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The irreducible minimum in cross-infection control and isolation nursing

By W. HOWARD HUGHES
Bacteriology Department, Wright–Fleming Institute, St Mary's Hospital Medical School, London, W.2

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SUMMARY

This is a survey of 10 years experience in trying to find out how to control hospital sepsis economically. We appear to have obtained reasonable improvements in hygiene by applying the teaching which has been given to students since the time of Leonard Colebrook. For our investigations we used only routine methods.

The order of importance of the factors in reducing cross-infection would appear to be: (1) single rooms for all septic cases and for those requiring protective isolation; (2) a sister supported in complete authority over anyone entering the unit; (3) a simple, inflexible drill to introduce an impermeable layer between the nurse or doctor and the patient—gloves and apron provide this; (4) overshoes and barrier mats; (5) hygienic disposal of linen; (6) an efficient wet dusting and floor cleaning system. Anything beyond this must be justified by saving of nursing time or some factor other than prevention of infection.

PRELIMINARY SURVEY

When the then Ministry of Health asked that Control of Infection Officers should be appointed, Dr John Ackroyd and I looked into local conditions and our findings formed the basis of later work. A record of all cross-infection was made and ward was compared with ward and surgeon with surgeon. Later a study was done of the working conditions in all wards. It might be supposed that the correlation would be between the lack of convenience and the sepsis rates—there was none. Some of the worst wards had the best records. The most eccentric surgeon, often quoted as an excuse for bad practice and clinical behaviour, was found to be faultless when judged by post-operative sepsis. It was also embarrassing to find that the private block had no cross-infection, at a time when the main hospital had had 23 fatal and 460 other cross-infections in the year. The ward assessment had been subjective but we were able to apply more accurate measurement when standards were published for hospital building and for offices.

We marked each ward or department against the standards suggested by Florence Nightingale (many of the buildings are of her period), and in those matters not dealt with by her we used the minimal standards for hospitals (Building Note no. 4). For staff facilities we followed the Bill, afterwards the Offices and Factories Act, 1963. Taken together these gave 14 heads for judging a ward, ranging from bed spacing and sterilizing facilities to changing rooms and staff

lavatories. Each was marked out of 10 without any weighting. The lowest score was 56 (40%); even our most recent ward, less than 30 years old, fell short of requirements.

There were two interesting parallels however. Where sepsis was prevalent, members of the nursing staff were being referred to the Student Health Service for psychiatric help, and the Medical Social Workers were receiving various complaints from patients' relatives. This suggested that good morale was more important than the physical environment. Since the private beds appeared immune, although mainly supplied with temporary staff and having inferior theatre facilities, the main objective of our policy became the provision of isolation cubicles in the main hospital, which had none at all.

It is not possible to arrange material in chronological order since many points were investigated in parallel and the results applied as opportunity and money was found.

SHEDDING AND SPREADING INFECTION

Dirt, alive and dead

Popular anxiety about cross-infection was followed by letters both in the lay and medical press pointing out flaking paint and other evidence of decorative neglect and claiming that this was responsible. There was confusion here between general untidiness and the presence of pathogenic bacteria, and limited resources might have been wrongly directed. To discover where the true danger was, we sampled areas of 100 cm^2. with a swab moistened in a tube of 2 ml. of nutrient broth, using masks cut in X-ray film (for conveying the findings to the cleaning staff this is conveniently about the size of a slice of toast). The swab was then shaken in the remaining broth and the organisms present counted by plating out.

Results showed that the area of greatest risk was always the floor. Horizontal surfaces at other levels, locker tops, window sills, etc., were about one-tenth as affected, while vertical surfaces, whether absorbent bed curtains or painted walls, were of insignificant importance.

For example, when a patient with a fatal *Staphylococcus aureus* infection was being nursed, the wooden floor gave total counts of 30,000, with his pathogenic strain 3000, per 100 $cm.^2$. The counts fell off rapidly up the wall until, level with his head, a total of 15 organisms was found, none his own strain. We therefore direct our main effort in cleaning to horizontal surfaces and to the dust in the air.

Dirt in our area is itself relatively harmless. We were fortunately in possession, in the laboratory, of a cupboard that had remained unmoved for over 20 years. The dust was 1·0 cm. thick and weighed amounts could be taken. It was surprising to find counts as low as 100 per g., all spore-bearers. The dust was acid, pH 4·0, and probably self-disinfecting.

Studies on air-borne particles had shown that the infective particle was much larger than single bacteria, 11–14 μ (Lidwell, Hoble & Dolphin, 1959). Using the skin shedders in our wards, Davies & Noble (1962) were able to demonstrate that the infected skin squame was the element responsible for transmission from patient to patient.

The extent of skin carriage is illustrated by a patient during a widespread outbreak. Normal persons shed between 100 and 2000 organisms while undressing and redressing in a cubicle. This patient while merely taking off and replacing his pyjamas shed 30,000 staphylococci of the epidemic strain. About 0·1 g. skin scales could be recovered from his pyjamas per hour.

Hospital linen

The role of sheets and blankets has been assumed to be to provide fluff as a vehicle of transport for pathogenic organisms; the fact that it is the skin squame that is responsible does not alter the importance of the linen. We found that instructions, aimed to prevent the theft of linen during the war, were still being followed. The night staff in wards and theatres was tipping all soiled linen, even that from heavily infected patients, onto the floor, sorting it into piles and then packing it in canvas bags for transport; no separate clothing was provided for this work and the bags were not sterilized. Wound dressing was done in the contaminated ward environment so created.

We substituted plastic bags, red for infected and foul linen, and white for the rest. Counting was stopped; losses of linen have not increased as it is not at this stage that they occur, as it is clean linen that is taken—who wants foul?

Sucking and blowing

In our Children's hospital Bate had demonstrated the spread of intestinal pathogens by a vacuum cleaner (Bate & James, 1958). Redesigning of these tools followed his report and now all sweepers are fitted with disposable paper lining bags. We endeavoured to get rid of all alternative forms of dry sweeping. This required a prolonged battle against the maids by the Domestic Supervisor. No sooner had all brooms been confiscated from the wards than they transferred them from other areas. These were in turn removed, only to be replaced by more from as far away as the nurses' homes and the laboratories. Only after 3 months was it possible for colleagues in the staff ward to be spared the sight of mops and brushes being shaken from upstairs windows and the dust floating down into the maternity ward.

Bate pointed out to us that suction cleaning carried with it the risk inherent in the venturi effect, the exhaust creating a cloud of dust behind the machine. We use extension hoses for all procedures, keeping the sweeper itself outside the ward as long as possible and moving it on to a cleaned patch of floor thereafter.

Once we had realized that all machines that sucked also blew, we directed our attention to all pumps, aspirators, etc. A suction line had been built into the operating theatres. When suction was required, in removing blood and pus from the peritoneum for example, the nozzle and tube were connected through a collecting bottle to this line. There was no filter in the system. The pump was sited at the most inaccessible position on the roof. We sampled the exhaust, and collected on a moistened disk, 2·5 cm. in diameter, exposed for 1 min. at a distance of 30 cm. 440,000 *S. aureus* of an epidemic strain. We had established a continuous culture of staphylococci with diluted blood as nutrient. By siting the pump

up-wind from the window of the sterilizing room it was possible to feed back into the theatre an aerosol of these organisms. The problem was dealt with by introducing formalin into the system and, as soon as possible, providing filtered air to the suite.

Even the provision of filtered air is not fool-proof. One of the staff required to change filters objected to the climb onto the roof. He economized his efforts by cutting hard-board to fit the carriers. When this was discovered, he justified himself by saying that in any case the ordinary filters only got dirty.

On other occasions selective culture systems were established. An eye infection with a Gram-negative organism drew our attention to the antiseptic hand-washing cream. The organism was present in the cream-dispenser's reservoir in pure culture. The dispenser was connected to a foot-pump which drew in air at floor level and over a period of months a resistant organism had been introduced. It is difficult to convince staff that containers for antiseptics must be heat-sterilized before refilling (in the case of liquid-soap dispensers mounted over sinks this is virtually impossible). The equipment was heat-sterilized and the technician devised a simple cotton-wool filter and inserted this into the input tubing. However, the same mistake was repeated not only at other hospitals but in two of our own theatres in the group, from a failure in reporting widely enough.

A similar selective culture system was established in the drains of a new theatre, which was constructed over a ward, without much space between its floor and the ceiling below. Although to be used primarily for orthopaedic work, the theatre was not provided with a plaster trap and repeated blockages of the drains ocurred. One of the porters who had to clean out and unstop these scratched his hand and developed an infection with a Gram-negative rod. Cultures of the drain showed that the slow flow had permitted a build-up of the strains of *Pseudomonas aeruginosa*, *Streptococcus faecalis*, *Proteus retgeri* and an atypical coliform, all resistant to the antiseptics then most used—benzalkonium chloride, chlorhexidine and hexachlorophene.

Anaesthetic and similar apparatus

An examination of all apparatus activated by pumps made it clear that in their design no attention had then been paid to the exhaust. We were able to correct this with only the simple addition of filters, made by the instrument curator. This has now become standard commercial practice.

An example of the risk involved in unfiltered aspirators was the frequency of streptococcal infection occurring in other children in a ward when it was necessary to suck out the fossae after a tonsillectomy. Again this was cured by introducing a filter into the exhaust, a method the manufacturers have adopted. Tests of the current commercial filters show that even when they are due to be discarded the external side is still sterile.

The incubators for premature babies received early attention, following a series of infections, usually with pseudomonads. Faults both of design and of management were discovered. The humidifying system had to be topped up with water through a filler with a hinged cap; this was incompletely closed. The instructions

were to fill with distilled water, but it was not specified that this should be sterile and from a sealed bottle and that bottles should be used once only and then discarded. We had long known that distilled water with only atmospheric gases was an adequate culture medium; we found that up to 400,000 organisms per ml. could be supported on this alone. Leifson (1962) has made the same observation.

Since disinfection of these incubators was so difficult, after any infected case the work was entrusted to a commercial firm (Vickers Medical Instruments) who used formalin. Ethylene oxide is also suitable. Tests with bacteria show that the relevant organisms, including *Str. faecalis*, *Ps. aeruginosa*, *Escherichia coli* and *Proteus* spp., are killed by these methods. Between cases the routine cleaning is done with chlorhexidene 0·5 % in 70 % spirit on all accessible surfaces, followed by filling the humidifying system with hypochlorite solution, at the strength used for the feeding bottles, and leaving this for at least 2 hr.

Anaesthetic apparatus itself has always been a focus of anxiety, though proof that it has ever been responsible for cross-infection is lacking. It is always felt that after a patient with tuberculosis or other lung disease has been anaesthetized there is a risk to subsequent patients. In fact, there is a no-return valve in the system and the only parts of machines from which organisms could be returned to the patient are on his side of this. The tubing and masks can be boiled or otherwise disinfected between cases. We were fortunate in finding tubing and connectors which had not been disinfected for 3 months. Swabs from 10 cm. of each end of the elephant tubing were taken, and from the metal joints. Plate counts of up to 2 organisms were found; even these were contaminants since the broth cultures were sterile. This agreed with many previous investigations of apparatus of this sort. The joints were not so satisfactory, up to 10 *S. albus* being found.

The self-disinfecting nature of some rubber is well known, but it was thought that the anaesthetic gases themselves might be sterilizing the apparatus. Nitrous oxide, fluorethane, trilene, penthrane, and cyclopropane were introduced into anaerobic jars in their working concentrations and a full range of upper respiratory organisms exposed to them. They all grew as well as in air alone.

We conclude that the minimum requirements for anaesthetic apparatus is boiling or chemical disinfection of the mask, valve and bag for each case; where special anxiety is felt over any special risk, boiling of all parts on the patient's side of the no-return valve. Although it is usual to send respirators for gas sterilization, this is not strictly necessary where a simple bacterial filter is introduced into the system on the patient's side to protect the apparatus. This alone might be enough to provide a harmless exhaust for the protection of staff and other patients but an exhaust filter is now fitted.

Transmission of organisms

Apart from the spread of microbes by currents of air, there is the part played by individuals in moving them round the hospital. In spite of Semmelweiss, we found the post-mortem room still was a source. It had cracked floors that could not be efficiently cleaned, and teaching and demonstrations were still carried out there irrespective of the nature of the disease or the virulence of the organism

causing death. An examination of the corridors leading from the mortuary to the rest of the hospital showed a much higher count of organisms, particularly from the bowel, than anywhere else. Two groups of students attended a tutorial and their shoes were swabbed. The first group had faithfully attended the P. M. demonstration, then walked a quarter of a mile and climbed six flights of stairs before swabbing; the second group had cut the demonstration. The subject had died with a staphylococcal pneumonia (4 Feb. 1959). Twelve shoes were cultured for each group.

Test group

On MacConky's medium 1–12 Gram-negative rods
Salt mannitol agar 80–440, average 288, *S. aureus*

Controls. No Gram-negative rods, no *S. aureus*. Technicians in the routine laboratory in a different wing of the building, however, gave 0–1 Gram-negative rods but 105 *S. aureus*.

The persistence of contamination of shoes was investigated by painting the sole of a technician's left shoe with *Serratia marcescens*. At intervals areas of 6 cm.^{2} were swabbed and counts made; the results are shown in Table 1. During the time while the shoe was being worn the girl was working, mainly standing, or walking to a canteen.

Table 1. *Survival of* Serratia marcescens *on shoes*

	Number of colonies from areas of 6 cm.^{2}				
	15 min.	30 min.	1½ hr.	2½ hr	4½ hr.
Left (infected)	+ + + +	240	60	75	1
Right (control)	18	12	0	0	0

+ + + + = uncountable.

If this tracer organism is any guide, then bacteria persist long enough to reach any part of the hospital. We felt it was justified to remove the teaching of clinical students from the P.M. room. Repairs to the floors were followed by total counts reduced to 15–70 per 100 cm.^{2} while that for the stairs and doorway was 4000, since here the structure was wooden and not so easily dealt with.

The assumption that only shoes of hospital staff carry pathogens is untrue. We obtained swabs from a shoe repairer's shop not near any hospital. Although the average counts were lower, *S. aureus* 25 per shoe, two gave confluent growth.

ATTEMPTS AT CONTROL

This information, together with the realization that the best way to sample the flora of a ward was to swab the trolly wheels, has permanently biased our barrier-nursing technique. The extent to which the floors represented a reservoir is indicated by the *S. aureus* count of the six main surgical wards at the time—range, 910–2540; average, 1830/100 cm^2. These were wooden floors. Where we have obtained terrazzo, linoleum or plastic covering for them the staphylococcal counts remained lower. Sealing the wood floors with polyurethane has also helped.

Failure to control epidemics without isolation facilities

The control of the spread of staphylococcal infections became almost impossible when a neomycin-resistant staphylococcus, then provisionally grouped as D/77Ad/B5, now 84/85, was introduced into the wards. This occurred in other hospitals that year, and as they have published their experiences we have not previously done so (Quie, Collin & Cardle, 1960; Temple & Blackburn, 1963; Jacobs & Willis, 1963). From 16 August 1962 until December 1963 we maintained an unbroken series of 123 cases, all direct contacts of one another.

Every attempt to stop the spread in a ward by closing it and cleaning it was futile. This was mainly because there were always some cases too ill to be sent elsewhere and because we had no cubicles. For example, in one ward block there were two male and two female wards separated by a central corridor. There were 28 beds in all; the larger had nine beds each, the smaller five. Repeated infections with this staphylococcus persuaded us to close and clean the ward block; all but four patients could be sent home or elsewhere. These remaining cases were confined to one small ward. Among the four, all men, was one with a sinus in the hip infected with the staphylococcus and also a pseudomonas. All other beds were stripped, disinfected and made up with fresh linen and the ward cleaned thoroughly. This was completed by 4 p.m. on one day. At 10 a.m. the following day the beds were sampled by sweep plate. The staphylococcus was already present on 11 of the unoccupied beds, the pseudomonas was on nine. Both were together on seven of these. This patient was a profuse skin shedder.

Attempts at fumigation with formalin vapour were also disappointing. As judged by the usual testing methods, using plates inoculated with a suitable tracer organism and distributed about the room during fumigation, formalin was successful in small wards. A large ward with 27 beds was prepared for fumigation by sealing the windows, a process taking more than a day for two of the maintenance staff. The method of distributing jars containing formalin solution at intervals and then dropping in permanganate of potash was attempted. So violent and unpleasant was the result that they were driven out after only one end had been dosed. The local fire officer sent a team with closed-circuit respirators to repeat the job; this time all pots were activated. Unfortunately plates were not sterilized and 3 days' work was lost. It was clear that only true isolation could solve our problem.

The isolation ward

The only space in the hospital that was free was a floor used as nurses' bedrooms. There appeared to be room for eight cubicles, with the necessary service areas. It was planned to divide the space so that four cubicles could be used for highly infected cases, and the remainder for those needing protective (or reversed) barrier nursing. The latter cases included kidney grafts, aplasias, and similar blood conditions. The committee planned the unit with an air-lock and facilities for changing, between the clean and infected areas. Perhaps fortunately, when the unit opened some months later, one cubicle, the changing area and the air-lock had become a laboratory; it was some time before I realized what had happened.

The sister appointed to take charge of the unit had recently left the Navy, so, when instructed to take both clean and infected cases and to nurse them together, she obeyed orders and did so. At the end of 3 months it was realised just what was happening, but it was also realized that no cross-infection had taken place. The situation was allowed to continue but with the more careful monitoring of the staphylococci of all patients and staff (this has continued until now, 8 years later) The next 6 months' record is given in Table 2.

Table 2. *Mixed barrier nursing: six months' record of seven cubicles*

Infected cases	40
For protective isolation	15
Staphylococcal carrier state	
Uninfected, not a carrier	15
Infected with hospital strain	
Became a carrier	11
Did not become a carrier	10
Carried own strain	2
Infected with own strain, carried own strain	4
Infected with other organisms	
No *S. aureus* carried	8
Carried own strain	3
Carried hospital strain	2

Carriage in the last two patients began outside the unit.

A second major innovation was similarly introduced by accident. It was intended that each cubicle should be entirely self-contained and that nothing should be moved out or in, except food. Everything possible was to be incinerated, and linen sent to the laundry in sealed bags. All was ready for the ward to open when it was found that nothing had been provided for the nurses to wear. As the situation was serious and the beds urgently needed, we sent out and bought housewives' plastic aprons and plastic overshoes, and these formed, and still form, the total protective clothing used, supplemented only with an unlimited supply of sterile gloves. No masks, gowns or head coverings were issued; so that the preparation consists of putting on shoe-covering, or a special pair of shoes or sandals which never leave the unit, and an apron and gloves; similar views have been presented by Hare (1964). After attending a patient, the nurse washes her apron with a sponge from a bowl of 2% benzalkonium chloride, the gloves having been washed on the hands in the cubicle hand basin, then dries off the apron and gloves on a paper towel and goes on with the next case. This modification to the traditional ritual saved at that time £500 p.a. With our present 14-bedded unit, now in the maids' attics, and the grafting unit replacing the previous isolation ward, the saving in laundry alone is about £1,500 p.a. The number of nurses required where there is no robing and scrubbing-up ritual between cases is far less than with more elaborate methods.

Incineration

The reasonable idea that no infected material should be carried through the hospital led to a fiasco. An incinerator was built into the unit next to the sluice and leading from it; it was hoped that all disposable dressings and similar materials would be burnt. The amount of material was underestimated and so the fire blazed night and day. This added greatly to the work of the night staff when no porters were available. The shovel was so heavy that clearing the ashes was a phsyical impossibility for the smaller nurses and maids. The heat generated in a room with limited ventilation stripped the tiles from the walls and split the brickwork. The disposable rubbish is now collected in paper bags which have the closed top turned over and stapled; they can then be taken safely to the main boiler house.

Visitors

The contribution of visitors to the pool of infectious organisms required study. We already had information on shoes; it was necessary to examine the clothes also. Three batches of persons were examined, visitors, porters and house officers; swabs were taken from the trouser turn-ups and cultured. Visitors had no pathogens there; house officers up to 3000 staphylococci per turn-up of the epidemic type; the porters were intermediate. The second sister on the ward had had psychiatric training, and she pointed out the need for unlimited visiting. This is now permitted, the only precautions being that the visitors, like anyone else, wear overshoes. All patients also have television sets, which are self-sterilizing inside and merely need a wipe over with antiseptic on the casing. It was the same sister who insisted on the ward being given a name, as this removed the supposed stigma from isolation, which is connected in the mind of the public with 'pest house'. Once patients were in the ward the special care was appreciated. One patient, with experience of both a London nursing home and our own private beds, on leaving thanked the sister, saying that she would advise all her friends that if they had to be ill they should be sure to be septic.

Barrier mats

The realization that staff and visitors on their shoes and the trolley wheels carried numbers of organisms persuaded us that some sort of antiseptic barrier was required. Overshoes such as those used in the chemical industry were provided, but any plastic or rubber shoe or sandal will serve. These are adequately disinfected every time they pass over an antiseptic mat; The inside flora is unimportant. They are not sterile but their organisms are diluted to a safer number; operating-theatre counts are not required in corridors. We have tried cellular mats filled with liquid antiseptic; these make a mess of the corridors: mats with sticky surfaces which always look dirty; it is possible to step round the edges because of their small size; and plastic fibre carpets with static charges which hold dust. All appear to work, as the count of organisms on the floor beyond is much less than the approaches. Sponge rubber or cellular plastic sheet is useless as it is torn to pieces by trolley wheels. Detergent antiseptics should be used as they destroy

ordinary shoes by detaching the soles, so people soon learn to use the overshoes provided. The mat must block the corridor completely and be not less than two paces long; no one will actually wipe his feet.

The conclusions we have reached are very close to those of Ayliffe *et al.* (1967). Mats are useful if used with overshoes. They also serve to reduce the numbers of persons tramping through the unit and were they chemically useless might still serve a valuable psychological purpose.

Antiseptics

Although the indiscriminate use of antibiotics is probably the most wasteful thing in the hospital budget, the careless use of antiseptics must run it a close second in some places. We ourselves began to bring order into the chaos by limiting the range and concentrations. For example, four preparations of iodine were in use ranging from 0·5 % to 2 %; three were made up in full strength spirit. We reduced the range to one and at the same time saved over £1000 p.a. by diluting all spirit used as an antiseptic or a vehicle to 70 % and so increased its bactericidal power. The total number of antiseptics was reduced to one of each type; this gave economy in buying, storing and dispensing. Care was taken to see that none were incompatible with the detergents used in cleaning. After this our failures were due to misunderstandings.

A hypochlorite preparation was chosen for use in sinks and sluices. While drinking coffee, we were nearly choked by the reek of chlorine from a nearby cubicle. The maid was pouring the neat solution all over the floor. It was found that the consumption had risen to £500 in three months. The reaction of the supply department was to arrange a bulk contract. This brought in an unlimited number of gallon containers with handles and spouts. These being plastic were ideal for filling car radiators, batteries and greenhouse heaters, so the maids were encouraged to empty them. It was clear also that the maids had no idea of the working strength. The supply department had issued instruction in English, saying how many ounces should be used to the gallon; the maids spoke only Italian or Spanish and understood only litres. The amount used by them in three months if properly diluted would, at working strength, have filled a standard swimming bath three times. The dilution and distribution was placed under the pharmacist. In his hands the cost in the next three months fell to £22 10*s*.

A similar situation occurred with our stock solution of benzalkonium chloride. When it was discovered that this was being used undiluted measures were ordered for each ward. This produced no improvement, and when asked, the sisters assured me that no measures had arrived. They were found in the instrument cupboards marked 'For lotions only'. No one knew that lotions were antiseptics so had not used them for anything. We solved the problem by tying a red plastic mug to the handles of the buckets and adjusting the stock so that one mug went to a bucket of water. Field trials showed that the average maid half fills a bucket.

It is assumed that instructions given to domestic staff will be carried out; they, however, introduce their own modifications. There were a series of Gram-negative infections, chiefly with pseudomonads, in the renal graft unit. A phenolic

disinfectant was demanded as a substitute for the benzalkonium chloride previously used. Within a few days complaints were received that the floors were filthy. This was due to the interaction of the rubber soles of overshoes and the antiseptic, the black marks left were almost indelible. Help was sought from the domestic staff of the hospital popularizing this phenolic. Their supervisor explained that they used the antiseptic as instructed and immediately neutralized it with a detergent. The medical staff were satisfied with the smell of phenol, the domestics with the clean appearances of the place. The fact that the phenol was given no time to act had not appeared to them important. The benzalkonium preparation that had been used throughout, although in the laboratory apparently inadequate against pseudomonads, did in fact leave the floors free of them when used.

The infections in this unit led to extensive investigation of the environment. Among the places from which pseudomonads were recovered were the plastic mop-heads—not only those in use but those fresh from the factory. Leigh & Whittaker (1967) showed that the benzalkonium chloride was neutralized by the mop. A full confirmatory study has now been made by Colquitt & Maurer (1969), who compare a number of antiseptics and the effects of mop materials.

RESULTS

Very fortunately soon after the work began a staphylococcus phage-typing unit was established by Professor R. E. O. Williams and it was this that enabled us to record the phage type of every organism isolated from the weekly swabbing of all staff and patients' noses and all wounds.

On the evidence so obtained we can state that there has been no cross-infection of clinical significance since the unit was opened. It should be pointed out that patients with aplasia, leukaemia, burns, radiation accidents and those on immunosuppressive drugs have been nursed by the same nurses at the same time as they were also nursing the most infectious septic cases in the hospital; the two groups were in succession in the same cubicles, or next to one another at the same time.

Up to the end of the experimental period of 9 months, nasal cream containing antiseptics and antibiotics was used. The observation that patients carrying their own strains of staphylococci in the nose did not acquire other strains either from the environment or from their wounds encouraged us to discontinue nasal creams and there is no clinical evidence that this was wrong. Although no clinical cross-infection has occurred there has been a low level of cross-contamination of the environment detected when persistent and exhaustive studies were done as part of an intensive study of the ventilating system (Williams & Harding, 1969).

The most severe test of the adequacy of the method used was in the case of a young woman who had elsewhere been given three times the maximum dose of radioactive gold. The complete aplasia from which she suffered showed no signs of recovery for 7 weeks but recovery was subsequently complete. During her whole illness she developed no infections.

The importance of the technique of barrier nursing and of cleaning demands special teaching efforts. Particularly with the maids, who at the start know little

English, 'in post' teaching is required. The King Edward Hospital Fund, at the Hospital Centre, arranged for teaching films to be made by us with Camera Talks. At least now everyone knows what is supposed to be done daily, weekly and after an infectious case.

The success of the teaching has brought its own troubles. Two luxury hotels have recently opened in our area; the first took 32 of our best girls and the second another 18; this is a tribute to the teaching but not to the pay scales, nor do our staff quarters compare with those in a hotel.

Assessment of a campaign against cross-infection is particularly difficult since the organism at first most important in our hospital, the penicillinase-producing *Staphylococcus aureus*, can now be treated with a range of antibiotics and no longer dominates the picture. Indeed our problems are with organisms of relatively low pathogenicity, which have taken advantage of situations of lowered immunity in the patients on steroids or immuno-suppressive drugs, and which are as likely originally to have formed part of the normal flora of the patient or part of the hospital environment.

We have, however, attempted in two ways to measure our results. The first is to record the staphylococcal coincidences, the occurrence of the same phage type in two cases in the same ward or unit within a month. In the case of infections in the new-born this is ignored since we know that in them all infections are hospital infections.

Table 3. *Staphylococcal cross-infections*

Year	Staphylococcal coincidences	Total staphylococcal infections	
1959	460	—	Incomplete record
1960	240	—	Incomplete record
1961	80	376	—
1962	113	456	50 maternity beds and cots added
1963	133	408	—
1964	130	598	Surgical operations up 1200
1965	74	623	Cubicles up by 14
1966	93	717	—
1967	95	341	—
1968	28	426	—
1969	36	367	—

Table 4. *Post-operative infections for four random weeks in each year*

Year	Type of operation	Total number	Infected on admission	Chest infections	Wound and urine infection
1965	Major	335	0	9	11
	Minor	82	0	0	0
1966	Major	208	14	15	11
	Minor	141	1	0	0
1967	Major	111	11	6	6
	Minor	153	5	0	0
1968	Major	65	4	4	11
	Minor	162	4	0	0

In Table 3 the amount of staphylococcal infection in the wards is given as a measure of the total risk against which the failure rate in the first column must be judged. Certain of the isolates were from carrier sites but the majority were frank infections; the same organism, no matter how many times it was isolated from different sites or lesions in the same patient, was counted once only.

The second check was introduced more recently to silence sceptical colleagues who thought our results too good. Using random number tables, 1 week in each quarter of the year was taken; the notes of every surgical case discharged in these weeks were examined for clinical, laboratory or therapeutic evidence of infection. Table 4 gives the results.

Attempts at assessing the changes over a longer period are not valid because of the changing nature of surgery. In 1959 the commonest operation was for varicose veins, now it is some form of arterial or intra-thoracic surgery.

DISCUSSION

It is difficult to suggest which of many factors was responsible for our satisfactory results. Morale improved as methods became standardized throughout the hospital. Proper cleaning and improved methods of handling laundry were probably useful, but the provision of cubicles where barrier nursing and reversed barrier nursing were possible was more important than all other measures together. The rules must be ruthlessly enforced on paper-boy, priest and physician alike.

The cost of establishing units of our type is one-tenth that of more usual ones. The equipment for a nurse is £1 5*s*. for 9 months, excluding disposable gloves. We were surprised to find that 14 beds were sufficient to meet the needs of a 450-bedded hospital. The success of the cubicle system supports entirely the views of Williams *et al.* (1966) that barrier nursing depends for its success on separate rooms for each patient. Throughout it must be remembered that the private block, in which separate rooms were the only factor differentiating the care from that of general ward patients, had only one staphylococcal coincidence, yet just as much sepsis is admitted here, since a considerable number of cases are flown in because surgery has failed abroad, or the condition is too advanced for local surgeons to take on.

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FILM STRIPS AND LOOPS. I: *Hospital Cleaning*. 1, 2: Daily cleaning in the ward area. 3: Cleaning of baths. 4: Cleaning of basins. 5: Cleaning of toilets. 6, 7: Washing up. Produced by Camera Talks Ltd. II: Barrier Nursing, with three loops.