Staphylococcal infection in orthopaedic surgery

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Infection in clean orthopaedic surgery varies widely from centre to centre. In most reported studies wound infection is not clearly defined and the lack of adequate bacteriological monitoring of the total environment of the patient leaves doubt as to the exact source of any infection which arises. It is well documented that operations on certain parts of the body carry an increased infection rate. Operations on the hip have a greater infection rate than operations on the spine or knee. This must be due to many factors, particularly the type of operation, the degree of operative trauma, the length of operation and the operative site.

Since Lister, surgeons have concentrated upon control of the theatre environment as the best means of reducing infection in the wounds they create, forgetting perhaps that such success as could be attributed to the nineteenth-century carbolic spray and dressing was as likely to be due to its barrier effect in the surgical wards as in the operating theatres of the time. As a result of this, surgeons have concentrated upon the functional architecture of the operating theatre, the environment and work routines which have passed through many developmental stages reaching the ultimate in ultra-clean environmental control systems such as the laminar flow-ventilated operating enclosure (Charnley, 1964) (fig. 1). The latter arose following the development of total hip replacement and the unacceptably high post-operative infection rate following such procedures. Professor Sir John Charnley (Charnley & Eftekhar, 1969) assesses wound contamination at operation from airborne bacteria as of extreme importance in the aetiology of post-operative sepsis and attributes a drop in wound infection over seven years to the use of an operating enclosure supplied with 300 air changes per hour and special exhaust-ventilated theatre clothing. The expense of such sophisticated theatres precludes their universal use and

the lack of the necessary bacteriological research to support their effectiveness leaves doubt as to the exact source of any infection. As a result of this orthopaedic surgeons have looked for other means of controlling infection in these procedures.

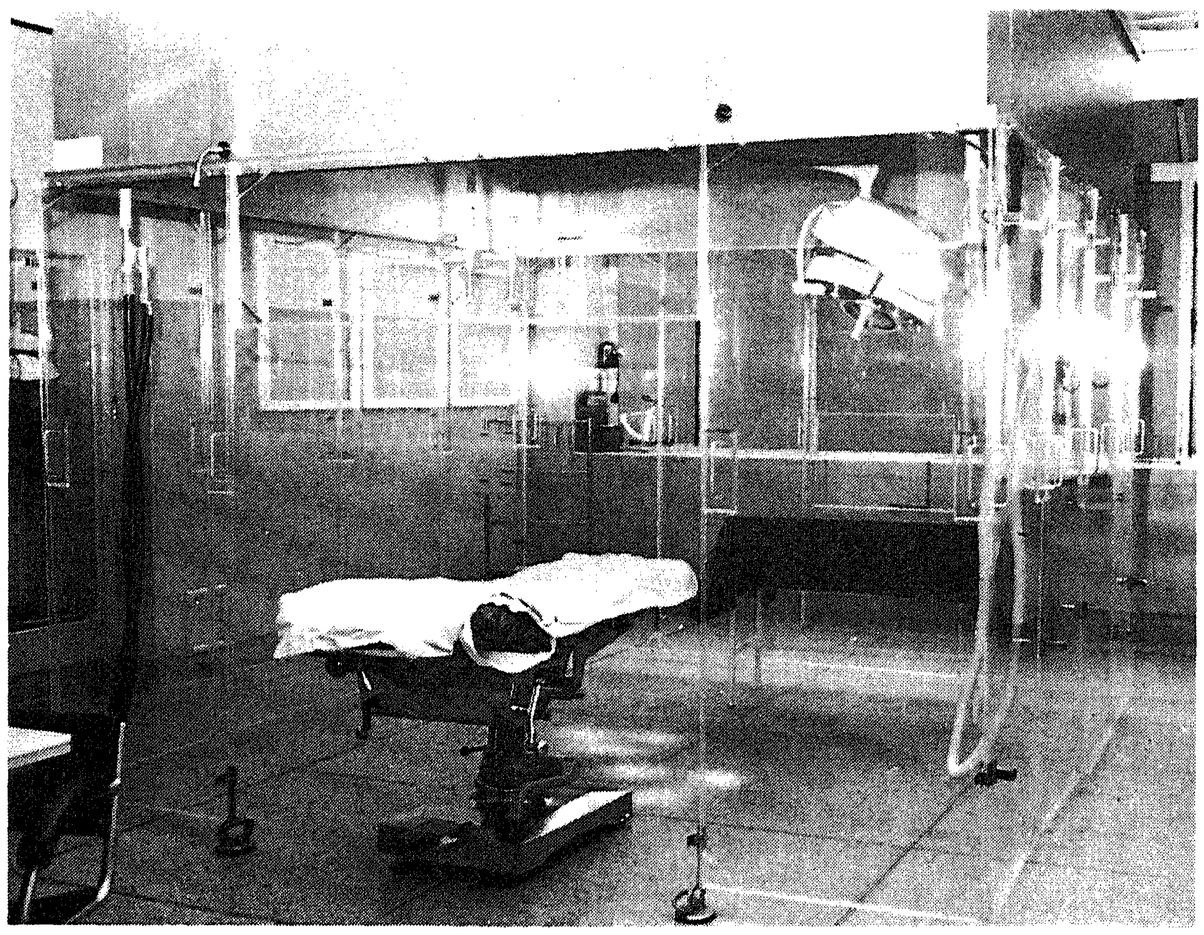

Fig. 1 Charnley Howarth Enclosure.

PROPHYLACTIC ANTIBIOTICS

Prophylactic antibiotics were used and as it was thought that infection occurred at the time of the operation they were given before, during and immediately after operation for a varying period of time. If they are given for a prolonged period one runs the risk of promoting resistant organisms. On the other hand, if they are prescribed for too short a period the patient is not covered for the period they are at risk from infection. It is generally agreed that a short, sharp course starting immediately before operation and lasting 48 to 72 h covers the period when the patient is at risk and does not promote the emergence of resistant organisms. Unfortunately there are no randomized controlled studies using prophylactic antibiotics in total hip

replacement. The retrospective studies that have been published show very low infection rates but the majority have included other methods such as limiting movement of theatre personnel during the operation and certain variations in operative routine.

Antibiotics used locally in the wound have a certain attraction particularly if one is convinced that infection occurs at the time of surgery. There is some evidence to suggest, particularly in general surgery, that wound irrigation with antibiotics reduces wound infection. Moylan, and Brockenbrough (1968) Scherr, Dodd and Buckingham (1972) carried out laboratory experiments to determine the effects brief contacts with high concentrations of polymyxin B sulphate and bacitracin might have on the most common contaminants of elective surgical wounds. They found that this combination killed off 100 per cent of *S. aureus* phage type 80, but only 91.46 per cent of one strain of *S. epidermis. Proteus vulgaris, mirabilis* and *morganii* were not adequately dealt with. In a controlled trial of 466 patients undergoing osseus and soft tissue orthopaedic operations Nachanie, Siffert & Bryer (1968) found that local irrigation of the wounds with neomycin sulphate had no effect on the subsequent wound infection rate.

Another method of using antibiotic locally in the wound is to incorporate it in the acrylic cement used for the fixation of the prosthetic components. Tissue fluids diffuse into the cement and the antibiotic dissolves and elutes out over a period of time. This can be measured *in vitro* using different solutions and cement shapes. The greater the surface area to volume of cement the greater is the elution. *In vivo* studies can be carried out by measuring the antibiotic levels in the wound suction drain post-operatively. A number of antibiotics have been used but the most predictable and commonly used antibiotic is gentamicin. There have been no reports of adverse systemic effects or of the development of resistance. This is an attractive method but no controlled studies have been carried out and the late effects of the reduction in mechanical strength of the cement with added antibiotic are awaited.

THE THEATRE ENVIRONMENT

A patient is at risk from infection from the time the wound is made in the theatre until is is healed or sealed in the ward. Traditionally surgeons have looked to changes in the theatre environment and routine as the best method of reducing post-operative wound infection. The bacteriological consequences of glove puncture have been reduced to negligible proportions with the introduction of efficient skin disinfection agents such as 'Phisohex'

(3 per cent hexachlorophane in detergent cream) and 'Hibiscrub' (4 per cent chlorhexidine detergent solution) (Smylie, Logie & Smith, 1973). All kinds of sterile supplies for the operative procedure are now guaranteed in most theatres via quality controlled Central Sterile Departments using the most efficient of modern sterilizing equipment. It would, therefore, appear that the ultimate has been reached in quality control, theatre design and routine. It was, therefore, with great interest that we first began studying the sources of infection following total hip replacement ten years ago. At that time it was thought that operating in a sterile or near sterile environment was of great importance as even non-pathogenic organisms settling out of the theatre air into the wound were thought to be potential sources of infection in the presence of a metal implant. The existing ultra-clean air systems were very expensive and we looked for a cheaper alternative. We knew of the work in the veterinary field where bacteria-free animals were produced by caesarean section using flexible film isolators, and we helped to develop a flexible film isolator for use in orthopaedic surgery (McLauchlan *et al.*, 1974) (fig. 2). This development provided precise control of the aerial

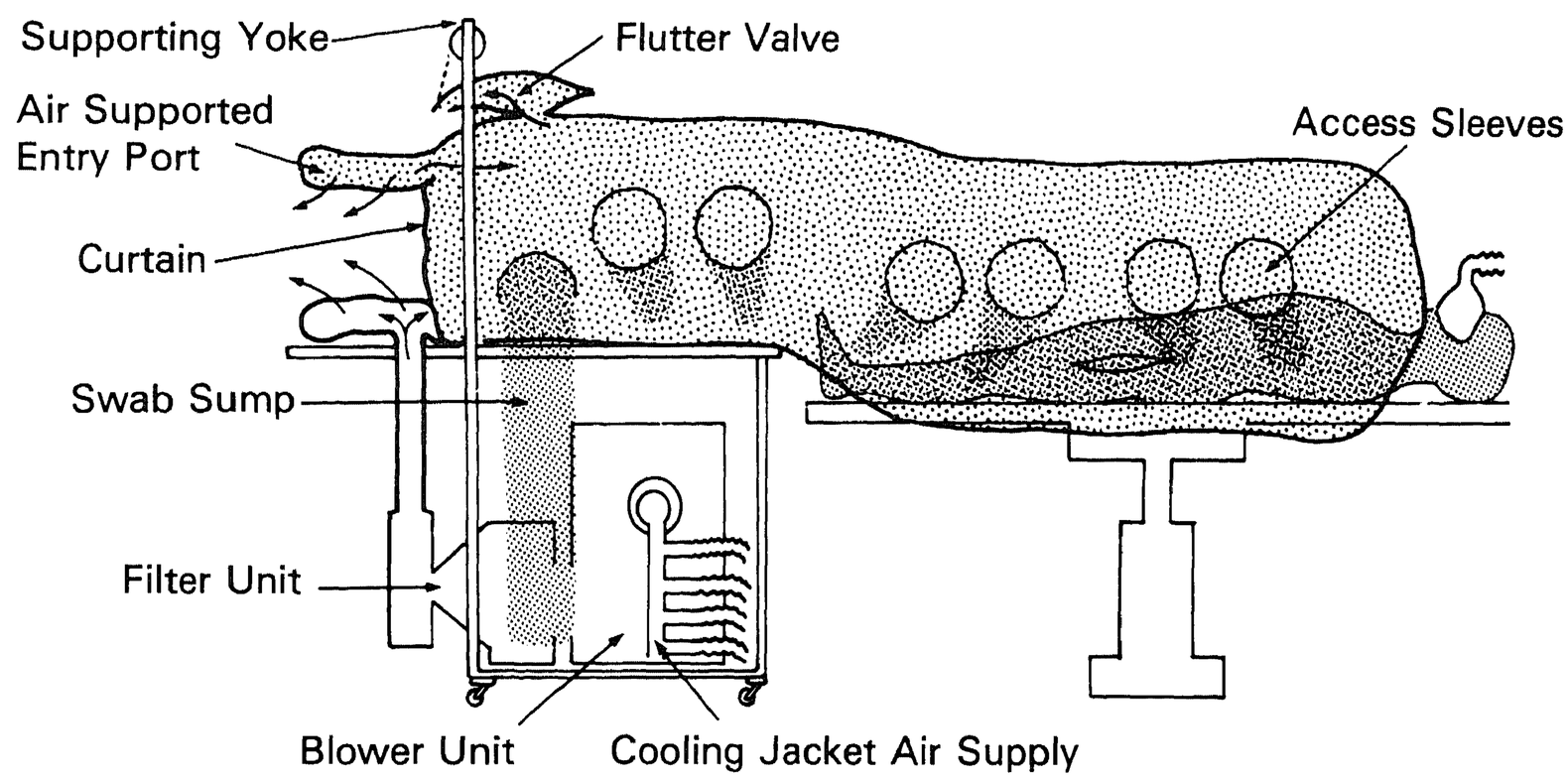

Fig. 2 Diagrammatic representation of the Operative Isolator.

environment of the wound at operation so that the elimination of the airborne and direct contact routes of cross infection could be guaranteed. A randomized controlled trial of the isolator in total hip replacement was set up with extensive bacteriological monitoring of the patient before, during

and after every operation and the operative team and the operative environment during every procedure (McLauchlan, Smylie, Logie & Smith 1976). Exhaustive air sampling checks proved the sterility of the aerial environment of the surgical isolator whilst those of the plenum ventilated theatre closely approximated to the reviewed standard for the efficient plenum ventilation of operating rooms (Blowers, 1962) (table I). Wound

TABLE I
Air sampling of operative Environment

Control	7.4 colonies/cu ft	256 colonies/cu m
Isolator	0.059 colonies/cu ft	2.04 colonies/cu m

TABLE II
Organisms grown from the wound during operation

	340 Isolators	345 Controls
No growth	183 (54.7 per cent)	127 (36.8 per cent)
1– 10	113 (33.2 per cent)	142 (41.1 per cent)
10– 50	21 (6.1 per cent)	44 (12.7 per cent)
50–100	5 (1.4 per cent)	14 (4 per cent)
100	15 (4.4 per cent)	19 (5.5 per cent)

TABLE III
Organisms involved in infections

	Isolator		Control	
	Major	Minor	Major	Minor
S. aureus	3	7	8	3
S. epidermidis	1	0	2	0
Mixed infections (intestinal organisms)	2	4	2	3

contamination during operation was apparent in both 'isolator' and 'plenum theatre' patients despite this difference in the aerial environment of the two operation systems, and was often far in excess of any contribution from airborne bacteria. The isolator did, however, significantly reduce the levels of bacterial contamination at operation (table II). Bacteriological monitoring of the surgical team by means of glove and finger streak cultures and measurement of glove punctures eliminated their hands as a source of this contamination. The only demonstrable source of these organisms which were predominately *S. epidermis* was the patient's skin. The degree of wound contamination at operation bore no relationship to cases of post-operative wound infection. Major infection, when it occurred, was related to wound drainage problems and heavy soakage of the wound dressings. On repeated bacteriological culture these discharges remained sterile only yielding positive cultures after 7–10 days. Interestingly, in the first half of the study these positive cultures consisted predominantly of a mixed faecal type flora such as it commonly isolated from both the bed clothes and the perineum of patients, and in the second half of the study the cultures yielded *S.aureus* of the same phage types as were found in the ward where the patients were nursed post-operatively (table III). This latter group of infections occurred during a period when there was an increase in staphylococcal infection in the ward. All infections whether major or minor were classed as secondary reflecting an aetiology which was properly related to the opportunities for infection in the ward rather than the operating theatre, It is tempting to regard the gram-negative infections as self infections but in any large multi-bedded ward this would be a rash assumption. Patient to patient cross-infection of wounds by gram-negative bacilli has been demonstrated repeatedly (Lowbury & Fox, 1953; Salzman *et al.*, 1967; Knittle *et al.*, 1975) and the development of seriological typing methods has underlined the possibility of 'hospital' strains of *E. coli* showing an 'above average tendency' to produce certain types of infection (Kennedy *et al.*, 1965). It would also be false to assume that design would have no bearing on the control of such infections for a significant fall in the incidence both of total infections with intestinal organisms and of major infections of this type has already been demonstrated following the transfer of a surgical unit from the large multi-bedded ward to a new ward providing 40 per cent of its patients with positively ventilated single bedded rooms (Davidson *et al.*, 1971).

In this particular study airborne bacteria, glove puncture, intra-operative bacterial contamination of both the wound and the external surface of the surgeon's gloves, non-sterility of surgical supplies, and direct contact cross-infection from the surgical team despite their heavy nasal carriage of *S.*

aureus were all ruled out as a cause of post-operative wound sepsis in those patients having their hip replacement carried out in a surgical isolator. There was no statistically significant difference in infection rate between this group and those patients having their hip replacements in an ordinary but adequate plenum ventilated theatre (table IV).

TABLE IV
Infections in operative isolator study

	346 isolators	354 controls
Major	6 (3) *	12 (8) *
Minor	11	6

* prostheses removed

Post-Operation Wound Isolator

As a result of the operative isolator study we felt that it was essential to provide some form of environmental control of the surgical wound post-operatively. A small flexible film plastic isolator was developed for post-operative wound care (McLauchlan, Scotland & Trexler, 1978) (fig. 3). This consists of a small PVC bag with a standard surgical drape welded into its floor. Access ports are welded into its upper surface to allow the introduction of sterile air and to enable swabs to be taken of the wound and aspirate any discharging haematoma. The isolator is attached around the wound immediately after operation after cutting a slot in the surgical drape which allows it to be stuck around the wound with 1.5 in. clearance. The isolator is inflated with sterile air, the pressure being kept positive with respect to the external atmosphere. The sterile air supply consists of compressed air fed through an in-line filter with a sodium chloride penetration of less than 0.001 per cent. It passes into the isolator and diffuses through a glass wool exit filter welded into its roof.

In order to assess the effectiveness of this sterile microenvironment a controlled trial was carried out using the wound isolator to isolate the wounds of patients who had had fractures of the neck of their femur pinned with a nail plate. Patients were randomly allocated to have their wounds dressed with a standard gamma-irradiated dressing or the wound isolator. Extensive bacteriological monitoring was carried out on the patient, the

operative wound, the ward environment and the immediate environment of the wound in the form of sheet sweeps and the aerial environment of the isolator in every single case. There was no significant difference in the staphylococcal carriage rates in the two groups (table V). Three patients grew *S. aureus* from their skin prior to disinfection with 2 per cent tincture of iodine. Only one of these patients subsequently went on to a wound infection but the organism was of a different phage type to that on the skin. Organisms were grown from the operative wounds of both groups. These

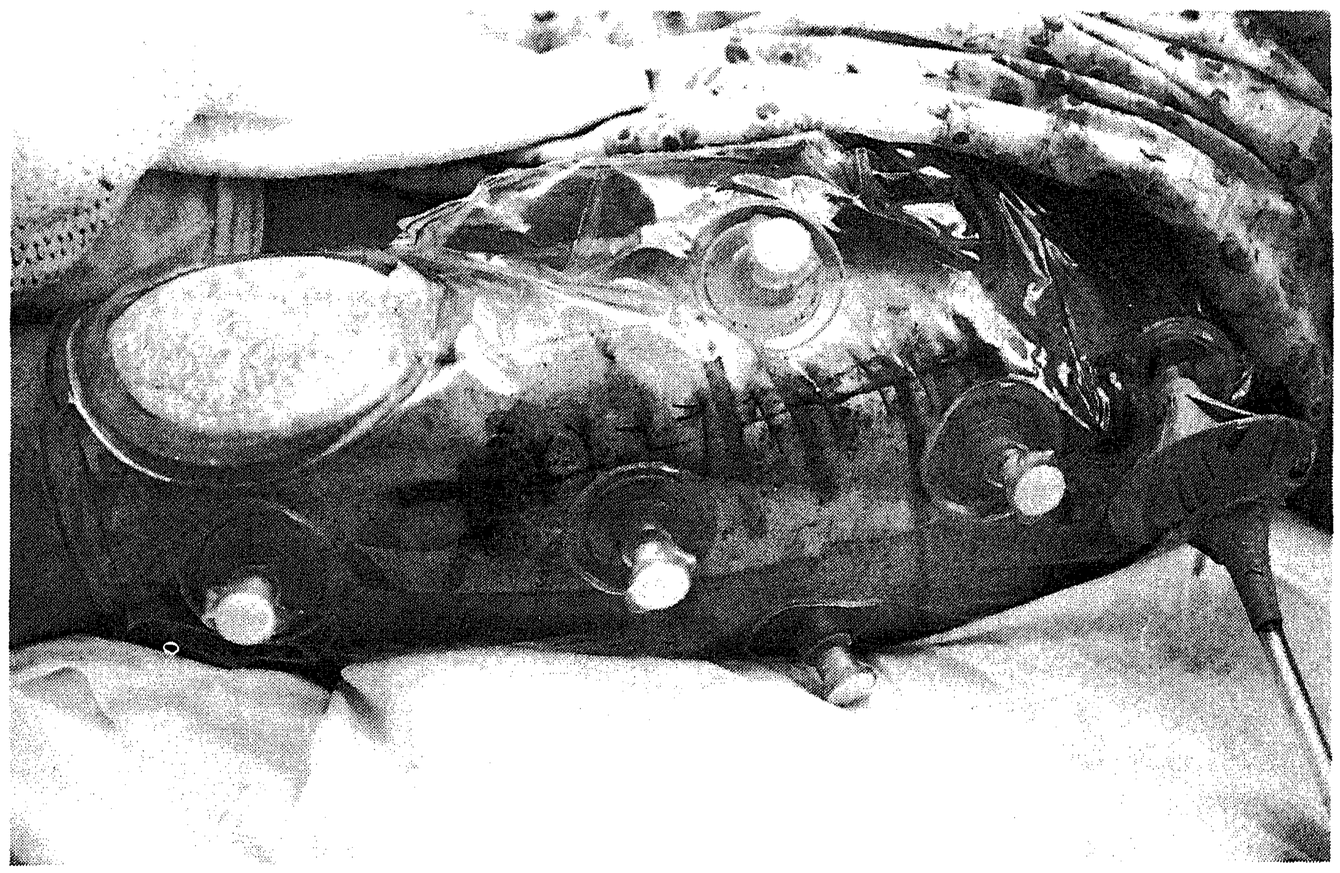

Fig. 3 Wound Isolator.

were all micrococci and did not appear to bear any relationship to subsequent wound infection. The ward environment in which both groups of patients were nursed grew between 7000 and 9000 colonies per square metre per hour, whereas the aerial environment of the isolator only grew 47 colonies in 2800 litres of air sampled in 55 patients. Twelve of these colonies were coagulase positive staphylococci of the same phage type as the only major infection which occurred in the isolator group. Sampling of the wall and the inner aspect of the exit filter of the isolator in the same patient revealed *S. aureus* of the same phage type as in the wound infection (table VI).

TABLE V

Staphylococcal carriage rate of patients in wound isolator study

	Controls	Isolators
Nose	11/62 (17.7 per cent)	10/55 (18.2 per cent)
Perineum	2/62 (3.2 per cent)	5/55 (9.1 per cent)
Skin of operative site	1/62 (1.6 per cent)	2/55 (2.5 per cent)

TABLE VI

Air hygiene studies of wound isolator and ward environment

WOUND ISOLATOR	Total no. of patients	Total volume of air sampled	Total no. of colonies
Membrane sampler	55	2800 litres	47
	Total no. of patients	Total no. of samples	Total no. of colonies
Swabs of isolator wall	55	560	1448
	Total no. of patients	Total no. of colonies	
Swabs of exit filter	55	682	

THE WARD

Settle Plates

	Day of operation	2nd post-op. day	10th post-op. day
Isolator	7676	7938	8302
Control	7623	8142	9026

Total number of colonies/sq m/h

Major wound infection occurred in 7 control cases and 1 isolator case (table VII). The latter was a *S. aureus* phage type 81 which was isolated from the ward environment but was found nowhere else except the wound and it was thought that it may have been introduced accidentally during daily swabbing of the wound which was done during the early part of the trial. There were 6 minor infections in the control group and none in the isolator group. Almost half the infections in the group were traced to a ward source by phage typing. Of the rest, one was an autogenous infection and the source of the others could not be identified.

TABLE VII
Summary on infections in wound isolator study

	Major	Minor
Isolator	1/55 (1.8 per cent)	0
Control	7/62 (11.3 per cent)	6/62 (9.7 per cent)

CONCLUSION

We have shown that the wound isolator provides a sterile microenvironment for the wound post-operatively and prevents direct contact and airborne cross infection. One patient had a large sacral bed sore which grew *S. aureus*. Following operation a wound isolator was applied and the wound healed without infection. The wound isolator reduced wound infection significantly after hip nailing operations for fracture of the neck of the femur. The group of patients on which the trial was conducted was elderly and tended to be confused and disorientated immediately after operation and many of them pulled their isolators off which necessitated the removal of the paired control in each case. As a result of this a large number of patients had to be admitted to the trial before we had enough patients who had kept their isolators on until their wounds had healed. We, therefore, must be cautious in recommending this device in its present form for this particular group of patients. I think, however that we have shown that wound infection does occur postoperatively from organisms found in the ward environment and if one can maintain the wound in a sterile environment post-operatively the wound infection rate can be reduced significantly. We have been unable to show that operating in a sterile environment reduces post-operative wound infection and in these days of escalating building and equipment costs we would recommend that surgeons use a standard plenum ventilated operating theatre and isolate wounds post-operatively in a simple and cheap sterile microenvironment.

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