

Attempts to control clothes-borne infection in a burn unit, 3. An open-roofed plastic isolator or plastic aprons to prevent contact transfer of bacteria*

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SUMMARY

An open-roofed plastic isolator was built in a single patient isolation room in a burn unit. It was designed to prevent contact contamination only, as this had been shown to be the important route of cross-colonization in the unit. To exclude any possible effect on airborne transfer of bacteria, the isolator was first examined by means of an airborne particle tracer of the same size as bacteria-carrying particles. Such experiments indicated that the isolator might prevent some transfer out of but not into the isolator. This was not confirmed in simulated nursing experiments nor in a patient study, where the air counts of bacteria were practically the same inside and outside the isolator wall. Two patients only were nursed in the isolator. Both patients acquired exogenous colonizations from other patients, one with *Ps. aeruginosa* and the other with *S. aureus*. Nursing in the isolator was difficult and staff-demanding. In simulated nursing experiments, plastic aprons and gauntlets as the only protective measures against contact contamination gave as much protection to a mock patient as did the isolator. *S. aureus* were released from nurses' clothes more easily during work with the isolator than in open nursing with aprons and gauntlets. In conclusion, the isolator did not seem to be a realistic alternative to impermeable clothes such as plastic aprons as a means of preventing clothes-borne cross-contamination between burn patients.

INTRODUCTION

Barrier nursing in isolation wards is not enough to prevent cross-contamination between burn patients (Cason *et al.* 1966; Hambræus, 1973*a*). Efforts have been made to reduce cross-contamination by diminishing air-borne transfer of bacteria, but the results have been disappointing (Lidwell & Towers, 1972). This is probably due to the fact that contamination is largely transmitted by contact via clothes, both in general surgical wards (Lidwell *et al.* 1975) and in burn units (Hambræus, 1973*b*). Attempts to make better clothes for barrier nursing have not as yet given the desired results (Ransjö, 1979).

If barrier nursing is not enough to prevent the spread of infection from patient to patient, more strict isolation is needed. Patient isolators have been developed

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in order to protect infection-prone patients from contamination and to contain patients who are potential sources of infection. Three main types of isolators are in use.

The air curtain. This is the simplest isolator, where the patient is surrounded by a curtain of clean air. The air flow is either horizontal (Penland, 1970) or vertical (Lowbury, Babb & Ford, 1971). No attempts are made to reduce contact contamination, and the results in patient care have been unfavourable (Lidwell, 1973).

The plastic bubble. This is the type of isolator that has been in use longest. The patient and part of his bed are enclosed in a sealed bubble of plastic, with diffuse ventilation (Levenson *et al.* 1964). Used as a protective isolator for burn patients, it has reduced the cross-contamination with *Pseudomonas aeruginosa* but not with *Staphylococcus aureus* (Lowbury *et al.* 1971). In use as a source isolator, it reduced the dispersal of wound bacteria from burn patients at changes of dressings (Babb *et al.* 1976).

The 'life island'. This is the type of isolator most extensively used, and the most complicated one. It consists of plastic walls, with devices for handling the patient, and is highly ventilated with ultra-clean air. It has been adapted for use in clean surgery (Charnley, 1972), and for the nursing of patients with immunodeficiencies (Levine *et al.* 1973; Bodey, 1975). Nursing burned children in an isolator that prevented transfer of bacteria both by contact and by air has led to a reduction of cross-infection rates to less than 10% in one investigation (Burke, 1972).

Theoretically, burn patients would be a group of patients for whom nursing in isolators would be well adapted, for three reasons: the damages to their defences against infection are only temporary; a large proportion of their bacterial infections are exogenous; their exogenous infections/colonizations are to a great extent transmitted by contact.

In the present investigation, an isolator was designed specifically to prevent contact contamination only, and not to affect airborne transfer of bacteria. The effects of this isolator in preventing transfer of bacteria in isolation rooms for burn patients were investigated experimentally and in clinical use.

There is evidence (Lidwell *et al.* 1974) that plastic aprons might be a simple means of preventing clothes-borne cross-contamination. Such aprons and gauntlets were used during nursing in the isolator. Experimental investigations of the effects of plastic aprons and gauntlets in the prevention of contact transfer of microorganisms were performed, to compare these simple devices to the isolator and to previously evaluated clothes.

MATERIALS AND METHODS

The isolator

The isolator (Plate 1) consisted of four walls, made of transparent plastic, 0.4 mm thick polyvinyl chloride (PVC). The plastic was stretched in a framework of aluminium sections (SYMA system^R) that was fixed between floor and ceiling

in an isolation room in the burn unit. Infra-red radiators were placed in the ceiling above the patient's bed. A gap of about half a metre was left between the top of the side walls and the ceiling, to let room air circulate. The side walls were movable, to provide space in the isolator for the patient and his bed. One side wall could also be fully opened. Nursing tasks were performed through horizontal flaps in the whole length of the side walls. Each side wall contained a bellows made of 0.25 mm PVC foil that could be expanded over the patient for nurses' convenience (Plate 2).

Clothes and clothing routines

Cotton suit. This consisted of jacket and trousers of cotton/polyester, and was the working suit used in the ward and underneath barrier garments. It was laundry clean each morning. When barrier garments were worn, cap mask and sterile gloves were also used.

Cotton gown. This was the barrier garment generally used in the patient rooms. Details of these clothes and clothing routines have been published previously (Hambraeus & Ransjö, 1977; Ransjö, 1979).

Apron and gauntlets. These were made of 0.1 mm polythene foil, and were used, factory clean, on top of the cotton suit in open nursing experiments and in isolator nursing.

Airborne tracer particles

A spinning disk particle generator was used to produce an aerosol of potassium iodide particles with a sedimentation rate of about 0.3 m/min. These were collected on Millipore filters, and visualized with palladium chloride (Foord & Lidwell, 1972). In one set of experiments, the particle generator was placed inside the isolator, to simulate its function as a source isolator. In another set of experiments, the generator was placed half a metre outside one side wall of the isolator, to simulate its function as a protective isolator. In both positions of the particle generator, three series of ten experiments were performed: with the isolator wall closed, with a mock nurse working through the flaps in the isolator wall and with the isolator wall fully open. A fan was used near the generator to mix the particles with the air in the room. The volume of air sampled onto filters was: near the particle source 12.6 l/min, and on the recipient side of the isolator wall 100 l/min. Each experiment was run for 30 min and sampling took place in 15 × 2 min periods. Calculations only took into account the measurements when a steady state of about 100–150 particles at the source was reached, usually after 5 min.

Sampling and identification of bacteria

Bacterial contamination of clothes was measured by a wash method (Hambraeus, 1973b). Airborne bacteria were collected on 13.5 cm blood agar settle plates. These were exposed in occupied patient rooms for 4 h/day on 5 days/week. Assuming a sedimentation rate of 0.3 m/min for the bacteria-carrying particles (Noble, Lidwell & Kingston, 1963), each plate sampled 1 m³ of air. In patient

studies with the isolator, settle plates were placed at 1 and 2.5 m above the floor, in the isolator at the head of the bed and in the room on both sides of the isolator. In nursing experiments, air from mock patient's room and isolator was sampled with a Casella slit sampler on blood agar plates. The sampler was run at 0.7 m³/min for 2 × 5 min before and 5 × 5 min during each experiment. Patients' cultures were taken from nose, throat, skin, perineum, urine and if possible stool, on admission, and from sampling sites at every 5% of burn wound surface area twice a week.

Staff cultures from nose and throat were obtained once a week. Samples from respiratory tract, skin and wounds were plated on haematin, mannitol salt and blood agar. Broth enrichment media were also used. Stool samples were also plated on cetrimide agar. Bacteria isolated were identified according to current methods. Presumptive *S. aureus* colonies were examined for DNase, and positive strains phage typed according to the international test system (Blair & Williams, 1961). On settle plates, up to a maximum of 8 colonies per plate were typed. *Streptococcus* colonies with beta-haemolysis were Lancefield grouped serologically (Cars, Forsum & Hjelm, 1975). *Ps. aeruginosa* colonies, identified by fermentation tests, were phage typed by L. Sjöberg, the National Bacteriological Laboratory, Stockholm (Sjöberg & Lindberg, 1968).

Mock nursing experiments

Mock nursing was performed as described before (Hambraeus & Ransjö, 1977). A staff nurse did a routine morning nursing of a burn patient, wearing a cotton suit and on top of that a cotton gown or on some occasions no barrier garment. By this nursing, the nurse's cotton suit became contaminated with the burn patient's wound bacteria. This contaminated cotton was donned by a mock nurse who then performed a nursing of a mock patient.

In isolator. In one set of experiments, the mock nurse wore a plastic apron and gauntlets on top of the cotton suit, and thus dressed nursed the mock patient through the isolator wall.

With apron. In another set of experiments, the mock nurse was dressed in a plastic apron and gauntlets as above, but the mock patient was lying on an open bed.

The mock patient wore a sterile gown and her bed was made with sterile sheet. The amounts of *S. aureus* of the burn patient's phage pattern that were transferred to the mock patient and to the air in the mock patient's room and in the isolator were measured.

RESULTS

Airborne tracer particles

The median values for the concentration of particles on the recipient side of the isolator wall, expressed as the percentage of the concentration on the source side are shown in Table 1. When particles were generated in the isolator, the transmission with the wall closed and during work in the flaps was the same, 19–22%, but when the wall was fully open twice as high, 45%. When particles

Table 1. *Transmission of tracer particles*

	% transmission	
	Median	Quartiles
Particles generated in the isolator		
(i) Wall closed	19	13-29
(ii) Work in the slit	22	15-33
(iii) Wall open	45	31-62
Particles generated outside the isolator		
(i) Wall closed	35	26-46
(ii) Work in the slit	31	23-41
(iii) Wall open	25	19-54

Table 2. *Transfer of Staphylococcus aureus during mock nursing*

	No gown*	Green*	Tyvek*		
			close coverall	Isolator	Apron
Counts on source jacket	64·000	7·500	1·500	8·300	36·000
Air contamination during experiments (median addition to background, c.f.u./m ³)	0·9	0·2	0·15	0·3 (room 0·1)	0·07
Transmission from mock nurse to mock patient (median ratio c.f.u. × 100)	1·1	0·8	3·5	0·3	0·2

* From Hambraeus & Ransjö, 1977 (see text).

were generated outside the isolator, the transmission when the wall was closed and during work in the flaps were equal.

Mock nursing

The results of mock nursing are summarized in Figs. 3 and 4, and in Table 2. Each figure is the median of 13 experiments with apron and 16 experiments in isolator. The counts on the source jacket were about fourfold higher in the apron experiments than in the isolator experiments.

For comparison, the results of an earlier study are included (Hambraeus & Ransjö, 1977). In that study, the ratio mock patient/jacket was estimated as the ratio of the median values, but here the median value of the ratios has been calculated from the same data, hence the discrepancy of the values.

Transfer from mock nurse's clothes to the air of the mock patient's room (Fig. 1)

In isolator. The median background counts in the isolator and in the room around the isolator were 0·1 and 0·2 c.f.u./m³, respectively. The median addition to the air counts during the experiments was 0·3 c.f.u./m³ in the isolator and 0·1 c.f.u./m³ in the isolator room.

With apron. The background counts in the apron experiments were low; in 10 of

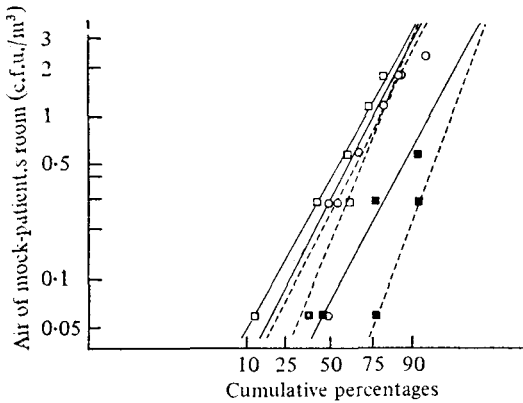


Fig. 1

Fig. 1. Transfer of marker *S. aureus* from mock nurse's clothes to air of mock patient's room, ○, Room outside isolator; □, in isolator; ■, apron+gauntlets; —, during experiment; --, background.

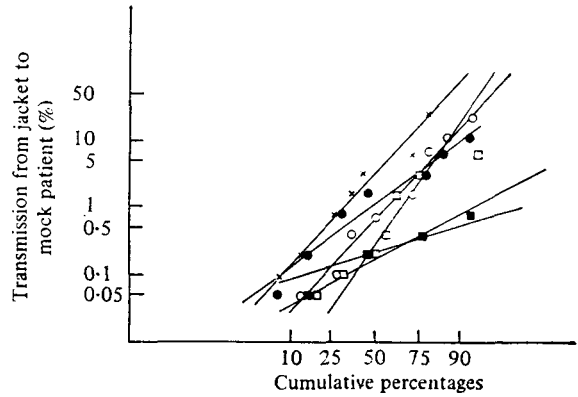


Fig. 2

Fig. 2. Transfer of marker *S. aureus* from mock nurse's jacket to mock patient. ●, No gown; ×, Tyvek; ○, green cotton; □, isolator; ■, apron+gauntlets.

the 13 experiments no. *S. aureus* colonies were found on the slit sampler plates. The median addition to the air counts during the experiments was less than 0.07 c.f.u./m³. The ratio of air counts to the contamination of the jacket was 18.6 times higher during nursing with the isolator than with apron and gauntlets only.

Transfer from mock nurse's jacket to mock patient (Fig. 2)

In isolator. The transmission from mock nurse's jacket to the mock patient when nursed in the isolator was 0.3%.

With apron. The transmission from the nurse's jacket to the mock patient on an open bed when the mock nurse wore a plastic apron was 0.2%. As can be seen from Fig. 2 the interquartile range in these experiments was much smaller than in all other series in this and the previous study.

Patient studies

Adult patients with 15–30% burn size were eligible for the study. During 18 months, only two such patients were nursed in the isolator. These two are described in some detail.

Case 1

Male, 31 years old, with full thickness burns on both legs and buttocks, burn size 30%. Needed much lifting and handling. Fasciotomy on legs performed in isolator on day 2 after admission. Staff wearing cotton barrier gowns entered the isolator several times during the first few days. On day 10 and afterwards, the

Table 3. Bacterial counts in air (c.f.u./m³) of isolator patient's strains

	Day	In isolator		In isolator room (% transmission)	
		<i>S. aureus</i>	<i>Streptococcus</i>	<i>S. aureus</i>	<i>Streptococcus</i>
Case 1	3	3	—	2.8 (92%)	—
	4	31.5	8	18.8 (60%)	11.5 (144%)
	5	106	32	92 (87%)	24.8 (77%)
	6	79	17	64.8 (82%)	16 (94%)
	9	43	21.5	33 (77%)	14.8 (69%)
Case 2	1	0	0	0	0
	4	85	—	77.8 (91%)	—
		6	—	13.3 (221%)	—
	5	185.5	—	183 (99%)	—
		44	—	48.5 (110%)	—

Table 4. Staphylococcus aureus in air (c.f.u./m³)

Case	day	Isolator	Isolator room	Source room
Case 1	2	0	0.25	22 + 14
	3	0	0	0
	4	0	2.75	5
	5	0	0	5
	6	0	0.25	0
	9	0	0.25	4
Case 2	1	0	0	6 + 17 + 43 + 30
	4	0	0	1 + 7 + 20 + 14
	5	8.5	5	1 + 6 + 2 + 5 + 11 + 7
Patient study	Median	< 1	< 1	5.5
Mock nursing	Median	0.4	0.3	—
Clinical study* control period	Median	—	< 1	8.9

* Ransjö, 1978.

patient left the isolator daily for bathing or surgery. He was removed from the isolator on day 16 because of an acute psychotic reaction.

Bacteriological findings. The patient was colonized on day 4 with an endogenous *S. aureus* strain and with an exogenous strain of *Ps. aeruginosa* from another patient. He also developed a colonization with *Streptococcus* group C which could have been derived from staff. Settle plates were placed in isolator and isolator room on days 2–6, 9–13 and 16. The findings of the patient's strains are shown in Table 3, and of strains from other patients in Table 4, both during the first 9 days when the patient was still permanently in the isolator. *S. aureus*, *Streptococcus* group C and *Ps aeruginosa* from the patient were found on all plates in isolator

and isolator room in comparable amounts from day 3 onwards. *S. aureus* strains from other patients were never found in the isolator, but twice in the isolator room. *Ps. aeruginosa* from other patients was never found in the isolator or isolator room.

S. aureus from the patient were detected once in another patient's room.

Case 2

Male, 29 years old, 23 % scald on face, chest and thigh. Needed no lifting, could feed himself. Developed an acute anxiety reaction which led to his removal from the isolator on day 5.

Bacteriological findings. The patient was colonized with four strains of *S. aureus*, one endogenous on admission, one epidemic from three other patients and one not traced on day 4, and one exogenous from a dispersing patient on day 11. The patient's strains (Table 3) were found in equal amounts in isolator and in isolator room as soon as the patient could be shown to be colonized with them. Other patients' strains of *S. aureus* (Table 4) were found in the isolator and isolator room once, in higher amounts than in the dispersing source patient's room. This occurred on day 5, and the strain appeared in the isolator patient's wound on day 11. No transfer into the isolator or isolator room of *Streptococcus* group G or of *Ps. aeruginosa* was detected although these were dispersed by other patients in the ward. In Table 4 are summarized the findings of *S. aureus* isolations of strains transferred into the isolator and isolator room from other patients' rooms. The median count in the source rooms was 5.5 c.f.u./m³. Transfer of a strain into the isolator air occurred once, when the source room count for that strain was close to the median for all source room strains.

DISCUSSION

Air particles and bacteria

In isolation wards with plenum ventilation, the remaining important route for cross-contamination between burn patients is by contact via nurses' clothes (Hambraeus, 1973b; Ransjö, 1979). For this reason, the isolator was designed to prevent contact transfer only, and was not intended to affect an air-borne transfer of particles. To investigate any unforeseen effects of the isolator on transfer of airborne bacteria within the patient room, some experiments were done with tracer particles of the same size as bacteria-carrying particles. Such experiments have been performed previously in isolators only with bacterial aerosols, where particles are usually much smaller (Van der Waaij, Wiegersma & Dankert, 1976; Babb *et al.* 1976). The results of tracer experiments indicated that the isolator might prevent some airborne transfer from the patient but had no effect on airborne spread into the isolator. This difference may have been due to uneven distribution of the particles because of turbulence. The distribution of bacteria in the air seemed to be the same inside and outside the isolator, both in mock nursing experiments and when real patients were nursed in the isolator.

S. aureus transfer into the isolator and isolator room in the patient trials was of the same order as that found in mock nursing (Table 4). The figures for dispersal in source rooms and transfer into the isolator and isolator room air were comparable to that found in isolation rooms during conventional barrier nursing (Ransjö, 1979), as expected (Table 4). The secondary dispersal from nurses' jackets to the air of the mock patient's room was much lower when plastic aprons were worn during open nursing than when nurses worked with the patient in the isolator. This was probably because the isolator walls were a hindrance to movements during nursing, and so increased the friction between nurses' garments and also increased nurses' sweating.

Protection of mock and real patients

The transfer from mock nurse's jacket to mock patient when nursed in the isolator was 0.3%. This can be compared with the results in a previous investigation with the same methods (Hambræus & Ransjö, 1977), where this transfer was 1.1% when no barrier garment was worn, 0.8% with an ordinary cotton gown and 3.5% with a new disposable coverall (Table 2). In our previous studies, the effects of transfer from real burn patients to nurses' clothes was measured as well as the transfer from mock nurse to mock patient. In the present study it was not possible to evaluate the transfer from burn patients, since only one isolator was available and very few burn patients could be nursed in the isolator. Thus, the isolator was investigated experimentally only as a protective isolator and not as a source isolator.

The fact that the results of mock nursing with the isolator were only marginally better than with previous barrier garments in prevention of transfer of *S. aureus* to the mock patient is in discordance with some results in burn patient nursing (Burke, 1972). In that study, however, many other factors such as early excision and grafting, and topical chemoprophylaxis, may have contributed to the good results (Burke, Bondoc & Quinby, 1974). Nursing experiments only measure the transfer of bacteria when clothes are dry, whereas the transfer through wet clothes may be a more important route of cross-contamination. To evaluate the effects of the isolator on reduction of the soiling of clothes with wet wound secretions, patient trials were included. Nursing in the isolator was time-consuming and difficult, which might lead to hazards to the patient. This made nursing staff reluctant to place patients in the isolator, and the study had to be limited to two patients only. One patient did not acquire an exogenous *S. aureus* colonization during his 16 days in the isolator or later, but did acquire a colonization with *Ps. aeruginosa* from another patient quite soon after admission. For patients with his burn size and an endogenous *S. aureus* colonization, the exogenous colonization rate with *S. aureus* was 80% and with *Ps. aeruginosa* 60% in the ward (Ransjö, 1979). The other patient acquired an exogenous colonization with an epidemic strain of *S. aureus* from possibly three other patients soon after admission. Judging from settle plate results, transfer of these exogenous colonizations must have been by contact. Both cases showed serious psychiatric complications from treatment in the isolator. This is not unusual in strict isolation (Vejlsgaard

& Baek, 1976), and is another factor which may limit the general use of isolators.

Plastic aprons and shoulder length gauntlets were used for nursing in the isolator. As aprons and gauntlets covered most of the contact surfaces between nurse and patient, the effect of these in nursing mock patients on open beds was evaluated. They permitted as little transfer from mock nurse to mock patient as did the isolator. Patient trials remain to be done. If nursing burn patients with plastic aprons and gloves can be proved to give as good results as an isolator in the prevention of transfer of bacteria by contact, it would mean a great reduction in the labour and cost of isolation nursing.

CONCLUSION

The results with the isolator as protective in mock nursing were similar to those achieved with good barrier garments but not dramatically improved. Tracer particle tests and settle plate studies showed, as expected, that the open-roofed isolator did not prevent airborne transfer of bacteria-carrying particles.

Both patients nursed in the isolator acquired exogenous colonizations transmitted by contact contamination after a few days, one of them with *Ps. aeruginosa* and the other with *S. aureus*. The isolator as protective, then, was a failure. None of the isolator patients could be shown to cause colonizations in other patients during the few days they were nursed in the isolator, but *S. aureus* from one of the isolator patients was detected in another patient room. Thus, the isolator was not a complete success as containment either.

The results with mock nursing in plastic aprons and gauntlets were quite promising. This clothing routine may be a far more practicable and less costly way of controlling clothes-borne cross-contamination in isolation wards.

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EXPLANATION OF PLATES

PLATE 1

One side wall of the isolator.

PLATE 2

Nursing in the isolator.