rooms for resterilization. Other general preventive measures include avoidance of contact between patients and staphylococcal carriers or infected personnel, and limitation, where possible, of urinary and intravenous catheterization. The routine use of prophylactic antimicrobial therapy has been condemned as ineffectual or harmful, but the practice continues to be widespread. It is therefore most important to encourage prompt culturing of suspect material so that effective antibiotic therapy may be instituted.

The incidence of postoperative wound infection was considerably lower at Doctors Hospital than that observed in a similar surveillance study.[12] Despite the low over-all rate it was very evident that surgical procedures involving transection of an organ contaminated with pathogenic bacteria were consistently associated with a high potential of infection. It is doubtful whether further refinements in aseptic techniques or the development of better antibiotics will ever eliminate postoperative Gram-negative infection in intestinal or urologic surgery. However, in recent years a steady decline has occurred in the incidence of staphylococcal infection.[5]

The ultimate aim of all surveillance programs is to depict accurately the extent of infection within the hospital but this goal is difficult to achieve. Colonization of bacteria in the neonate or adult patient often precedes clinical infection by many days. The patient may be discharged apparently well and develop a wound infection, abscess, or pneumonia at home. Such cases are rarely reported to the infection committee and may constitute a significant proportion of nosocomial infections. Another possible source of error is the failure to report infections of brief duration without microbial confirmation. A continuous program of surveillance is necessary in all hospitals so that effective measures of prevention and control may be implemented.

Summary

1) An infection surveillance study of 18,357 patients discharged from Doctors Hospital in 1966 and 1967 revealed 343 cases (1.9 per cent) of nosocomial infection.

2) Approximately 90 per cent of the nosocomial infections occurred in operative wounds, the urinary tract, or the respiratory tract; the remaining infections involved the gastrointestinal tract, uterus, eye, and skin.

3) A total of 8,649 operations were performed during the period of surveillance and there were 115 cases (1.3 per cent) of postoperative wound infection comprising 33.5 per cent of the total nosocomial infections.

4) Comparison of the monthly incidence of postoperative wound infections revealed no relation to seasonal variations.

5) The predominant pathogens isolated from wound infections were *Escherichia coli*, *Staphylococcus*, and *Proteus*, which totaled 80 per cent of the isolations; in the remaining 20 per cent the pathogens were *Klebsiella-Aerobacter*, *Enterococcus*, *Pseudomonas aeruginosa*, *Pneumococcus*, and *Streptococcus*.

6) Operations on the gastrointestinal tract comprised 6 per cent of the total operations and accounted for 40 per cent of the total wound infections; Gram-negative bacilli were the predominant organisms isolated.

7) Urinary tract infections comprised 30 per cent of the total nosocomial infections; the predominant pathogen isolated from the urine was *Escherichia coli; Proteus and Staphylococcus* were next in frequency.

8) Infections of the respiratory tract comprised 22 per cent of all nosocomial infections; the predominant pathogen isolated from the sputum was *Staphylococcus; Streptococcus* and *Escherichia coli* were next in frequency.

9) *Staphylococcus* was the predominant pathogen isolated from nosocomial infections of the skin and eye; of the seven cases of eye infection four occurred in neonates.

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