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A source isolator for infected patients

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SUMMARY

A plastic, mechanically ventilated source isolator with filters in the air effluent was designed to enable infected patients to be nursed and treated in a general ward or to be transported without risk to staff or other contacts.

Two models of isolator were developed. Their potential value was tested by the challenge of heavy dispersal, inside the isolator, of bacteria (*a*) from patients with burns, during the change of dressings, (*b*) from contaminated bedding during simulated bed-making, and (*c*) from the dispersal of a suspension of *Bacillus subtilis* var. *globigii*.

Sampling of air by slit samplers outside the isolator and, in comparable control patients, from the air of the room in which dressings were changed, showed consistently lower counts of bacteria and of *Staph. aureus* during dressings when the isolator was used; on removal of the isolator canopy there was, in some experiments, a considerable increase in airborne bacteria, due to residual bacteria in the isolator or to the re-dispersal of bacteria which settled on the patient and his bedding during the dressing.

Simultaneous sampling with slit samplers inside and outside the isolator during and after bed-making or dispersal of *B. subtilis* var. *globigii* showed an almost complete protection of the air outside the isolator against contamination by bacteria released inside the isolator.

INTRODUCTION

Isolators, which were originally developed for the study of germ-free animals (Reyniers & Trexler, 1943; Coates, 1968) have been used for protective (or reverse) isolation of patients in whom infection presents a special hazard; for example, in the treatment of leukaemia with cytotoxic drugs (Jameson, Gamble, Lynch & Kay, 1971; Dietrich, 1973), for operations which involve special infective hazards (Levenson *et al.* 1962; Barnes *et al.* 1969; Beal *et al.* 1967), and for severely burned patients (Levenson *et al.* 1966; Haynes & Hench, 1966; Burke, 1967). A controlled trial of protective isolators for patients with burns in this Unit (Lowbury, Babb &

acquired significantly less burn infection with *Pseudomonas aeruginosa* than was found in a comparable series of patients who were treated in the open ward; in previous studies, isolation of such patients in two-bed or single-bed rooms had not been found to reduce the incidence of pseudomonas infection (Cason *et al.* 1966).

Patients are more often nursed in isolation because they are infected than because they are hyper-susceptible to infection. When source (or containment) isolation is required for infected patients, it is usual for the patients to be transferred to an infectious diseases hospital or to the isolation unit of a general hospital or to a ward side room, if such facilities are available. The transfer of a patient away from the ward where he is receiving specialized treatment may be undesirable on clinical grounds. Moreover, the transfer of a patient with a highly infectious disease (e.g. smallpox) to another hospital may expose susceptible persons to severe hazards of infection. In both of these situations it would be useful to have an isolator in which an infected patient could be enclosed, so that the pathogenic organisms dispersed from his body would be prevented from gaining access, through the air or by contact, to patients and staff, or to inanimate surfaces and fluids in the periphery.

We describe here an experimental isolator designed to test the potential value of source isolation, as shown by its effectiveness in preventing contamination of the environment with bacteria released into the air during the change of burn dressings; previous studies (e.g. Bourdillon & Colebrook, 1946; Lowbury, 1954) have shown that particularly heavy dispersal of pathogens is likely to occur when dressings are removed from infected burns; bedding is another profuse source of airborne contamination (Rubbo, 1963).

MATERIALS AND METHODS

The isolator

The polyvinyl chloride canopy was supported on a metal framework covering a table, 3 ft. 8 in. (1·12 m.) by 2 ft. (0·61 m.) on which the serving nurse in the dressing team prepared dressings for application to the burns, and a supported extension of 6 ft. 6 in. (2 m.) at right angles to the serving table, under which a patient's bed could be wheeled, usually with feet towards the table (see Plate 1); the canopy was attached by rings to rails above the bed on both sides, along which the canopy could be drawn over the patient and tucked under the mattress when the bed was in position, and withdrawn when the patient's bed was to be removed at the end of the dressing. In the original design (Model 1) there were five shoulder-length sleeves with replaceable gloves on each side of the canopy flanking the bed, for nurses changing the dressing, and two similar gloves in the canopy alongside the serving table, on the opposite side from the bed, for the nurse who prepared the dressings. In an improved isolator (Model 2), ventilated 'half suits' with helmet, visor, sleeves and gloves were inserted on each side of the canopy for the nurses who changed the dressings, to facilitate movements and access to service area. Bags to receive dressings removed from the patient's burns and bed linen were

attached to the canopy on either side of the bed and sealed before removal at end of dressings. Plate 1 shows the isolator (Model 2) in use during the dressing of a patient.

The isolator was thoroughly cleaned with a spray of 0·5% chlorhexidine digluconate in 75% ethanol to the inner surfaces after use, in preparation for use on another patient. Swabs were taken from the isolator before and after treatment to assess the effectiveness of such disinfection.

Ventilation of the isolator

Model 1 was a combined source and protective isolator with filtered air entering at the ceiling near the head of the bed and removed through a vent near the foot of the bed. The filters consisted of three layers of fibreglass filter media $\frac{1}{2}$ in. thick (FM 004, Chemicals Trading Co., London) wrapped around a cylindrical supporting frame and sterilized in the autoclave. Separate blowers used for the input and extract filters provided a change of air within the canopy in less than $6\frac{1}{2}$ min. No attempt was made to direct the airflow within the canopy to avoid turbulent mixing.

Model 2 was a source isolator, allowing unfiltered air to enter through a circular aperture about 10 in. by 8 in. in area, in the roof of the canopy at the head of the bed. Air was extracted through two vents at the foot of the bed which passed air through ducts to the filters. The same filters and blowers were used on both models, with both filters attached to the suction ports on Model 2. This arrangement doubled the flow of air through the canopy, providing an air change in less than $3\frac{1}{4}$ min.

Tests on control of dispersal of bacteria from patients

Tests were made during routine lists in the dressing station of the Burns Unit (Bourdillon & Colebrook, 1946; Lowbury, 1954).

Two patients, whose burns were of similar extent and showed, in all but one of the experiments, similar heavy colonization by bacteria, had their dressings changed at the end of a dressing list. In the first of these, the dressings were changed with the patient inside an isolator (Model 1); the other patient served as a control, having the dressings changed in the dressing station without an isolator at the end of the list. During both of these dressings the plenum ventilation of the dressing station was switched off, but before the first dressing and between the first and second dressings it was switched on for a period of ten minutes to remove residues of airborne bacteria released during the previous dressing.

A series of bacterial samplings of the air outside the isolator was obtained with a large slit sampler (with three slits blocked – 6 ft.^{3}/min.) throughout the course of both dressings, using plates of phenolphthalein diphosphate agar (PPD) (Barber & Kuper, 1951) to show both total organisms and presumptive *Staphylococcus aureus*. The first sample was taken before the patient was wheeled, on his bed, into the dressing station; the last sample was taken after the departure of the patient from the dressing station.

Culture plates were incubated at 37° C. for 24 hr. Counts of viable bacteria and of presumptive *Staph. aureus* (shown by phosphatase reaction of typical colonies)

were made. A representative number of colonies of *Staph. aureus* from the air samples and from the burns of patients dressed in isolators and in the open dressing station (*all* colonies if few were present) were picked, confirmed by slide and tube coagulase tests, phage typed and tested for sensitivity to seven antibiotics by a ditch plate method.

Three further selected pairs of patients with comparable burns were examined, as described above, for control of airborne dispersal of bacteria during the change of dressings in this isolator. In addition to the assessment of airborne bacteria, the time taken to complete the dressings inside the isolator and without use of an isolator was recorded.

The Model 2 isolator was used in similar assessment of source isolation on two further pairs of patients.

Tests on control of bacteria dispersed during bed-making or as aerosol of B. subtilis *var.* globigii *inside isolator*

Like the removal of contaminated dressings from extensive infected burns, bed-making is a major source of airborne contamination and potential cross-infection from patients in wards, particularly with *Staph. aureus* and other Gram-positive organisms.

To test the value of a source isolator in preventing dispersal of bacteria from bedding into the open ward, three experiments were made in which contaminated sheets from beds of burned patients treated by the exposure method were placed on empty beds and agitated, in simulated bed-making, inside the source isolator (Model 2). A series of samples of air (6 ft.^{3} (170 l.)/min.) were taken onto PPD agar by a slit sampler outside the isolator; simultaneous samples of air inside the isolator were taken by a second slit sampler through a tube 2 in. in diameter attached to the air-intake cylinder of the slit sampler.

A series of samplings of air, taken simultaneously inside and outside the isolator as described above, were obtained in a period during which a suspension of *Bacillus subtilis* var. *globigii* was dispersed into the air from a 'Defensor 505' Nebulizer/Atomiser; the dispersal took place in two periods, one of 3 min. and one of 2 min., with a quiet period of 10 min. between the two dispersals.

RESULTS

Table 1 shows the mean numbers of bacteria-carrying particles and of presumptive (often confirmed) *Staph. aureus* in 1 min. samples (6 ft.^{3}) taken by slit sampler from the air of the dressing station immediately before, during and after the dressing of four patients with and four patients without the use of the source isolator (Model 1). In all but two of the dressings, samplings taken before the dressing yielded less than five bacteria-carrying particles (in four experiments less than four bacteria-carrying particles) per cubic foot of air; the unexpectedly high counts in Expts. 1 and 4 (with patient in isolator) were probably due to an unusual degree of activity in the room. In each experiment the samples taken during the dressing showed a greater increase compared with pre-dressing samples, in bacterial

Table 1. *Bacteria in air of dressing station during dressing of burns with and without source isolators (Model 1)*

Expt	Organisms	Mean counts per min. of bacteria in air of dressing station (6 ft.³ samples) with: Patient in isolator — Before dressing: Mean	Before dressing: Range	During dressing: Mean	During dressing: Range	During dressing: S.E.M.	After dressing: Mean	After dressing: Range	No isolator used (control) — Before dressing: Mean	Before dressing: Range	During dressing: Mean	During dressing: Range	During dressing: S.E.M.	After dressing: Mean	After dressing: Range
1	Total	205	201–10	89	65–153	6·9	84	72–98	27	18–36	273	120–542	29·5	235	202–68
	Staph. aureus	1·0	(0–2)	0·7	0–3	0·2	0·6	0–2	0·7	0–2	214	9–450	27·1	190	160–220
	Observations		2		14			5		3		16			2
2	Total	15	10–19	27	13–37	1·5	159	99–219	21	—	137	72–297	17·1	323	—
	Staph. aureus	1·0	0–2	4·2	1–10	0·5	89·5	50–129	8·0	—	11	4–31	1·95	38	—
	Observations		2		20			2		1		15			1
3	Total	13	9–17	81	47–107	3·5	202	116–285	17	13–22	134	15–199	10·4	120	—
	Staph. aureus	0·5	0–1	3·8	1–8	0·6	13	4–21	1·0	0–2	12	1–32	1·6	13	—
	Observations		2		18			4		4		20			1
4	Total	78	37–120	134	63–400	16·5	387	267–682	26	9–52	196	93–468	24·0	255	—
	Staph. aureus	10	2–24	24	4–104	5·0	93	63–155	7·0	1–16	33	6–87	5·1	66	—
	Observations		4		22			8		4		15			1

Table 2. *Bacteria in burns of patients on day of dressings in isolators, with controls*

Experiment	Bacterial growth from burns of patients dressed in: Source isolator — Site	Source isolator — Bacteriology	Without isolator (control) — Site	Without isolator (control) — Bacteriology
1	Chest	*Staph.** +	Abdomen	*Staph.* + + +
	Left arm	No growth	Left hand	Micrococci
	Right arm	No growth	Right leg	Diphtheroid + micrococci
			Left leg	No growth
2	Left thigh	*Staph.* + + +	Buttocks	*Staph.* + + *Ps. aerug.* + Micrococci + +
	Right leg	*Staph.* +	Abdomen	Micrococci + coliform
	Left elbow	No growth	Back	Micrococci + coliform *S. faecalis*
3	Leg	*Proteus* + + + *Staph.* + + +	Thigh	*Staph.* + + +
			Leg	*Staph.* + + +
4	Arm	*Ps. aerug.* + + + *Staph.* + + +	Left arm	*Ps. aerug.* + + *Staph.* (2T) + + + †
	Hips	*Ps. aerug.* + + + *Staph.* + + Micrococci + + Yeast +	Right arm	*Ps. aerug.* + *Staph.* (2T) + +
	Left leg	*Staph.* + + Micrococci + +	Chest	*Proteus* + + *Ps. aerug.* ± *Staph.* + + +
	Right leg	*Ps. aerug.* + + *Staph.* + +	Back	*Ps. aerug.* + + *Proteus* + + *Staph.* + + Coliform + +
	Left buttock	*Ps. aerug.* + + + Micrococci + +	Neck	*Ps. aerug.* + + *Staph.* (2T) + + +
	Right buttock	*Ps. aerug.* + + *Proteus* + + *S. faecalis* + +	Right ear	Coliform + *Staph.* + + + Coliform ±
	Left arm	No growth	Left ear	*Ps. aerug.* + + + *Staph.* + + + Coliform + + +
	Right arm Face	*Staph.* ± Coliform ± Micrococci ± *Ps. aerug.* + + + Coliform ± *Staph.* + Micrococci + Diphtheroid +	Trachea	*Staph.* ±

* Staph. = coagulase-positive staphylococci.
† 2T = 2 types.

counts and, with one exception, in staphylococcal counts when the dressings were changed in the open dressing station than when they were changed in the source isolator. The post-dressing samples, however, showed an increase in bacterial and staphylococcal counts compared with the counts obtained during the dressings. Many bacteria dispersed from the dressings were probably still present in the air

Table 3. *Time taken for dressings with and without isolator*

Experiment	Patients dressed in isolator			Patients dressed without isolator (controls)		
	Age (years)	Area of burns (%)	Duration of dressing (min.)	Age (years)	Area of burns (%)	Duration of dressing (min.)
1	21	15	38	18	9	21
2	18	9	42	14	14	30
3	18	9	27	8	5	27
4	37	20	58	32	30	38
Mean	27	13·2	41	18	14·5	29

inside the isolator when the isolator was removed from the patient; many bacteria dispersed during the dressing must also have fallen onto the patient's body and bedclothes during the dressing, and these may have been re-dispersed after removal of the isolator. To remove residual airborne bacteria, patients were kept in the isolator for 3 or 5 min. after the completion of dressings in the experiments that followed (see Table 4). There was no evidence of deposition of bacteria on the inside of the canopy.

Table 2 shows the details of bacterial colonization found on sampling the burns at the time of the dressings in the source isolator or under control conditions, as summarized in Table 1. All patients showed a growth of *Staph. aureus* which was heavy in all except Expt. 1 (with isolator) and mostly in mixed culture with other bacteria.

Table 3 shows the time taken to complete the dressings in the isolator and without an isolator; the mean time required for the former was 41 min. (excluding time to set up the isolator), for the latter 29 min.

Table 4 shows the results of tests in which two pairs of patients with comparable burns and burn infections were dressed in the Model 2 isolator, or in the dressing room without an isolator. Slit sampler counts, as in the tests with Model 1 isolator, showed a smaller increase in ambient bacteria and *Staph. aureus* when dressings were changed in the isolator than when they were dressed in the room without an isolator. In these tests patients were kept in the isolator with ventilation running for a period of 5 min. (Expt. 5) and 3 min. (Expt. 6) between the completion of the dressing and removal of the canopy; there was less evidence than in the use of the Model 1 isolator of an increased dispersal of bacteria on removal of the canopy from the patients in Expts. 5 and 6.

Some of the staphylococci found in the air outside isolators in which patients' dressings were being changed were similar in phage type and antibiotic sensitivity pattern to those found in the burns of the patients in the isolators. As the same type of *Staph. aureus* was found in many patients in the Burns Unit it was uncertain whether these staphylococci had escaped from the isolator to the peripheral air, though this seemed a likely explanation.

Table 5 and Fig. 1 show the numbers of bacterial colonies and of presumptive (often confirmed) *Staph. aureus* in series of slit sampler plates (1 min. samples in a

Table 4. *Bacteria in air of dressing station during dressing of burns with and without source isolators (Model 2)*

Expt.	Time (min.) from end of dressing to removal of isolator	Organisms	Mean counts per min. of bacteria in air of dressing station (6 ft.³ samples) with: Patient in isolator — Before dressing: Mean	Before dressing: Range	During dressing: Mean	During dressing: Range	During dressing: S.E.M.	After dressing: Mean	After dressing: Range	No isolator used (control) — Before dressing: Mean	Before dressing: Range	During dressing: Mean	During dressing: Range	During dressing: S.E.M.	After dressing: Mean	After dressing: Range
5	5	Total	20	15–27	54	34–86	4·2	50·5	48–53	33	11–57	110	58–198	11·6	168·5	159–178
		Staph. aureus	0	—	0·4	0–1	0·13	0·5	0–1	0	—	1·4	0–4	0·5	1·0	—
		Observations		4		14			2		4		10			2
6	3	Total	71·5	65–78	49	18–88	5·3	111	108–114	15	7–21	94	73–136	8·1	109	83–135
		Staph. aureus	0	—	2·1	0–7	0·5	4·0	0–8	0	—	5·3	3–11	0·9	8	8
		Observations		2		16			2		4		8		2	

Table 5. *Bacteria in air during bed-making* in source isolator (Model 2)*

		Mean counts per min. (6 ft³ samples) of bacteria in air					
		Of dressing station			Inside isolator		
Expt.	Organisms	Before bed-making	During bed-making	After bed-making	Before bed-making	During bed-making	After bed-making
1	Total	49·5 (6)†	31 (3)	45·5 (4)	12·5 (2)	7760 (1)	3366 (4)
	Staph. aureus‡	1	0·3	2·3	0	848	408
2	Total	49·7 (6)	26 (3)	39·8 (4)	7·8 (4)	437 (3)	227·8 (4)
	Staph. aureus‡	1·0	1·7	0·8	0·5	129	64·3
3	Total	21·3 (6)	35·3 (3)	42·8 (4)	12 (4)	6333 (3)	3677 (4)
	Staph. aureus‡	0·7	1·3	2·8	0·5	3·3	1·7

* Simulated, ie. manipulation of sheets on bed.
† Figures in brackets = numbers of observations.
‡ Presumptive (phosphatase positive) often confirmed by coagulase test.

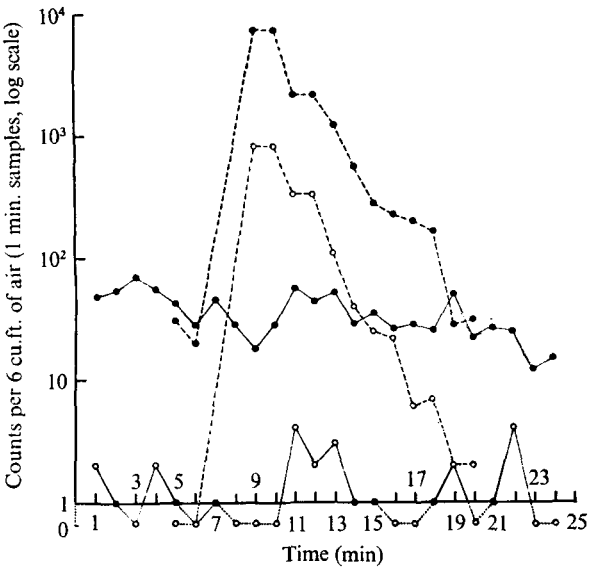

Fig. 1. Total viable counts and counts of presumptive *Staphylococcus aureus* inside and outside source isolator (Model 2) before, during and after simulated bed-making. Outside: ●——●, total; ○——○, *Staph. aureus*. Inside: ●— —●, total; ○— —○, *Staph. aureus*.

large slit sampler with three slits occluded, 6 ft.³) exposed inside and outside the source isolator (ventilated with 18 air changes per hr.) before, during and after a simulated bed-making inside the isolator (i.e. vigorous movement of sheets from the bed of a patient with infected burns). Very large numbers of *Staph. aureus* appeared in the samples taken inside the isolator after agitation of the sheets, but these died away during a quiet period; there was no evidence of any increase in the numbers of total bacteria and of *Staph. aureus* in samples of air taken at the same time by the slit sampler outside the isolator.

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Table 6. *Bacteria in air during dispersal of* B. subtilis *var.* globigii *in source isolator* (*Model* 2)

		Mean counts per min. (23 ft³ samples) of bacteria in air					
		Of dressing station			Inside isolator		
Expt.	Organisms	Before dispersal	During dispersal	After dispersal	Before dispersal	During dispersal	After dispersal
1	Total	27 (6)	52 (3)	28 (9)	10·5 (2)	> 50,000 (1)	6753 (5)
	B. subtilis var. *globigii*	0	0	0·8	0	> 50,000	6745
2	Total	21 (1)	32·5 (2)	29·0 (4)	—	> 42,500 (2)	5589 (4)
	B. subtilis var. *globigii*	0	0	1·3	—	> 42,500	5581

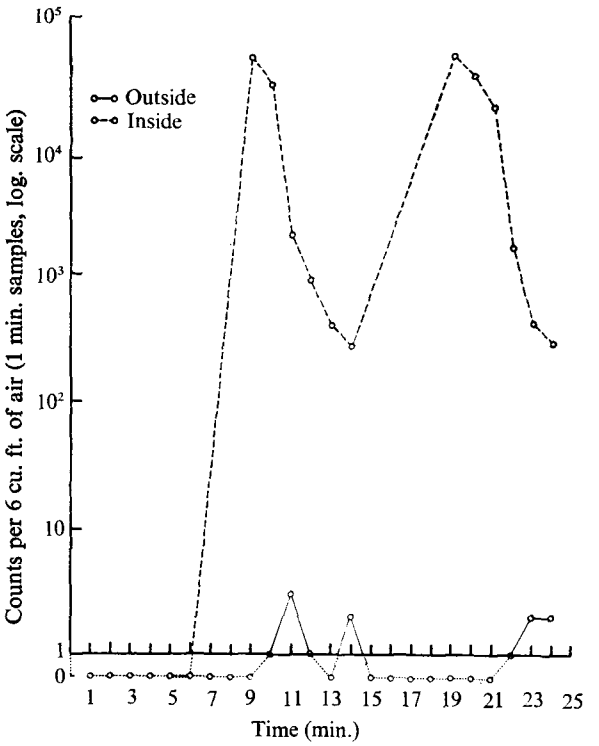

Fig. 2. Counts of *Bacillus subtilis* var. *globii* inside (○--○) and outside (○——○) source isolator (Model 2) before, during and after dispersal of aerosol of the organism inside the isolator.

Table 6 and Fig. 2 show a similar record of 1-min. slit sampler counts obtained inside and outside the isolator in a period during which a suspension of *Bacillus subtilis* var. *globigii* was dispersed from the 'Defensor 505' nebulizer into the isolator. Very high counts of *B. subtilis* var. *globigii* were found inside the isolator after two periods of dispersal of the bacterial suspension followed by a fairly rapid fall in counts; very small numbers of colonies of the bacillus were found outside the isolator after each of the two periods of dispersal of the organism inside the isolator.

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DISCUSSION

The experiments described in this paper were made in an attempt to see whether a plastic ventilated isolator could be effectively used for source isolation of an infected patient. For this purpose we chose the dispersal of bacteria from burn dressings while they were being changed, and the shaking of contaminated bedding, as activities which were likely to disperse particularly large numbers of bacteria into the air and to present a particularly severe clinical challenge to the isolator; an even greater bacteriological challenge was presented in the form of an aerosol of *B. subtilis* var. *globigii* dispersed into the isolator. Slit sampler counts showed the isolator to be highly effective in preventing contamination of the surroundings with bacteria released inside the isolator. Though the protection appeared to be not quite so good when the isolator was used for the dressing of a patient as on artificial contamination by shaking of bedding or dispersal of an aerosol, part, if not all, of the increase in bacterial contamination of air during the change of dressings in the isolator may have been due to dispersal from the dressing team. In addition to control of airborne contamination from the infected patient, the isolator would prevent contamination of the hands or clothing of staff either by direct contact with the patient, or through dressings, bedclothes and other fomites, for which safe handling arrangements were included in the design of the isolator.

Though dispersal of bacteria into the surrounding air during dressing of burns was controlled by the use of a source isolator, there was evidence of some delayed dispersal of bacteria – either residues in the air of the isolator not yet removed by the mechanical ventilation, or bacteria re-dispersed after settling on the patient's body and bedding – at the time when the isolator canopy was removed and the patient was wheeled out of the dressing station; this was less apparent when the patient was kept in the isolator for 5 min. after completion of the dressing, before the canopy was removed.

It was concluded from these findings that the isolator could provide effective source isolation for infected patients. If isolation is restricted to short periods when there is likely to be heavy dispersal of bacteria into the air, a sufficient period should be allowed, before removal of the patient from the isolator, to remove residual micro-organisms from the air inside the isolator. If used for transporting an infected patient the isolator should not be removed until the patient is inside the isolation room which he will occupy in the hospital to which he is admitted. Though our experiments were made on the dressing of burns, this does not seem to be an appropriate application for the source isolator; burn dressings in an isolator were laborious and time-consuming; the use of a mechanically ventilated dressing station is more convenient and demonstrably effective (Lowbury, 1954). Our findings suggest that a specially designed source isolator for continued segregation of an infected patient could be effective, and potentially useful in providing a means by which such a patient could be retained under isolation in his original ward, to facilitate the continuance of treatment which it would be difficult to provide in an isolation ward or hospital.

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EXPLANATION OF PLATE

Source isolator (Model 2) during change of dressings.

J. R. BABB AND OTHERS (*Facing p.* 366)

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