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Protective isolation in a burns unit: the use of plastic isolators and air curtains

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SUMMARY

The use of plastic isolators and of an 'air curtain' isolator for protection of patients against infection was studied in a burns unit.

Preliminary bacteriological tests showed that very few airborne bacteria gained access to a plastic ventilated isolator; even when the filter and pre-filter were removed from the air inflow, settle-plate counts inside the isolator were much lower than those in the open ward, but the difference was smaller in tests made with an Anderson air sampler, which showed also that fewer large bacteria-carrying particles appeared inside the isolator than outside it. An open-topped isolator allowed virtually free access of bacteria from ambient air. The numbers of airborne bacteria inside an air curtain were appreciably lower than the counts of airborne bacteria in the open ward, but not as low as those in the plastic ventilated isolator.

Controlled trials of isolators were made on patients with fresh burns of 4–30% of the body surface; the patients were given no topical chemoprophylaxis against *Staphylococcus aureus* or Gram-negative bacilli. Patients treated in plastic isolators showed a significantly lower incidence of infection with *Pseudomonas aeruginosa* than those treated in the open ward; this protective effect was shown by isolators with or without filters or with an open top. Ventilated isolators, which protected patients against personal contact and airborne infection, gave a limited protection against multi-resistant 'hospital' strains of *Staph. aureus*, but no such protection was given by an open-topped isolator, which protected only against personal contact infection, or by air curtains, which protected only against airborne infection; the air curtain gave no protection against *Ps. aeruginosa*, and there was no evidence of protection by any isolator against *Proteus* spp. and coliform bacilli.

Both the controlled trials and evidence from the bacteriology of air, hands, fomites and rectal and nasal swabs taken on admission and later, supported the view that *Ps. aeruginosa* is transferred mainly by personal contact, *Staph. aureus* probably by air as well as by contact and coliform bacilli mainly by self infection with faecal flora, many of which are first acquired from the hospital environment in food or on fomites.

The use of plastic isolators is cumbersome, and of limited value except in the control of infection with *Ps. aeruginosa*. For this reason and because of the effectiveness of topical chemoprophylaxis such isolators are unlikely to have more

than an occasional use in the treatment of burns. Though air curtains greatly reduce airborne contamination, their use in a burns unit does not appear to protect patients against infection when the alternative (and, for *Ps. aeruginosa*, more important) routes of contamination by personal contact and fomites are left open.

INTRODUCTION

Patients with uninfected burns are commonly assumed to require protective isolation in hospital (e.g. Colebrook, 1950; U.S. Public Health Service, 1970). In this hospital the subdivision of an open ward into cubicles and the subsequent installation of air conditioning units in the cubicles did not lead to any fall in the incidence of infection with *Streptococcus pyogenes*, *Staphylococcus aureus* or *Pseudomonas aeruginosa* (Cason, Jackson, Lowbury & Ricketts, 1966). It appeared that the protection given by such structural barriers was insufficient, and that a more effective system should be sought. One method which would be expected to give better protection was the use of plastic isolators. This type of equipment, originally developed for the study of germ-free animals (Reyniers & Trexler, 1943), has been adapted for use in the treatment of burns by Levenson, Trexler, La Conte & Pulaski (1964) and Levenson *et al.* (1966) and by Haynes & Hench (1966); it offers protection against bacterial contamination transferred both by contact and by air. Another method, which offers protection only against airborne contaminants, is the use of special systems of ventilation, such as unidirectional ('laminar') air flow (Lidwell & Towers, 1969) and of air curtains surrounding the patient's bed.

In the studies reported here we have examined the value of plastic isolators and of air curtains in the treatment of freshly burned patients. Controlled trials were made to assess the frequency of infection with the common pathogens of burns. The relative importance of airborne and of personal contact transfer was studied in a comparison of isolators which gave protection against one or the other of these routes, or against both of them.

THE ISOLATORS

Plastic isolators

The Vickers patient isolator was adopted for study after preliminary investigation of some other systems, including an isolator made of rigid plastic. The Vickers isolator (Model 55) consists of a 'canopy' of transparent, flexible plastic (polyvinyl chloride) which is suspended on a metal framework attached to the bed (see Pl. 1, fig. 1); when closed and inflated the canopy completely envelops the patient and rests on the mattress. On each side of the canopy are five glove ports for aseptic handling of the patient, and a pouch with inner and outer zip fasteners, the inner one being opened and closed from the inner aspect through a glove port; one pouch is for the supply of clean or sterile materials to the patient, the other for removal of discarded and contaminated objects.

To admit a patient, the canopy is opened by a zip fastener which runs along the upper surface from one end to the other. When this is closed, the canopy is inflated

and ventilated with air pumped from the ward by a quiet centrifugal fan unit through a coarse pre-filter of spun nylon, to trap the larger dust particles, and a main filter of glass paper with an efficiency of more than 99·9% against particles down to 0·58 μm. in diameter. The coarse filters were changed weekly; the fine filter was changed after 12 months use. The fan unit delivered air at approximately 40 ft.^{3} per min.

During the study many improvements were made in the design of the isolators, based on observations of their use in the treatment of patients with burns. Special modifications included a ventilated half-suit to allow better access by the nurses to all parts of the enclosure. In one of the trials an isolator was used without a main filter, in another both main filter and pre-filter were removed. For the last trial in this series an open-topped canopy was used (Pl. 1, fig. 2), providing free circulation of air to the patient; this isolator protected the patient only against personal (especially manual) contact transfer of bacterial contaminants.

Air curtains

The 'Sterair' Patient Isolator (W.H.S. Pathfinder Ltd.) was used to provide air curtains around the patient's bed; its appearance and mode of action are shown in Pl. 2, figs. 3 and 4. Air is pumped from the open ward by a quiet fan unit in the console at the head of the bed through coarse pre-filters, one on each side of the console, and then through a main filter. The horizontal canopy above the bed has parallel linear apertures on its lower surface, from which air sweeps downwards at a low velocity over the bed, and downwards and outwards from a peripheral aperture at a higher velocity around the bed, with a total turnover of about 1200 ft.^{3} per min.; the peripheral air flow acts as the air curtain. The efficiency of the pre-filters (woven cotton) or glass fibre is stated to be 98% on particles of 5–10 μm., and that of the main filter (glass fibre) to be more than 99·9% for particles of 0·3 μm. The coarse filters were checked by daily tests with an anemometer, and when the air flow rate began to fall a new filter was inserted; such replacement was usually needed every 3 or 4 weeks.

BACTERIOLOGICAL STUDY ON ISOLATORS

Tests were made in empty isolators to assess the degree of protection they provided against contamination with airborne bacteria.

Plastic ventilated isolators

Groups of 6–12 settle plates containing phenolphthalein diphosphate agar (Barber & Kuper, 1951) were exposed for 6 hr. on the bed in the isolator and on tables at about the same level outside the isolator. The plates were incubated at 37° C. overnight, and the total numbers of colonies were counted. Viable counts of airborne bacteria inside and outside the isolator were made on phenolphthalein diphosphate agar plates exposed in an Anderson sampler, from which the bacteria-carrying particle-size distribution could also be assessed. In some experiments

presumptive *Staph. aureus* colonies were counted (i.e. colonies of staphylococcal type giving a positive phosphatase reaction after exposure to ammonia vapour).

Separate tests were made on isolators provided with coarse and fine filters, with coarse filters only and with no filters.

Results

The results are shown in Tables 1 and 2. Mean settle-plate counts obtained outside the isolator were 46·7, compared with mean counts of 0·1 in an isolator with filter and pre-filter and 1·0 in an isolator with neither filter nor pre-filter; this

Table 1. *Airborne bacteria inside and outside plastic ventilated isolators*

	Settle plate counts*		Andersen sampler counts (total per ft.^{3} of air)		
	Mean counts per plate	No. of observations	Expt. 1 (quiet ward)	Expt. 2 (busy ward)	Expt. 3 (quiet ward)
Isolator with filters	0·1 (range 0–0·4)	5	0·2	<0·01	0·03
Isolator with coarse filter only	—	—	—	0·5	0·22
Isolator with no filter	1·0 (range 0–2·2)	10	1·2	—	0·13
Open ward	46·7 (range 11·0–82·8)	15	2·4	7·3	2·3

* Mean counts of colonies on 3½ in. (8·8 cm.) plates exposed for 6 hr. Each observation represents a sampling with a number of settle plates on one day.

showed that air pumped into the isolator with no filters lost a considerable proportion of its bacterial content, presumably through deposition in the duct conveying air from the fan unit to the canopy. The tests with an Andersen sampler showed a smaller difference between the airborne bacteria in the open ward and those in the isolator without filters than between settle-plate counts from the same areas; from which it could be inferred that most of the bacteria settling in the air-duct were carried on the larger particles – a conclusion supported by the size distribution of bacteria-carrying particles (Table 2). Most of the bacteria in the open ward during a busy period were carried on particles of 5·5 μm. and above, but in isolators with no filter or with a pre-filter only, the majority of airborne bacteria were carried on particles ranging from 1 to 2 μm. in diameter; these included some staphylococci. Very low counts (in Expt. 2 no detectable bacteria) were obtained in samples from the isolator with both coarse and fine filters.

Open-topped plastic isolator and air-curtain isolator

A Vickers plastic isolator with open top was used to assess protection of patients against personal (especially manual) contact transfer without control of airborne infection; in the trial, it was compared with a 'Sterair' patient isolator in which air curtains control the access of airborne bacteria without affecting the transfer of bacteria by contact. Before the clinical trial, sets of 5–10 settle plates were

Table 2. *Particle size distribution of bacteria inside and outside plastic ventilated isolator*

Estimated particle size	Expt. 1. (quiet ward) (viable counts per 30 ft.³ of air)				Expt. 2 (busy ward) (viable counts per 60 ft.³ of air)			
	Isolator with filters	Isolator with coarse filter only	Isolator with no filter	Open ward	Isolator with filters	Isolator with coarse filter only	Isolator with no filter	Open ward
9·2 μm. and above	1	—	1	15* (1 *Staph. aureus*)	0	0	—	145
5·5–9·2 μm.	2	—	3 (1 *Staph. aureus*)	15 (1 *Staph. aureus*)	0	1	—	109
3·3–5·5 μm.	0	—	5	19	0	0	—	79
2·0–3·3 μm.	2	—	6	11	0	7	—	63
1·0–2·0 μm.	0	—	19 (2 *Staph. aureus*)	11	0	22	—	42
Less than 1·0 μm.	1	—	1	0	0	0	—	0

* *Staph. aureus* were counted only in Expt. 1.

exposed for 6 hr. simultaneously on the unoccupied bed inside each isolator, on a table outside the isolator but close to it, and on a table at some distance from the isolator (at one end of the ward).

Results

The results are shown in Table 3. The mean settle plate counts inside the open-topped isolator were only slightly lower than those on settle plates exposed outside but next to the isolator, which was standing in a cubicle with door open to the ward but little traffic through it; though much higher counts were obtained on plates exposed in the open ward which was full of patients than in the unoccupied cubicle, the small difference between settle plate counts in the cubicle and in the isolator was taken to indicate a free circulation of airborne bacteria from the environment to the isolator; the slightly higher counts obtained outside the isolator were probably due to the settlement of heavier particles which would not reach the top of the canopy.

Table 3. *Settle plate counts inside and outside isolators*

	Mean settle plate counts (total)*		
Isolator	Inside isolator	Outside isolator (near bed)	Open ward (remote from bed)
Air curtains ('Sterair' unit)	9·2 (range 2·5–16·8)	29·0 (range 20·5–42·9)	90·6 (range 50·5–179·8)
Open-topped plastic isolator	16·7 (range 9·3–21·5)	23·6 (range 17·2–31·5)	98·3 (range 79·0–153·3)

* Five tests were made in each isolator, with five or six plates exposed for 6 hr. in each test.

The mean settle-plate counts inside the air curtain were about one tenth of the mean counts in the remote ward air; the ward air near the air curtain gave lower settle-plate counts than remote ward air, presumably because of the removal and recirculation of air from this zone through the filters of the 'Sterair' isolator.

CONTROLLED TRIALS OF ISOLATORS

Three trials were made on patients in the Burns Unit of this hospital, with the following treatment and control groups:

Trial 1. Treatment in (*a*) plastic ventilated isolator with coarse filter (pre-filter) and main filter; (*b*) plastic ventilated isolator with pre-filter only; and (*c*) the open ward (control group).

Trial 2. Treatment in (*a*) plastic ventilated isolator with pre-filter and main filter; (*b*) plastic ventilated isolator with neither main filter nor pre-filter; and (*c*) the open ward (control group).

Trial 3. Treatment in (*a*) plastic isolator with open top; (*b*) 'Sterair' isolator (air curtains); and (*c*) the open ward (control group). The purpose of this trial was mainly to assess the relative importance of airborne and direct contact contamination and the effect of barriers against each of these routes of contamination used separately.

Conduct of trials

In each trial patients with burns of between 4 and 30% of the body surface, if considered eligible on clinical examination, were allocated in rotation to treatment groups (*a*) and (*b*) and to the control group (*c*). Patients were kept in these groups for periods up to 3 weeks.

Local treatment of burns was by exposure method or (more usually) by application of a cream containing penicillin (1000 units per gram) covered with dressings of gauze, cotton-wool and crêpe bandage; penicillin cream was applied for protection against *Strep. pyogenes* only (Lowbury, 1960). Cloxacillin (250 mg. 6-hourly) was given by mouth to all patients in the first week, partly as prophylaxis against tetanus in those not known to be immune. Specific chemoprophylaxis against *Staph. aureus* and Gram-negative bacilli was not used; when such treatment was needed, patients were not put into the trial of isolators.

In Trial 3 a degree of barrier nursing was used for all patients in isolator and control groups; the precautions included individual washing bowls and bed pan supports, which were disinfected after use, and separate supplies of bed linen; they did not include the use of plastic or rubber gloves, apart from those incorporated in the plastic isolators. Barrier nursing was not used for the control groups in Trials 1 and 2.

Bacteriology

Swabs moistened with peptone water were taken from burns at every change of dressings, or daily if treatment was by exposure; the swabs were inoculated on horse blood agar (with 4% New Zealand agar), on 0·03% cetrimide agar and in cooked meat broth, which were incubated at 37° C. and examined in the manner described by Lowbury (1960) and Cason *et al.* (1966). Nasal swabs were taken daily and examined for coagulase-producing staphylococci (*Staph. aureus*). Antibiotic sensitivity tests were made by a ditch plate method (Topley, Lowbury & Hurst, 1951; Davis, Lilly & Lowbury, 1969) on all strains of *Staph. aureus* from burns and noses. Stool specimens or, if stools were unobtainable, rectal swabs were taken from all patients on admission and at intervals during the course of treatment; these were examined for Gram-negative bacilli by the methods used for burn swabs.

Results

Table 4 shows the comparability of patients in the treatment and control groups of the trials. The age of patients, areas of burn, and proportion treated by cover and by exposure methods fell within a similar range in each group.

Table 5 shows the incidence of infection of burns with *Staph. aureus* resistant to two or more antibiotics (multi-resistant or 'hospital' strains), *Ps. aeruginosa*, *Proteus* spp. and miscellaneous Gram-negative bacilli (coliform bacilli) in the trials of plastic ventilated isolators (Trials 1 and 2). Results entered as '+' refer to growth occurring on blood agar as well as in liquid medium; 'CM' refers to growth occurring only in liquid medium (cooked meat broth) and therefore very scanty.

Patients treated in isolators had a significantly lower incidence of infection with *Ps. aeruginosa* (4/37, 11%) than those in the control group (11/17, 65%) ($\chi^2 = 14{\cdot}5$, $P < 0{\cdot}001$); this applies to patients in isolators without filters as well as to those in isolators with filters. Though multi-resistant *Staph. aureus* appeared on burns more often in the open ward than in isolators, the difference was not significant. *Proteus* spp. and miscellaneous coliform bacilli appeared on burns at least as often in isolators as in the open ward.

Table 4. *Controlled trials of isolators: comparability of groups*

	Trials 1 and 2			Trial 3		
	Group *a*	Group *b*	Group *c*	Group *a*	Group *b*	Group *c*
Number of patients...	20	17	17	10	10	10
Number in age groups:						
<5	5	10	7	5	5	9
5–10	6	4	4	2	3	1
10–20	7	2	4	2	2	0
20–30	1	0	2	0	0	0
>30	1	1	0	1	0	0
Mean area of burn (%)	13·5	17	14	11	9	11
Range (%)	(4–30)	(7–19)	(5–30)	(6–20)	(5–13)	(8–20)
No. treated by covered method	15	12	15	6	5	8
No. treated by exposure method	4	2	1	2	5	1
No. treated by mixed covered and exposure methods	1	3	1	2	0	1

Table 6 shows the frequency of nasal acquisition in Trials 1 and 2 of multi-resistant *Staph. aureus*; such colonization occurred more often (during the first week significantly more often) in the control series than in the patients treated in isolators. Like the burns, the noses of patients treated in isolators often acquired hospital staphylococci, showing the limited effects of protection against airborne and personal contact transfer with very incomplete control of contact transfer by fomites or food.

Table 7 shows the colonization of burns by different groups of bacteria in the treatment and control groups of patients in Trial 3. The numbers of patients are small, but this trial, like Trials 1 and 2, showed a significantly lower incidence of *Ps. aeruginosa* in the burns of patients treated in the plastic isolator than in those treated in the open ward, though in this trial the isolator had an open top allowing circulation of air from the ward to the patient. By contrast, patients treated in the 'Sterair' isolator behind air curtains showed as high an incidence of *Ps. aeruginosa* infection of burns as those in the open ward. The other groups of bacteria appeared as often in the burns of patients treated in the open-topped plastic isolator and in the 'Sterair' isolator as in those treated in the open ward. Multi-resistant ('RR') *Staph. aureus* was less often acquired by patients in the control group of this trial than in those of Trials 1 and 2, possibly because of the use of some barrier nursing

Table 5. *Controlled trials of plastic isolators: bacterial infection of burns*

	Staph. aureus (multi-resistant)			*Ps. aeruginosa*			*Proteus* spp.			Coliform bacilli			
Patients in	+	CM	%+ or CM	+	CM	%+ or CM	+	CM	%+ or CM	+	CM	%+ or CM	Total patients
Isolators with filters	12	1	65	2	0	10	9	3	60	17	1	90	20
Isolators with coarse filters	4	1	55·5	1	1	22·2	3	1	44·4	7	1	88·8	9
Isolators with no filters	3	2	62·5	0	0	—	1	2	37·5	7	0	87·5	8
Isolators (all types)	19	4	62·2	3	1	10·8†	13	6	51·1	31	2	89·2	37
No isolators (control)	10	4	82·3	11	0	64·7†	3	2	29·3	16	0	94·1	17

† $\chi^2 = 14{\cdot}5$, $P < 0{\cdot}001$.

+ = growth on solid medium. CM = growth only in fluid medium (cooked meat).

techniques in the control series of Trial 3. In contrast with the findings on ventilated isolators in Trials 1 and 2, there was no hint of any protective effect against *Staph. aureus* by treatment in the open-topped isolator or in the 'Sterair' isolator.

Table 6. *Controlled trial of plastic isolators: acquisition of* Staph. aureus (*Trials* 1 *and* 2)

Patients in		Multi-resistant *Staph. aureus* (+ and CM)				Total patients
		In burns		In nares		
		Patients	%	Patients	%	
Isolators	Whole period	23	62†	20	54†	37
	1st week	15	40†	9	24*	
Control series	Whole period	14	82†	14	82†	17
	1st week	11	64†	10	59*	

* $\chi^2 = 4{\cdot}4$, $P < 0{\cdot}05$. † Not significant.

PROBABLE SOURCE OF INFECTIONS

Cross infection and self-infection

Table 8 shows the incidence on admission of multi-resistant *Staph. aureus* in the nose and of Gram-negative bacilli in rectal swabs and stools of patients in the trials of isolators, in relation to the subsequent isolation of these organisms from the patients' burns. Out of 43 patients whose burns subsequently yielded *Staph. aureus*, only three had such an organism in the nose on admission. *Ps. aeruginosa* and *Proteus* spp. were usually absent from admission rectal swabs, though often acquired by burns later; other Gram-negative bacilli were usually present in rectal swabs on admission, but these did not include multi-resistant *Klebisiella* spp. which often appeared subsequently in burns. The results suggest that *Staph. aureus*, *Ps. aeruginosa*, *Proteus* spp. and *Klebsiella* spp. are usually acquired by cross-infection, while other Gram-negative bacilli (in particular *E. coli*) are acquired by self-infection from the patients' intestinal flora.

The predominance of cross-infection over self-infection with *Ps. aeruginosa* is also shown by the results of typing (see Table 9). Of the six patients from whom these data were obtained, two (Numbers 5 and 6) had *Ps. aeruginosa* in rectal swabs, one apparently acquired by cross-infection, but never had the organism in their burns. Another patient (Number 2) had *Ps. aeruginosa* in the burn but not in rectal swabs. One patient (Number 3) had two types of *Ps. aeruginosa*, both found in the Burns Unit; one never appeared in a rectal swab, the other appeared in a rectal swab after several previous negatives and after the same type had appeared in a burn. In one patient (Number 4) the rectal swab showed the strain of *Ps. aeruginosa* (of a type present in the Burns Unit) before it appeared in the burn, but there had previously been several negative rectal swabs. In patient Number 1 the strain (also of a type present in the Burns Unit) appeared at about

Table 7. *Controlled trial of isolators: air curtains and open-topped plastic isolator*

	Numbers of patients who acquired														
	In burns												In nares			
	Ps. aeruginosa			*Staph. aureus* RR			*Proteus* spp.			Coliform bacilli			*Staph. aureus*			
Isolator	+	CM	%+ or CM	+	CM	%+ or CM	+	CM	%+ or CM	+	CM	%+ or CM	+	CM	%+ or CM	Number of patients
'Sterair' isolator (air curtains)	5	0	50*	4	0	40	3	3	60	7	3	100	3	2	50	10
Open-topped plastic isolator	0	0	0*†	6	1	70	4	0	40	8	0	80	3	0	30	10
Controls (open ward)	5	0	50†	3	1	40	2	1	30	6	1	70	3	0	30	10

* and †: $\chi_c = 2{\cdot}06$, $P < 0{\cdot}025$ (see Fisher & Yates, 1948).

the same time in a burn and in a rectal swab, after a negative rectal swab on admission. From these data it appeared that infection was usually acquired in hospital, though sometimes acquired first by the alimentary tract, from which it was transferred to the burns.

Contamination from fomites

Bacteriological samples were taken from a wide range of items supplied to patients in the ward; cotton-wool swabs moistened with peptone water were used for the sampling, and the bacteriological examination was made in the same way as that of swabs from burns.

Table 8. *Carriage of bacteria by patient on admission and subsequent infection of burns*

Bacteria	Site of carriage on admission	Bacteria carried on admission: Not in burns later	Bacteria carried on admission: In burns later	Bacteria not carried on admission but in burns later	Total: Sampled for carriage on admission	Total: Patients
Staph. aureus (RR)	Nose	0	3	40	73	84
Ps. aeruginosa	Rectum	2	1	18	54	
Proteus spp.	Rectum	0	4	23	54	
Coliform bacilli	Rectum	4	41	4	54	

From a number of items, of which 172 specimens were sampled (see Table 10), bacteria were grown, sometimes in moderate but usually in small or very small numbers. Patients in isolators (and also in the control group during Trial 3) had their washing bowls and disposable bedpan supports disinfected with 0·5% aqueous chlorhexidine solution. The bacteria usually found were multi-resistant *Staph. aureus* and miscellaneous coliform bacilli; *Ps. aeruginosa* and *Proteus* spp. appeared each in one specimen only. Of the 45 specimens of food, nine were contaminated with coliform bacilli. Even if personal contact and airborne transfer were completely excluded from patients in isolators, these fomites-borne contaminants might be expected to cause infection with staphylococci and with coliform bacilli in many patients.

THE NURSING OF PATIENTS IN PLASTIC ISOLATORS

Most of the patients treated in plastic isolators were children, and these usually accepted the isolation without complaint, sometimes with pleasure. The plastic canopy was virtually no barrier to conversation, and the patient did not feel cut off. Moreover, the visiting parent could touch the child through glove ports and did not have to wear cap, mask and gown. Adults were, on the whole, less happy about a prolonged stay in the isolator, and for larger patients the model of isolator with which we were supplied was too small for comfort.

The nursing care of patients in plastic isolators presented many problems. Such simple procedures as washing the patient or giving him a drink could be exhausting

Table 9. *Types of* Ps. aeruginosa *in faeces or rectal swab and on burns of patients in plastic isolators*

			Ps. aeruginosa isolated						
			From burns			From faeces or rectal swab			
Patient	Date of admission	Isolator group	Serotype	Phage type	Date	Serotype	Phage type	Date	Comments
1	14. iv. 68	Pre-filter and filter	3	16/31/68/F8/109/119X/ 352/M6/Col 11	21. iv.	—	Not typed	22. iv.	Burns Unit strain; rectal swab on admission negative (i.e. no *Ps. aeruginosa*)
2	10. xii. 68	Pre-filter and filter	—	Not typed (one isolate only)	20. xii.	—	None isolated	—	—
3	9. iv. 68	Pre-filter only	(*a*) 5*c* (*b*) NT	7/F7/119X 119X	14. iv. 27. iv.	5*c* —	7/31/F7/119X Not isolated	17. iv. —	(*a*) Recent Burns Unit strain (*b*) Current Burns Unit strain. First 4 rectal swabs negative
4	1. viii. 68	Pre-filter only	NT	119X	14. viii.	NT	119X	11. viii.	Burns Unit Strain. First 4 rectal swabs negative
5	19. v. 68	Pre-filter only	—	None isolated	—	NT	119X	27. v.	Burns Unit strain. First 5 rectal swabs negative
6	29. vii. 69	No filter or pre-filter	—	None isolated	—	3	21/31/44/68/ F7/F8/109/119X	—	Not Burns Unit strain. First rectal swab negative

and frustrating to both nurse and patient. During the trials many improvements were made in the design of the isolator to facilitate nursing. Sleeves of glove ports were lengthened and made of more pliable material; the seams were strengthened, with the result that they did not often tear while in use; the canopy was enlarged (but further enlargement is needed); the zip fasteners were moved to more convenient positions. In spite of these improvements many difficulties remained, especially in the more complex nursing and clinical procedures, such as changing of dressings, passing of gastric tubes, setting up of infusions and taking of X-rays, especially in a wriggling and screaming child. The change of dressing required an extra 15–20 min. compared with the usual time. Bandages applied in isolators

Table 10. *Contamination of various items issued to patients*

Items	Number of samples	Number of samples contaminated with: *Staph. aureus** +	*Staph. aureus** CM	Gram-negative bacilli +	Gram-negative bacilli CM
Books, papers, etc.	20	—	—	2	1‡
Washing bowls	16	1	3	—	3
Crockery, glassware	55	3	—	1	3
Cutlery	8	—	2	—	—
Clean pillows	7	1	—	—	1
Disposable bedpan supports	8	6	—	2	1†
Urine bottles	2	1	—	—	1
Toys	8	1	—	—	—
Receiving bowls	3	—	1	—	1
Foods (various)	45	1	1	4	5
Total	172	14	7	9	16

* All strains were found resistant to two or more antibiotics except those from food, which were not tested.

† *Ps. aeruginosa.* ‡ *Proteus* sp.

have tended to be insecure, and dressings have, in consequence, sometimes fallen apart. To overcome these difficulties an isolator with an invaginated 'half-suit' has been produced, but although this gave the nurse much better access to all parts of the isolator, she could not stand upright while wearing the half suit in such a small isolator. It has been easier to manage patients in the open-topped isolators, but even these were cumbersome.

One of the special difficulties has been to prop the patient in a comfortable sitting position. Lifting and turning a heavy patient are very difficult and, for some nurses, impossible. Although the patient can be seen clearly through the transparent plastic of a new canopy, after a few days the plastic becomes clouded and the inspection of the patient becomes more difficult.

USE OF ISOLATORS AND AIRBORNE BACTERIA IN THE WARD

Effect of ventilation on airborne bacteria

The Sterair isolator recirculated a large volume of air (about 1200 ft.^{3} per min.) through filters. This led to a reduction of airborne bacteria in the immediate vicinity of the isolator (see Table 3), but the effect was localized, and the mean settle-plate counts in the ward during periods when the Sterair fan was working (93·6 per plate, mean of 30 plates) were little lower than those found during periods when the fan was switched off (110·0 per plate, mean of 20 plates).

Change of filters

Viable counts of bacteria in the air of the ward were not increased during the careful removal and replacement of pre-filters. Mean total counts were 3·9 per ft.^{3} before (6 min. sampling), 3·7 per ft.^{3} during (4 min. sampling) and 3·0 per ft.^{3} after (6 min. sampling) the change of pre-filter.

Ps. aeruginosa *and other bacteria in air*

From the evidence of the controlled trials it appeared that *Ps. aeruginosa* was transferred by contact but not by air. Air sampling with a slit sampler on cetrimide agar has shown very few colonies of *Ps. aeruginosa* in the air of the ward. At a time when a patient heavily infected with *Ps. aeruginosa* was in the ward, three samples of 414 ft.^{3} of air showed no colonies of *Ps. aeruginosa* on cetrimide agar; when the infected patient made vigorous movements, three colonies of *Ps. aeruginosa* were obtained in a sampling of 414 ft.^{3} taken next to her bed. In air samples on phenolphthalein diphosphate agar taken on the same occasion, total counts ranging from 3·0 to 33 per ft.^{3} and presumptive *Staph. aureus* counts ranging from 0·1 to 2·4 per ft.^{3} were obtained. In the dressing station during the change of dressings of the patient heavily infected with *Ps. aeruginosa*, small numbers of *Ps. aeruginosa* were grown from the air; the highest count (about 0·1 per ft.^{3}) was obtained during the removal of old dressings. Colonies of *Proteus* spp. were almost as infrequent in air samples as those of *Ps. aeruginosa*.

DISCUSSION

The studies reported here were made in order to assess the efficacy of certain types of isolator when used for protective isolation of patients with burns; the practicability of nursing patients in such isolators; and the relative importance of airborne and personal contact transfer of bacteria, as judged by the protective value of isolators which blocked either one or the other or both of these routes.

Preliminary bacteriological tests showed that airborne contamination was largely excluded in a plastic isolator with filters; when one or even both filters were removed, there was still an appreciable exclusion of airborne bacteria, especially of those carried on larger particles which settle quickly (and are therefore likely to contaminate the patient). Air curtains also excluded a considerable

proportion of the bacteria carried by the ambient air, and the filtration of air recirculated by the 'Sterair' unit also led to some reduction in the airborne bacteria in the immediate neighbourhood of this isolator. In an open-topped plastic isolator, however, there was very little exclusion of airborne bacteria.

Because of the necessity of avoiding topical chemoprophylaxis in assessing the value of isolators, the controlled trials were made on patients with burns of small or moderate extent in whom the clinical hazards of infection were negligible. There was a constant and significant protective effect against *Ps. aeruginosa* in plastic isolators, whether filters were present or not, and even when the top of the canopy was removed. There was also a small protective effect against endemic hospital staphylococci (especially against early nasal acquisition) in ventilated isolators, but no hint of such an effect in the open-topped isolator; nor was there any evidence of protection against *Ps. aeruginosa* or *Staph. aureus* by the 'Sterair' isolator, or against *Proteus* spp. and coliform bacilli by any of the isolators.

These failures are disappointing, and show that a degree of structural segregation greater than that provided by air conditioned cubicles (Cason *et al.* 1966) was still insufficient to achieve a useful protective result except against *Ps. aeruginosa*. This is not surprising, for a single momentary break in the protective barrier during the course of 2 or 3 weeks is likely to allow penetration by contaminants, which are abundant in a burns ward. The plastic ventilated isolator gives considerable protection against airborne and personal contact (especially manual) transfer, but none against contact transfer by fomites or food, and these may have been the vectors that caused much staphylococcal infection even in isolators with filters; sampling of a number of items supplied to patients showed that these bacteria were often present on them. Although air curtains did not appear to prevent infection of burns, they reduced the amount of contamination with airborne bacteria, including staphylococci. The effects of reduced exposure to airborne staphylococci inside air curtains would probably become apparent if contamination with the same bacteria by manual and fomites-borne contact were as effectively controlled by barriers against these routes of infection.

The comparison of air curtains with an open-topped plastic isolator supported the view that *Ps. aeruginosa* is usually transferred by personal (especially manual) contact, more rarely by fomites, and not by air. This is consistent with the frequent presence of *Ps. aeruginosa* on the hands of nurses working in the Burns Unit and other areas where infection with the organism is common and with the rarity of *Ps. aeruginosa* in air samples taken in the ward (Lowbury & Fox, 1954; Lowbury *et al.* 1970). The airborne transfer of *Ps. aeruginosa* in a dressing station for burns (Lowbury, 1954) must be regarded as exceptional, and due to the dispersal of *Ps. aeruginosa* surviving in dried exudate on removing dressings from extensive, heavily infected burns. Evidence from typing of *Ps. aeruginosa* and from rectal swabs supports the view that self-infection is rare, though sometimes infection of burns may be preceded by ingestion of the organism and its excretion in the faeces. With the other types of bacteria, since there was little or no difference in the acquisition of these by patients in the two types of isolator and in the controls, it seems that neither airborne nor direct contact transfer plays the predominant role. Since

the combined protection against airborne and direct contact transfer reduced the amount of staphylococcal infection when protection against neither route by itself had this effect, it could be inferred that staphylococci were transferred both by air and by direct contact. Since much infection occurs when both routes are blocked, indirect contact contamination by fomites, food, etc., also seems important in the transfer of staphylococci.

The patients for whom isolators, if effective, might be considered potentially valuable are those with extensive burns. The protective value of isolators for such patients is likely to be smaller (certainly not greater) than it has been shown to be for the less extensive burns studied in our trials; the difficulty of nursing burned patients in isolators, however, is even greater when the burns are extensive than when they are of small or moderate severity. In view of the success of local chemoprophylaxis by silver compounds and other agents in keeping burns free from many types of bacteria, it seems unlikely that isolators will play a large role in the routine treatment of burns in hospital. But the significant protection by plastic isolators against *Ps. aeruginosa* gives this method a role in the treatment of certain patients, e.g. those in whom effective topical agents cause toxic or allergic effects. If their use is restricted to this extent, it might be practicable, from the nursing angle, to use the full range of precautions against contamination by food and fomites as well as against manual and other personal contact contaminations. But though improved design of isolators should facilitate their use in selected patients, experts trained in their use will be needed. Since burns often become infected with one pathogen while remaining free from others, it is important that isolators used in the treatment of burns should be suitable for containment of bacteria (by the use of filters in the air-effluent) as well as for protection against contaminants.

Unlike the plastic isolator, air curtain isolators present no difficulties in the nursing or medical treatment of patients. Unfortunately, they also show no sign of giving the patient any useful protection against contaminants – at least, when used without other effective barriers. It is possible that air curtains might be found to have some value if nurses and others wore gloves and protective clothing when attending to patients inside them, but this hypothesis cannot be accepted without further study. It seems likely too, that a physical barrier, such as that provided by the open-topped isolator, is valuable not only because it gives protection against contamination from the hands and uniform of nurses, but because it acts as a barrier against accidental contamination and social contacts with visitors who are not familiar with the rules of hospital hygiene.

In a parallel study (Ayliffe, Collins, Lowbury & Wall, 1971) it was found that patients in a self-contained, plenum-ventilated isolation suite with air-locks were protected against nasal acquisition of *Staph. aureus*. A plastic ventilated isolator might be expected to give a higher degree of protection than isolation in a hospital room, but the burns ward where isolators were used presented a much greater challenge of contamination than that to which the isolation suite in a clean surgical ward was exposed. The high degree of isolation provided by the suite with air locks must also have contributed to the good result with this form of isolation.

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EXPLANATION OF PLATES

Plate 1

Fig. 1. Plastic ventilated isolator. The isolator, in which a patient is having dressings changed, is equipped with a half-suit and ventilated headpiece to facilitate nursing.

Fig. 2. Plastic isolator with open top.

Plate 2

Figs. 3 and 4. Air curtain isolator. Air is drawn through grids on each side of the console at the head of the bed, filtered, and pumped out through slits on the under surface of the canopy over the bed. The air curtain is illustrated in the diagram (Fig. 4).

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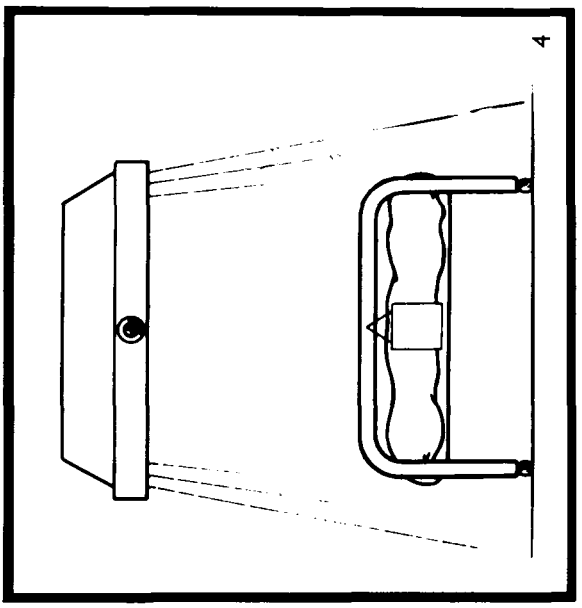

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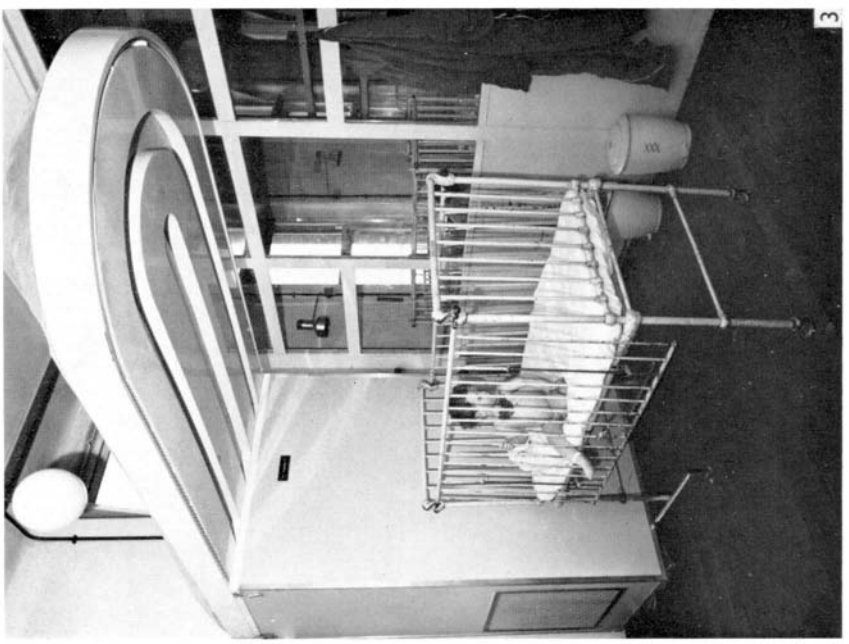
Diagrammatic representation of air curtain effect



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