PAPERS AND ORIGINALS

Ward Design in Relation to Postoperative Wound Infection: Part I

H. G. SMYLIE, A. I. G. DAVIDSON, A. MACDONALD, G. SMITH

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Summary

The incidence of postoperative wound infection in a general surgical unit is reported both before and after transfer from a "Nightingale" type multibed ward to a new "race-track" type of surgical ward with controlled ventilation and with 40% of its beds in single rooms. Following transfer postoperative wound infection was reduced by about 55%.

With the use of certain types of staphylococcal infection as an index of cross-infection it was shown that transfer was followed by a 72% reduction in cross-infection of wounds.

A case is made for control of hospital cross-infection in surgical wards. The principal change in ward architecture resulting from the transfer was the extensive division of ward space into separate compartments (40% of single-bed rooms), which make controlled ventilation easier.

Introduction

In 1962, when a new surgical unit for the Aberdeen Royal Infirmary was being planned, two basic ward designs were popular. One provided a ratio of three single-bed rooms to every 16 beds (Nuffield Provincial Hospitals Trust, 1955), the other grouped its beds in bays or semipartitions within a multibed open-ward plan.

Cross-infection control pre-eminently influenced the design of the new ward. Bays or semipartitions in large multibed open wards offer little or no control of surgical ward cross-infection; hence it seemed rational to attempt control by providing as many separate rooms as was feasible within ward areas. This facilitates both individual patient isolation and controlled ventilation, which in the large open ward is virtually impossible. Overcrowding of open wards is a constantly recurring infection hazard, which can be abolished only by designing new wards so that extra beds cannot be fitted in. Thus it was felt that the higher the percentage of efficiently ventilated single-bed rooms the greater would be the opportunity to minimize cross-infection. These general principles apply to the care of surgical patients at risk from infection and those liable to cause cross-infection or requiring intensive therapy, and this view led to the building of a ward with twice the number of single-bed rooms than in the much publicized recommendation of the Nuffield Provincial Hospitals Trust.

To assess this experiment in ward design a prospective study of wound infection was carried out over a period of four years, from September 1964 to September 1968. The study was undertaken in the professorial general surgical unit, which during the first two years occupied a pair of multibedded open wards built some 35 years previously (Fig. 1.). Each main ward pavilion housed 27 beds. On 26 September 1966 the unit, complete with staff and patients, transferred to the newly designed "race-track type" surgical ward with 40% of its beds in single-bed rooms, the rest being in rooms with four or five beds, and all under controlled ventilation. The single-bed rooms are entirely separate from one another, being completely enclosed with solid walls and conventional door. The plan of this unit and a diagrammatic representation of the ventilation system are shown in Figs. 2 and 3 respectively. The epidemiological study of wound infection then continued for a further two years.

As a separate part of the study 1,000 clean surgical wounds, about 500 in each two-year period, were investigated intensively at the time of incision (see Part II). This was done to detect any influence on infection incidence which may have arisen in the old and new theatre suites.

Methods

At the transfer from old to new accommodation no attempt was made to exclude patients or staff who were infected or carrying the epidemic strain of *Staphylococcus pyogenes*, previously identified as a cause of major wound infection throughout the first two years of study. Apart from the con-

University of Aberdeen
H. G. SMYLIE, M.D., M.R.C.PATH., Senior Lecturer in Bacteriology
A. I. G. DAVIDSON, CH.M., F.R.C.S.ED., Senior Registrar in Surgery
A. MACDONALD, M.A., M.D., Professor of Bacteriology
G. SMITH, CH.M., F.R.C.S., Regius Professor of Surgery

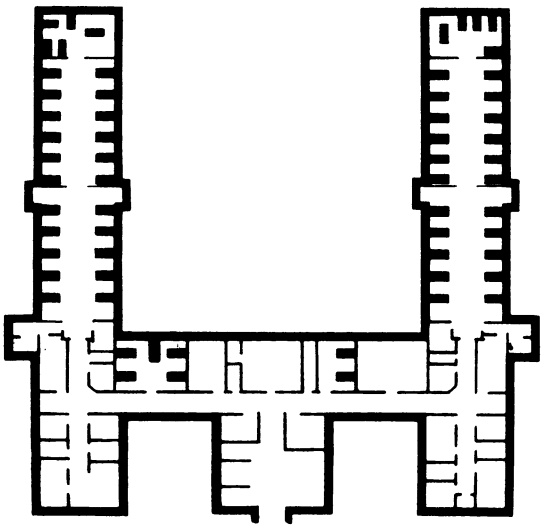

FIG. 1—Floor plan of the "Nightingale" type of multibed ward occupied during the first two years of this study.

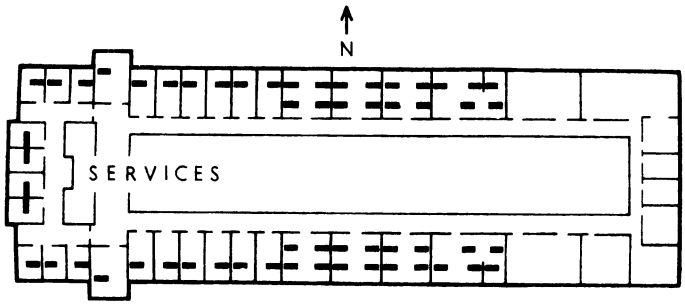

FIG. 2—Floor plan of the new ward. (Note U-shaped distribution of single-bed isolation around west end of ward.)

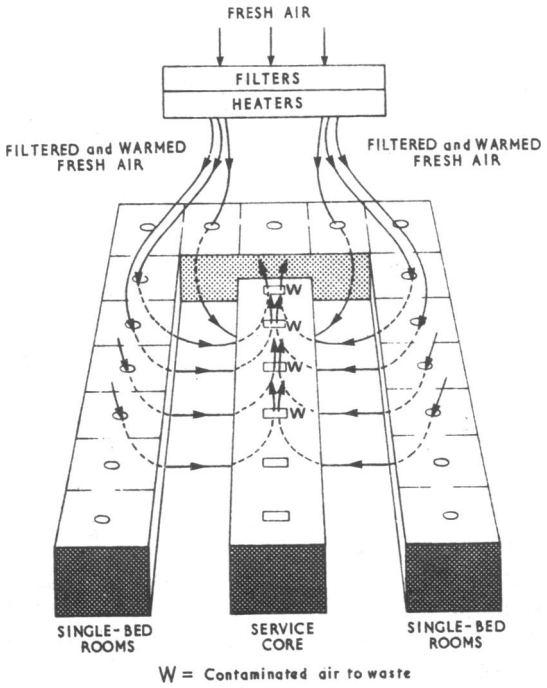

FIG. 3—Cross-section of new ward showing the pattern of controlled ventilation.

sequential changes in environment—namely, fixed bed complement, controlled ventilation, and a high degree of isolation in single rooms—all other environmental factors in the ward remained essentially unchanged. Staff administration, observational methods, and the analysis of results remained constant throughout the four-year period. No attempt was made to change surgical habits, and the work performed, both qualitatively and quantitatively, was similar throughout. To help prevent surgical bias the inspection and swabbing of wounds and recording of clinical observations was carried out by an infection control sister (Moore, 1963). The analysis of these data was carried out by the bacteriologists. Bacteriological investigation included the patients' wounds and environment, with particular emphasis on nasal carriage of potential pathogens by patients and staff, and an analysis of air hygiene studies in both wards.

The infection control sister was responsible for observing the progress of all wounds and recording this on individual patient record cards. She also assisted in providing the following bacteriological samples from patients, staff, and ward environment:

(1) Swabs from wounds were taken at first and all subsequent dressings. If no intermediate dressings were performed, then the first wound swab was taken at stitch removal. Patients sent home with sutures in place were asked to return to the ward as out-patients for removal of sutures and wound assessment; otherwise the patient's general practitioner was asked to send a swab from the wound and to report on its condition on a prepaid postcard. This was rarely necessary.

(2) Nasal swabs from patients on admission and thereafter at weekly intervals, or on discharge from hospital if ward stay was less than one week.

(3) Regular nasal swab survey samples from the entire staff of the professorial surgical unit.

(4) Slit-sampler specimens and "settle-plates" for the investigation of ward air hygiene.

Gram-stained smears from all wound swabs were examined for pus cells and bacteria, and swabs were then plated-out for both aerobic and anaerobic culture. If the specimen was seen to be "dirty" antibiotic sensitivity tests were performed directly on swab material to facilitate therapy. All other isolates of potential pathogens were also subsequently "disc"-tested for antibiotic sensitivity.

Individual strains of all isolates of pyogenic staphylococci, whether from wounds, nasal swab surveys, slit-sampler, or "settle-plates," were submitted to an extended antibiogram (penicillin, erythromycin, novobiocin, cloxacillin, tetracycline, neomycin, and bacitracin) and bacteriophage typing with the routine typing set of filtrates issued by the Public Health Laboratory Service, Colindale. This was done in the belief that it would enable us to use *Staph. pyogenes* as an "index of cross-infection." Staphylococci were typed in batches from storage on Dorset's egg medium. At the outset of the survey many highly insensitive wound isolates of *Staph. pyogenes* failed to show reaction. Samples of these strains were therefore sent to the Staphylococcal Reference Laboratory at Colindale where they were typed with phage filtrates 77AD/B5/- and subsequently identified as phage type 84/85/-. In this way a major epidemic strain of *Staph. pyogenes* was shown to be prevalent in the surgical unit, causing many serious postoperative infections.

At the end of each month the infection control sister, the technologist and the bacteriologist reviewed the clinical records of wounds with associated bacteriological reports before finally classifying them as either "clean" or "infected." Every type of wound infection was included in the survey. Apart from the obvious case of infection with inflammation and pus arising in a major incised wound, the following incidents were also included in the final diagnostic count of the overall incidence: infection around any drainage tube, whether a simple rubber drain or a tracheostomy tube; infections induced locally or systemically as a result of "cut-down" or "needle puncture" infusion or transfusion; infections seen to develop in wounds which were clean on admission to the unit—for example, deep lacerations or extensive burns—and superinfection arising at the site of a dirty operation, such as

excision of fistula-in-ano or ablation of ingrowing toenail, and clearly due to hospital cross-infection.

The records included information on whether the wound was open or closed, wet or dry, reddened, or discharging pus or serous or bloody fluid. If it was associated with drainage this was also recorded. If it healed by first intention its clinical state was recorded as "satisfactory." A wound was classified as infected whether grossly affected or merely showing a stitch abscess, and clean if it healed satisfactorily and the bacteriological reports recorded no pyogenic exudate, even though they may have recorded a growth of potential pathogens. Wound infections were subdivided into two main groups.

Group 1 contained all wounds infected with organisms which were definitely endogenous or likely to be so. Such wound infection is described as "autogenous infection." It was possible to be sure about the placing of cases in group 1, even with respect to non-coliform infection—for example, admission nasal swabs constituted an important step in the diagnosis of autogenous staphylococcal wound infection.

Group 2 included all wounds infected with an organism which could with reasonable certainty be characterized as peculiar to the hospital environment. Such wound infection is described as "cross-infection."

For practical purposes group 1 infections refer to all organisms other than hospital staphylococci, which conversely were virtually the sole cause of group 2 infections. The investigation was not geared to the study of coliform and other Gram-negative bacilli as a cause of cross-infection. Thus when infection appeared to be due solely to such organisms after dirty abdominal or genitourinary surgery it was regarded as autogenous. Goup 2 also included any wound infected with a penicillin-insensitive strain of *Staph. pyogenes* (whether or not characterized by a bacteriophage type) and unaccompanied by nasal carriage of the same organism in the patient on admission. Postoperative wound infections in group 2 were regarded as the index of cross-infection in this study.

Results

During the comparative study periods in old and new accommodation the operations investigated numbered 1,573 and 1,812. Clinical and bacteriological assessments were completed respectively in 1,477 and 1,737. The operations making up these numbers were similar in type and frequency for both periods.

The results indicate that a highly significant decrease in the incidence of postoperation wound infection occurred during the two years after September 1966 (Table I). The index

TABLE I—*Incidence of Postoperative Wound Infection during the Two-year Periods before and after Change of Ward*

Ward	No. of Wounds Observed	Wound Infections		
		Total	Group 1 Potentially Autogenous	Group 2 Staphylococcal Cross-infection
Old	1,477	478 (32·3%)	307 (20·7%)	171 (11·5%)
New	1,737	259 (14·9%)	200 (11·5%)	59 (3·3%)

of hospital cross-infection (staphylococcal cross-infection) diminished by about 72% after the change over. This reduction of wound infection associated with the highly antibiotic insensitive epidemic strain phage type 84/85/- is related exactly in time to the two-year period following the change over (Fig. 4). When the move to the new ward took place patients and staff were transferred, including eight patients with discharging wounds, four being grossly infected with the epidemic staphylococcus.

The 44% decrease in potentially autogenous infection requires further analysis (Table I). Obviously not all infection

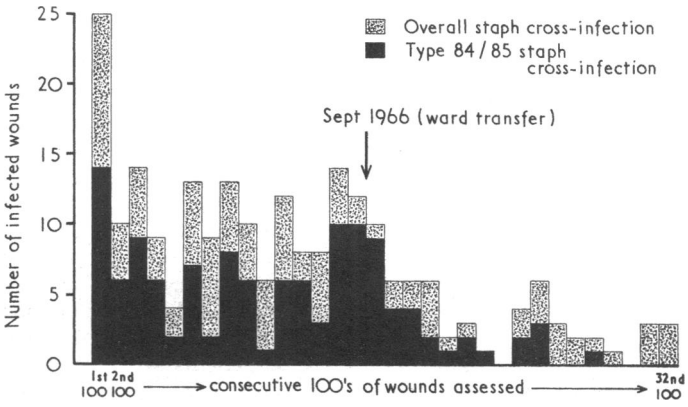

FIG. 4—Incidence of staphylococcal cross-infection during the two-year periods before and after change of ward. Staphylococcal sepsis rate is expressed as infections per consecutive hundreds of wounds assessed.

with intestinal organisms such as Gram-negative bacilli and enterococci is autogenous. This group also contains those pyogenic staphylococcal infections identified by phage typing as autogenous, and, as expected, no significant reduction was found in this type of wound infection, for there were 42 (2·8%) and 51 (2·9%) such incidents in old and new wards respectively. The drop in the incidence of the other types of potentially autogenous infection may partly be explained by the lower rate of wound drainage in the new ward and the more frequent association of this surgical manoeuvre with sepsis in wounds in the old ward. Thus 420 (28·4%) of the wounds assessed in the old ward were associated with wound drainage and 124 (29·5%) of these became infected. All drained wound infections were included in this survey even though the drain entry site was separate from the main surgical wound. As the drained wound is at greater risk in an environment conducive to cross-infection probably our potentially autogenous group of wound infections conceals some cases of cross-infection due to enteric organisms.

NASAL CARRIAGE, COLONIZATION, AND CONVERSION

In the old environment 1,505 patients provided admission nasal swabs (Table II). While 380 (25·2%) were found to be

TABLE II—*Nasal Carriage Rate of Staphylococcus pyogenes in Patients on Admission*

Ward	No. of Patients Swabbed (on admission)	No. of Carriers	No. Carrying Penicillin-insensitive Strains
Old	1,505	380 (25·2%)	78 (20·5%)
New	2,372	570 (24·3%)	125 (21·9%)

carriers of pyogenic staphylococci, 78 of these (20·5%) carried a penicillin-insensitive strain. By comparison, in the new ward 2,372 admission swabs showed 570 (24·3%) nasal carriers, of whom 125 (21·9%) carried a penicillin-insensitive strain. Bacteriophage typing revealed group 1 staphylococci as the commonest isolate (45·3% and 43·6% of all carriers admitted to old and new wards respectively). Four patients were admitted to the old ward and six to the new with established nasal carriage of the epidemic staphylococcus. Only three of the 10 patients had not had previous hospital contact. There was therefore no great difference between the two groups in either the quantity or quality of the nasal carriage of pyogenic staphylococci on admission to hospital.

Of these patients who apparently acquired carriage during

their stay in hospital, about one-half had become carriers by the end of their first week in the wards. Undoubtedly many of those apparent acquisitions were from carriers missed when admitted. The dominance of phage type 84/85/- among acquisitions, and its very low detection rate on admission, is strong evidence that it was a hospital acquisition. The time taken to acquire such strains varied between 6 and 110 days in the old ward and 6 and 94 days in the new, but more patients acquired them earlier in the old ward. The average interval between entry to the ward as a non-carrier and the acquisition of penicillin-insensitive nasal carriage can be estimated as 18 or 22 days, depending on whether admission was in the old or the new ward respectively. In the old ward 5·9% and in the new ward 1·9% of patients were shown to acquire penicillin-insensitive nasal carriage. In this study acquisition of penicillin-insensitive organisms was seen to be two to three times more frequent in the first fortnight of ward stay than in the next four weeks. Since most patients were discharged within three weeks of admission, the approximate two-thirds reduction in the acquisition rate of penicillin-insensitive staphylococci in the new ward is all the more notable.

In the group of patients with positive nasal carriage when admitted several appeared to have had their resident strain supplanted by another, as judged by a difference of at least two major reactions in phage type, with or without a change in antibiotic sensitivity. In the old ward 23 patients appeared to convert in this way, as compared with 16 such patients in the new ward. There were 13 and 9 conversions respectively to the epidemic strain type 84/85/-, with type 52A/79/80/+ as the next most common conversion.

STAFF

The entire staff of the surgical unit, whether temporary or permanent, contributed nasal swabs at intervals of 6 to 10 weeks throughout the four-year study period. These showed a nasal carriage rate of pyogenic staphylococci varying between a peak 40·5% and a low 11·8%, with average carrier rates of 28% (88% penicillin-resistant) over the first two-year study period and 24% (43% penicillin-resistant) over the second. At the beginning of the survey in the old ward and throughout the first two years of study, about one-third of the carriers regularly yielded type 84/85/- staphylococci. At the time of change over to the new ward three of those carrying the epidemic strain were surgeons, while one was a ward sister. Except for one negative result four months earlier, the ward sister had been a carrier for the previous 17 months. The surgeons appeared to have collected their epidemic strains during the last six months in the old ward. The ward sister, who was a consistent carrier of type 84/85/- in the old ward, appeared to lose this strain after transfer to the new ward. No surgeon has been a carrier of type 84/85/- since March 1967, and the last carrier of this strain, observed during January 1968, was a theatre attendant.

AIR HYGIENE STUDIES

Air hygiene was assessed in both old and new wards. Slit sampling provided the most convenient method of assessment in the old ward, while settle plates were best suited to the layout of the new unit. This difference in suitability of sampling method underlines the difficulties inherent in the application of a limited technique to the study of two very different environments. Results obtained from both ward air studies are only generally comparable, but the comparison is nevertheless useful.

Smoke tests confirmed that the old ward possessed no set ventilation pattern, and demonstrated the existence of "wild" air streams from occasionally opened windows, together with variable positive or negative air pressures from adjacent structures. The bacterial content of the air was assessed by running the slit sampler each day at the same time during both busy and quiet periods. This was done during separate weekly periods in the first quarter of 1965 and 1966. The sampler was operated in the centre of the often overcrowded open ward. A typical week's results during January 1965 is seen in Table III. The cumulative results for each week showed that

TABLE III—*Air Hygiene in Old Ward. Total Plate Counts and Numbers of Infectious Staphylococcal Particles per Two-minute Slit Sample (2 cubic feet) Obtained at Different Times on Seven Consecutive Days*

Day of Week	10.30 a.m. Ward always Busy (Some Beds Being Made)		2 p.m. Ward usually Quiet (Afternoon Rest Period)	
	Total Plate Count	No. of Infectious Staph. Particles	Total Plate Count	No. of Infectious Staph. Particles
1	149	3	92	1
2	86	2	37	0
3	380	5	126	2
4	159	1	49	1
5	174	2	72	2
6	208	3	30	0
7	184	4	41	1

the average bacteria-carrying particle count per cubic foot of ward air ranged from 95 to 110 during busy periods and 32 to 47 during quiet periods. The average range of colony-forming staphylococcal particles per cubic foot of ward air contained in the same samples was 1·3 to 1·6 and 0·5 to 0·9 respectively. These findings are similar to those obtained from a comparable study in adjacent surgical wards of the same design (Smylie, 1960). Of 184 pyogenic staphylococcal isolates from these slit-sampler studies 60 could not be phage-typed, and of the 124 strains successfully characterized 64 were typed 84/85/-. Settle plates were exposed in parallel with slit samples and throughout the intervening periods.

Architecturally the new ward is a deep rectangular block with all bed areas arranged peripherally on two sides and one end, where they form an intensive care unit. The ward is therefore of the "race-track" type, with an encircling corridor between service core and bed areas (Fig. 2). The service core includes the ward's administration offices, lifts, admission rooms, patients' W.C.s, clean and dirty utility rooms, ward kitchens, and nurses' stations. All external windows are double glazed and, except for maintenance purposes, kept permanently locked. Filtered warmed fresh air is supplied under pressure through the ceilings of the wards and all other peripheral areas. It then sweeps from all sides across the encircling corridor to forced extraction grills on the corridor walls of the service core, from whence it goes to waste (Fig. 3). This non-recirculating ventilation uses Vokes Mark 3 Auto-roll filters, spinning disc humidifiers, and steam coil heating. Final adjustment for temperature and airflow rate is made at ward level via terminal control units, and four or eight changes per hour are achieved in all bedrooms. Smoke tests have consistently shown that the movement of air in bed areas is continually towards the door and out to the corridor. This occurs even when doors are open, and is more pronounced from single-bed rooms than from rooms with four or five beds.

With a limited number of slit samplers it was impossible to sample total air hygiene in such a compartmented ward at any one time, but phased comparisons were still useful as a demonstration of the standard achieved. The counts obtained from three ward areas on 12 separate but consecutive occasions (Table IV) are shown for comparison with Table III.

The cumulative results demonstrate the average bacteria-carrying particle count per cubic foot of ward air to be 11·6 for a single-bed room, 17·6 for the corridor, and 12·8 for a five-bed room. Large counts occurred from time to time only

in single rooms (Table IV). The true significance of such counts is not known, since there was not always a parallel increase in the infectious staphylococcal particle count. This was more accurately measured by the settle plate technique, 6-in. (15-cm) diameter settle plates being exposed for 12 hours at a time, at set points in the ward. The average infectious staphylococcal particle count per cubic foot of ward air ranged from as little as 0·01 in some bedrooms to as much as 0·6 in dirty utility rooms and 0·7 in some single-bed rooms.

TABLE IV—*Air Hygiene in New Ward. Total Plate Counts and Numbers of Infectious Staphylococcal Particles per Two-minute Slit Sample (2 cubic feet) Obtained in Different Ward Compartments*

Single-bed Room		Corridor		Five-bed Room	
Total Plate Count	No. of Infectious Staph. Particles	Total Plate Count	No. of Infectious Staph. Particles	Total Plate Count	No. of Infectious Staph. Particles
7	0	14	0	10	1
2	0	8	0	10	1
1	0	29	1	7	0
14	1	12	0	13	0
6	0	27	1	2	0
5	1	2	0	6	0
2	0	4	0	38	0
3	0	7	0	13	0
73	0	12	0	6	0
1	0	3	0	25	1
0	0	49	2	11	0
1	0	2	0	4	0

This latter figure for some single rooms is artificially high as it is modified by episodes of high-frequency dispersal. To begin with, the results of phage typing showed that type 84/85/- was still the dominant isolate from both slit sampler and settle plates. Its frequency then diminished regularly, so that after April 1968 no further isolate of this strain has been recorded. One of the more important findings from both slit-sampler and settle-plate studies was the repeated observation that the occasional high bacterial particle counts found in any one-bed room did not lead to any detectable increase in the counts in contiguous bed areas.

Discussion

Published reports on the incidence of wound infection show considerable variation in the definition of surgical sepsis. In this study the additional exercise of reading all case notes retrospectively showed them to be an incomplete record of the incidence of infection as compared with that detected by the survey team.

Using the criteria we have laid down, a significant reduction occurred in postoperative wound infection in those patients nursed in the newly designed unit. That this was not due to improved theatre rather than ward environment is borne out by the detailed study of the 1,000 clean wounds described in Part II.

During this four-year survey there was a virtual disappearance of an epidemic of postoperative sepsis caused by a particularly virulent strain of *Staph. pyogenes* identified as phage type 84/85/-. There is no doubt that this occurred in the two-year period following transfer from the old-style multibed ward. Would this epidemic have disappeared in a similar fashion if the unit had remained in the old ward? In trying to answer this question it must be re-emphasized that no attempt was made to start operations in the new ward with a fresh patient and staff population. Both epidemic infection, in the form of patients with discharging wounds, and nasal carriage of the offending pathogen were introduced into the new ward at the outset. The experimental criteria and methods used in this survey have remained constant throughout. It may be significant that during the autumn of 1968, many months after the disappearance of the epidemic strain from the new ward, cases of type 84/85/- staphylococcal infection, with the same antibiotic-resistance pattern, were detected in a surgical ward in the same building as housed the professorial unit before transfer.

An important factor to be considered in relation to the observed reduction in postoperative sepsis is the improvement in ward air hygiene effected by the transfer. This would seem probable on the evidence presented of a pronounced reduction in the particle count per cubic foot of ward air, and of the barrier effect of controlled "one-way out" ventilation with consequent prevention or diminution of the spread of particles from one bedroom to another.

When planning ventilation it soon became apparent that experience of the best methods of ventilation control in this type of hospital building was not available. To the casual observer it may seem that hospital bedroom air should be discharged outside the building immediately, and not collected in the service core. It is now well understood, however, that there is considerable inherent danger in any attempt at balanced forced exhaustion within each bedroom. Alternatively, allowing all air from bedrooms to exhaust naturally under doors and across corridors towards the service core presents a contamination risk at this point. To combat this, areas in need of special protection, such as the clean-utility room, have been given their own individual supply of clean air. We believe that this latter provision, coupled with the dilution of contaminants achieved by continuous ventilation, is a far safer procedure than intra-bedroom exhaust with its attendant hazard of room-to-room cross-contamination. The ventilation diagram (Fig. 3) shows the simplicity of this peripherally pressurized system.

We have shown that some patients readily acquired nasal carriage of antibiotic-insensitive staphylococci on admission to hospital. The relation between acquisition of hospital staphylococci and an increased risk of wound infection is generally accepted, as is that between the onset of carriage and the degree of environmental staphylococcal contamination (Henderson and Williams, 1963). A hundredfold reduction of infectious staphylococcal particle counts was frequently observed in the air of new ward bedrooms as compared with air in the old multibed open ward. Therefore it can be inferred that most patients in the new ward inhaled very many fewer pyogenic staphylococci per day than patients in the old ward. A few patients in the new ward were occasionally exposed to high bacterial contamination of the air, but as the source of this was usually a high-frequency disperser in a single room and as the ventilation pattern limited spread, the epidemiological consequences could presumably also be limited. In contrast all patients in the old ward shared the worst air hygiene conditions, and these recurred daily in a regular pattern.

It is tempting to speculate that both the observed decrease in penicillin insensitivity and the waning of the epidemic strain among carriers were a direct result of a decrease in the number of staphylococci in ward air achieved by the new ventilation system. Certainly there is some experimental evidence concerning dose-response relationships to support this view. For example, the acquisition rate of tetracycline-resistant strains has been found to be greatly reduced in a ward providing isolation rooms for all patients harbouring such strains (Williams *et al.*, 1966). Our observations show a 66% decrease in the apparent acquisition of penicillin-resistant staphylococci following transfer to controlled ventilation and isolation. Probably the reduction in the number of staphylococcus-carrying particles per cubic foot of ward air achieved by the combination of controlled ventilation and isolation has had an effect on the carriage of this pathogen both by patients and by personnel.

During the first two-year study period in the old ward seven deaths may have been associated with staphylococcal wound sepsis and septicaemia. Six of these seven involved the epidemic strain type 84/85/-. After two and a half years in the new ward no death had been shown to have any association with staphylococcal sepsis.

The decreased incidence of potentially autogenous Gram-negative bacillary infections may well be unrelated to the change in ward architecture, but the criteria used to classify cross-infection meant that some of the intestinal type of infections labelled autogenous were in fact cross-infections. As expected, the incidence of definite staphylococcal autogenous infection remained substantially the same over the four years of observation.

References

Henderson, R. J., and Williams, R. E. O. (1963). *Journal of Clinical Pathology*, **16**, 452.
Moore, B. (1963). In *Infection in Hospitals*, ed. R. E. O. Williams and R. A. Shooter, p. 7. Oxford, Blackwell Scientific.
Nuffield Provincial Hospitals Trust (1955). *Studies in the Functions and Design of Hospitals*. London, Oxford University Press.
Smylie, H. G. (1960). M.D. Thesis, Aberdeen University.
Williams, R. E. O., Blowers, R., Garrod, L. P., and Shooter, R. A. (1963). *Hospital Infection: Causes and Prevention*, 2nd edn. London, Lloyd-Luke.

Ward Design in Relation to Postoperative Wound Infection: Part II

A. I. G. DAVIDSON, H. G. SMYLIE, A. MACDONALD, G. SMITH

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Summary

A detailed investigation has been carried out into the behaviour of wounds after 1,000 general surgical operations, about equal numbers of patients having been studied in two different ward and operating theatre environments. The wound sepsis rate was reduced after transfer to the new type of ward. It is concluded that features of the new ward environment were responsible for the observed fall in the incidence of cross-infection.

Introduction

At present, despite a considerable volume of published work, there would appear to be neither accepted criteria for the definition of wound infection nor any clear classification based on aetiological factors. The significance of wound sepsis is related both to its frequency and severity and to its probable source. This paper describes briefly some of the findings in a detailed investigation of 1,000 patients studied in two ward and operating theatre environments.

Terminology

In any consideration of the incidence of wound infection it is essential to define the terms used.

TYPE OF OPERATIVE PROCEDURE

Infection has been defined as the "deposition and multiplication of organisms in the tissues" (Williams *et al.*, 1966). Exogenous wound contamination depends both on the patient's environment in the operating theatre and in the ward and on the extent of the operation undergone. Endogenous contamination is, however, a feature of particular types of operation. Operations can therefore be subdivided into two main groups: *(a) clean operations*—procedures where no source of infection is normally encountered, the tissues being sterile when incised—for example, herniorrhaphy, mastectomy, thyroidectomy, etc.; and *(b) potentially dirty operations*—procedures with an existing source of contamination—for example, biliary, intestinal, urological, etc.

Both types of operation are at risk from exogenous contamination, but endogenous contamination is an especial risk in the potentially dirty group.

DEGREES OF WOUND INFECTION

It is obviously misleading to include under the same heading a severe cellulitis with abscess formation, resulting in complete disruption of a wound, and a minor degree of stitch-hole sepsis. Wound infections were therefore divided into two main groups, all being classified by the same person (A.I.G.D.): *(a) major infection*—severe sepsis with pus formation requiring drainage, frequent dressings, and almost invariably a prolonged hospital stay followed by outpatient attention until final healing; and *(b) minor infection*—a slight purulent discharge, transient cellulitis, or isolated stitch-hole sepsis, with no significant increase in morbidity.

For inclusion as an infected wound of either group the clinical classification was supported by a positive culture of pathogenic organisms from swabs taken of the wound discharge. There are advantages to this type of subdivision in that the effects of major infections could be considered separately. In this study only organisms of known pathogenicity were recorded as significant. These included *Staphylococcus pyogenes*, *Escherichia coli*, *Streptococcus faecalis*, and *Proteus*. *Staph. pyogenes* was considered alone, but the remaining pathogens were taken together and described as "intestinal organisms," the term being simply collective to describe the group and not necessarily implying an origin from the intestinal tract. Mixed growths of organisms of this group were often found, pure cultures being the exception. Phage typing of *Staph. pyogenes* was carried out when this organism was grown. Some phage subcultures, however, were lost, this aspect of the investigation being deficient, especially in the early months.

CLASSIFICATION OF WOUND INFECTIONS

In the past a problem in any discussion of postoperative wound infection has been whether the infections have arisen from bacterial contamination in the operating theatre or from cross-infection in the ward. A detailed study of the bacteriological environment of patients during operation, together with a complete follow-up of the subsequent behaviour of the

University of Aberdeen
A. I. G. DAVIDSON, CH.M., F.R.C.S.ED., Senior Registrar in Surgery
H. G. SMYLIE, M.D., M.R.C.PATH., Senior Lecturer in Bacteriology
A. MACDONALD, M.A., M.D., Professor of Bacteriology
G. SMITH, CH.M., F.R.C.S., Regius Professor of Surgery