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Observations on the role of hospital blankets as reservoirs of infection*

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INTRODUCTION AND GENERAL ARRANGEMENTS

In view of the widespread interest in hospital blankets as possible reservoirs of infection (cf. Report, 1959) and the paucity of relevant objective data (*Lancet*, 1958), an investigation was made into the effects of regular disinfection of blankets on bacterial contamination of patients, their blankets and the air of the three hospital wards comprising the acute geriatric unit of this hospital.

The female geriatric unit of twenty-four beds occupies one pair of wards on the first floor of a pavilion and there is full movement of medical, nursing and domestic staff between the two wards. The male unit of twelve beds is in one ward on the first floor of another pavilion; its opposite ward is empty.

The wards were completely redecorated just before this investigation was begun; woollen blankets were in use. There were at least 8 ft. between centres of adjacent bed-heads, so there was no overcrowding. No attempt was made to isolate patients with sepsis.

PROCEDURES AND METHODS

(1) *Course of the investigation*

The investigation lasted from 21 October 1959 to 23 August 1960.

The male ward (henceforth referred to as ward M) was used as a control ward and its blankets were laundered and disinfected only at the ward-sister's discretion. In practice this meant infrequently, only when there was obvious soiling.

The female wards were the test wards (F1 and F2). After an initial period of 16 weeks during which the blankets were washed or disinfected only at the ward-sister's discretion, the blankets in one ward (F 1) were disinfected regularly at least every fortnight by formaldehyde vapour *in vacuo* (Caplan, 1959). Thus, each patient was given disinfected blankets on admission and, thereafter, at least every 14 days. This was continued for 17 weeks during which the blankets on the other female ward (F 2) were laundered every fortnight in soap and water. During the final phase of the experiment, which lasted 12 weeks, the blankets of ward F 2 were formalinized, and of F 1 laundered at fortnightly intervals. The course of the investigation is summarized in Table 1.

* Based on part of a thesis accepted for the M.D. degree of the University of London.

(2) *Nasal swabs*

Anterior nasal swabs were taken from all patients on admission, usually while the patient was still in the ambulance just outside the ward, and thereafter at weekly intervals. Swabs were cultured within an hour on blood agar plates including sensitivity disks to penicillin 1·5 units per disk, erythromycin 10 μg., streptomycin 30 μg., chloramphenicol 30 μg., and tetracycline 30 μg.

Table 1. *Summary of the course of the investigation*

Phase	Duration	No. of weeks	Blanket treatment		
			Ward M	Ward F1	Ward F2
I	21 Oct. 1959 to 4 Feb. 1960	16	Nil	Nil	Nil
II	9 Feb. 1960 to 31 May 1960	17	Nil	Formalin	Laundering
III	7 June 1960 to 25 Aug. 1960	12	Nil	Laundering	Formalin

(3) *Blankets*

Sweep-plates (Williams, quoted by Blowers & Wallace, 1955) were taken of the top blanket of each bed at weekly intervals, on a given day of each week. The culture medium was nutrient agar (no. 2 Oxoid) in which 0·1 % phenolphthalein diphosphate was incorporated (Barber & Kuper, 1951). Counts were made of the total number of colonies on each plate, and of the phosphatase-producing rounded colonies morphologically resembling *Staphylococcus aureus*. Up to three representative staphylococci-like colonies were subcultured on blood agar plates with sensitivity disks, Gram-stained and tested for coagulase production.

All blankets were of the ordinary woollen type and laundering was done by low-temperature process employing pure soap and water.

(4) *Slit-sampler counts*

Air was examined by a Bourdillon slit-sampler (Bourdillon, Lidwell & Thomas, 1941) during bed-making time on one day in each week, usually the same day as the blanket sweep-plates and nasal swabs were taken. The apparatus was mounted so that the slit was 2 ft. above floor level and placed 3 ft. away from the foot of each bed, as it was being made, in the centre line of each bed. The culture medium was nutrient agar containing phenolphthalein diphosphate and the plates were treated exactly as the blanket sweep-plates.

In this paper only coagulase-positive strains of staphylococci are considered. They are referred to as *Staph. aureus* or just staphylococci.

RESULTS

(1) *Blanket sweep-plates* (Table 2)

During the period when blankets were formalinized on ward F1 the mean total colony count per blanket fell from 149 to 64 colonies, i.e. to 43 % of the count for the control period. On ward F2 the count fell from 188 to 66 colonies, i.e. to 34 % of the count for the control period. With ordinary laundering in soap and water the respective falls were to 64 % and to 88 %. These figures should be assessed in con-

junction with the fact that on the control ward (ward M), with no special treatment, the count dropped during the course of the investigation from 242 to 166 colonies, i.e. to 69 % of its initial figure.

The effect of formalinization on the number of blankets contaminated and the

Table 2. *Total bacteria and* Staphylococcus aureus *colony counts of blanket sweep-plates*

Ward	Phase	Blanket processing	No. of occupied beds/week	Mean total colony count/ occupied bed	Mean total colony count as percentage of control period	Mean *Staph. aureus* colony count per occupied bed	Mean *Staph. aureus* colony count as percentage of control period	Percentage of beds contaminated with *Staph. aureus*
M	I	Nil	122	242	100	33	100	60
	II	Nil	178	268	105	45	136	78
	III	Nil	132	166	69	34	103	87
F1	I	Nil	152	149	100	25	100	74
	II	Formalin	190	64	43	5	20	46
	III	Laundering	139	95	64	14	50	73
F1	I	Nil	131	188	100	20	100	69
	II	Laundering	171	166	88	26	130	84
	III	Formalin	128	66	34	5	25	50

Table 3. *Total bacteria and* Staphylococcus aureus *colony counts of slit-sampler plates taken during bed-making*

Ward	Phase	Vol. of air sampled (cu. ft.)	Total colony count	Colonies per cu.ft. of air	Total staph. colony count	Mean staphs. per cu.ft. of air
M	I	271	27,844	103	3,214	11·9
	II	342	34,875	102	5,181	15·2
	III	253	27,659	109	3,468	13·7
F1	I	262	24,525	94	2,860	10·9
	II	350	10,683	30	729	2·1
	III	258	17,826	69	1,536	6·0
F2	I	259	22,766	80	2,333	9·2
	II	284	19,791	70	1,928	6·8
	III	266	10,346	39	672	2·9

severity of blanket infestation with *Staph. aureus* is more striking. On the control ward M the percentage of blankets infected with *Staph. aureus* varied between 60 and 87 % of those examined. On ward F1 during the control period, staphylococci were grown from 113 out of 152 blankets (74 %), during the laundering phase from 101 out of 139 (73 %), and during formalinization from 88 out of 190 (46 %). The figures for ward F2 were 90 out of 131 (69 %), 143 out of 171 (81 %), and 63 out of 128 (50 %) respectively. The numbers of staphylococci-carrying particles per occupied bed fell with formalinization to five on each ward, i.e. 20 and 25 % of the control figures on wards F1 and F2 respectively, whilst, at the same time there was no significant change in the blankets on the male ward. With ordinary laundering the staphylococcal colony count per bed fell from 25 to 14 (56 %) on ward F1, and actually rose from 20 to 26 (130 %) on ward F2.

(2) *Slit-sampler counts* (Table 3)

Throughout the experiment the total bacterial content and staphylococcal content of the air during bed-making on ward M were remarkably constant over a given period, there being an average of just over 100 bacteria carrying particles per cu.ft. of air; the staphylococcal colony count varied from 11·9 to 15·2 per cu.ft. On ward F1 the number of bacterial colonies per cu.ft. of air fell during the formalinization of blankets phase from 94 to 30, i.e. to 32 % of the number for the control period; on F2 the fall with formalinization was to 39 colonies, i.e. 49 % of the count for the control period.

The number of staphylococci colonies per cu.ft. of air fell, with blanket formalinization, from 10·9 to 2·1, i.e. to 19 %, and from 9·2 to 2·9, i.e. to 32 %, on wards F1 and F2 respectively. Regular laundering was associated with reduction of total colony counts to 73 and 88 % of the control figures, and of staphylococcal counts to 55 and 74 % of the control figures respectively for wards F1 and F2.

Table 4. *Summary of number of patients with* Staphylococcus aureus *in anterior nares*

Ward	Phase	No. of patient/weeks	No. of positive nasal swabs	Antibiotic resistant *Staph. aureus*
M	I	154	93 (60·4 %)	49 (31·8 %)
	II	193	94 (48·5 %)	64 (33·2 %)
	III	134	76 (56·7 %)	70 (52·2 %)
F1	I	188	124 (66·0 %)	63 (38·5 %)
	II	205	112 (54·6 %)	81 (39·5 %)
	III	145	78 (53·8 %)	38 (26·2 %)
F2	I	162	71 (43·8 %)	19 (11·7 %)
	II	169	73 (43·2 %)	48 (28·4 %)
	III	129	55 (42·9 %)	18 (14·0 %)

(3) *Nasal carriage of* Staphylococcus aureus (Table 4)

The gross figures for nasal carriage of *Staph. aureus* show little variation attributable to blanket disinfection, but these figures do not take into account the number of patients admitted as carriers. Analysis of the figures for acquisition of new strains of staphylococci (as judged by antibiotic sensitivity patterns) is more revealing. During phase I of the investigation 14 out of 31 patients (45 %) on ward M acquired a new strain of staphylococcus in the nose. During phase II the percentage rose to 57 (17 out of 30 patients).

On ward F2 there was a similar rise from 35 % (9 out of 26) in phase I to 54 % (15 out of 28). But on ward F1 this trend was reversed, 61 % (20 out of 33) of the patients at risk acquired a new staphylococcal strain during the control period, phase I, whilst 55 % (24 out of 44) acquired a new strain during the blanket formalinization period, phase II.

During phase III the acquisition rate on the control ward M did not change; the rate rose to 73 % (19 out of 26) on ward F1 with the change from blanket formalin-

ization to ordinary laundering, and fell to 44 % (8 out of 18) on ward F 2 with the introduction of blanket formalinization.

Taking wards F1 and F 2 together, the number of patients acquiring nasal staphylococci during the control period was 29 out of 59 (49 %), during the phases of formalinization 32 out of 62 (52 %), and during the phases of laundering 34 out of 54 (63 %). These figures are not statistically significant ($\chi^2 = 2{\cdot}73$: $P > 0{\cdot}5$; M. P. Curwen, 1961, personal communication).

However, if the number of such acquisitions in each period is expressed as a percentage of the number acquired during the control phase it can be seen that the general trend is upwards (Fig. 1) and that this trend was reversed on both test wards during the period of formalinization.

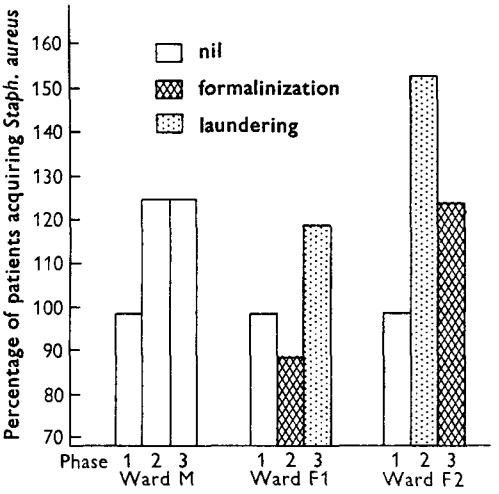

Fig. 1. Rate of acquisition of *Staph. aureus* by hospitalized patients expressed as percentage of rate for control period.

(4) *Inter-relation of nasal carriage and contamination of blankets with* Staphylococcus aureus

The records of 224 patients observed over a total of 1511 weeks were available for analysis. 186 patients (83 %) carried at some time *Staph. aureus* in the anterior nares, including 115 patients (51 %) who carried staphylococci resistant to at least one of the antibiotics tested. In 54 of these 115 patients (45 %) a staphylococcus of the same antibiotic-sensitivity pattern as that found in the nose was never found on the patients' blankets; in 27 cases (23 %) an antibiotic resistant staphylococcus was found in the patient's nose before being found on his blankets; in 17 cases (15 %) staphylococci of the same antibiotic sensitivity pattern appeared for the first time on blanket and nose on the same day; and in a further 17 cases (15 %) an antibiotic resistant staphylococcus of a given sensitivity pattern was found on a patient's blanket before his nose.

In 163 cases (72 % of all those examined) there was no apparent relationship between nasal and blanket carriage, and in only 17 cases (i.e. 8 % of all the patients

studied; 15% of the nasal carriers of antibiotic-resistant staphylococci), was it possible that a staphylococcus from a patient's blanket infected his nose. It is very likely that had a more precise method of typing the organisms been used the number would have been even smaller.

(5) *Sepsis*

There were only six cases of staphylococcal infection in the unit during the investigation, far too few for any conclusions to be drawn. There were two cases of staphylococcal pneumonia and three of skin sepsis among nasal carriers, and one case of skin sepsis in a persistent non-carrier.

(6) *Bacteriological checks*

On many occasions in the past four years bacteriological tests of the formaldehyde disinfection with pre-evacuated chamber method have been carried out using test cultures and blanket sweep-plates.

Table 5. *Sweep-plate colony counts of blankets, before and after formalinization*

	Before treatment		After treatment	
Blanket no.	Total colonies	Colonies of *Staph. aureus*	Total colonies	Colonies of *Staph. aureus*
1	76	2	Nil	
2	54	11	Nil	
3	149	12	Nil	
4	62	5	Nil	
5	55	4	Nil	
6	201	2	Nil	
7	52	9	Nil	
8	166	14	2 (*B. subtilis*)	Nil
9	137	16	Nil	
10	118	34	Nil	
11	85	15	Nil	
12 (*a*)	125	1	Nil	
12 (*b*)	111	2	Nil	

Test cultures

Test cultures of *Bacillus subtilis* of known thermal death-point (105° C., 15 min. incubation) and *B. stearothermophilus* (Southern Group Laboratories. Thermal death-point, 121° C.) have been placed in the centre of the load and have invariably been killed.

Sweep-plates

Sweep-plate cultures of marked blankets before and after formalinization showed that vegetative forms were completely destroyed and that the kill for spore-forming bacteria was of the order of 99%.

Table 5 shows the results on twelve marked blankets, part of a load of forty blankets which were formalinized on 9 March 1961.

DISCUSSION

Blanket sweep-plate counts

In the test wards, with regular formalinization of blankets, the mean total bacterial colony counts of sweep-plates fell to 43 and 34 % respectively, whilst the proportion of beds contaminated with *Staph. aureus* fell from about three-fourths to less than one-half, and the mean numbers of staphylococci per occupied bed were 20 and 25 % of the control figures. Even allowing that sweep-plate counts are no more than semi-quantitative, changes of these magnitudes must be considered as indicating that regular disinfection of blankets with formaldehyde vapour *in vacuo* results in a considerable reduction in the degree of bacterial, especially staphylococcal, contamination.

Slit-sampler counts

The reduction following blanket formalinization, in total colony counts per cu.ft. of air sampled, to 32 and 49 % of the control periods on wards F 1 and F 2 respectively, and of staphylococcal counts to 19 and 32 % respectively must be considered significant.

Inter-relation of nasal carriage and blanket contamination with Staphylococcus aureus

Apart from the work reported here and a small-scale investigation reported by Hutchinson & Green (1956) there is a remarkable paucity of objective data on this point. These authors studied a group of thirty-two healthy girls under preliminary nurse training. Spread of a girl's strain to the bed of her colleague(s) in the same room was found on two occasions, and probably to the bed of a girl in an adjacent room on one occasion. Nevertheless, there was a complete failure to demonstrate cross-colonization between girls.

The results reported here, namely that on only seventeen occasions out of 224 patients studied over 1511 weeks was it possible that a staphylococcus from a patient's blanket infected his nose, suggest that such transmission is but a small factor in the acquisition of *Staph. aureus* by hospitalized patients.

The fact of atmospheric bacterial pollution by the agitation of blankets is proven (cf. Report, 1959) but it is not easy to prove that these organisms outside the human body, in dust and on inanimate objects, can actually produce clinical infection, and it might be argued that in the dried state these pathogens are so emasculated as not to be able to initiate infection. There is recent experimental evidence (Hinton, Maltmain & Orr, 1960) that *Staph. aureus* after having been allowed to dry in air and then rehydrated suffer from a degree of sublethal damage manifest in decreased virulence for mice by intra-muscular, intravenous and intracerebral injection.

However Colbeck (1960), who in a series of experiments inoculated rabbits with infected threads, would seem to have established that staphylococci dried on textiles survive and some, at any rate, of the organisms do not lose their virulence for up to fourteen days. This conclusion supports Williams' (1960) opinion that 'the

abundance of staphylococci and streptococci so often demonstrated in the dust of hospital wards, schools and the like, show that, even if many die, yet many still survive, and one would think that the survivors are sufficiently numerous to serve as a source of infection'.

The effect of blanket disinfection on environmental pollution and cross-infection remains unproven. The many investigations demonstrating the high bacterial content of the so-called secondary reservoirs of infection have led to numerous measures being instituted for their control as, for example, chemical air disinfection, ultraviolet radiation and oiling of floors and bed-clothes. Experimental investigations have shown that the methods are effective in reducing the degree of environmental contamination without, however, a corresponding reduction in the cross-infection rate (Williams, Blowers, Garrod & Shooter, 1960) except, perhaps, in the presence of a severe epidemic.

The investigation reported here seems to fall into this category, i.e. an appreciable reduction in the degree of environmental contamination with little or no effect on cross-infection rates. The possible explanations for this failure are various and include the wide 'normal' variation in disease incidence which makes it difficult to judge the effect of a specific control measure; the fact that even if one mode of transmission be abolished other modes remain operative; the possibility that the degree of environmental contamination was not lowered sufficiently to be effective; and our inability to measure factors such as host susceptibility and bacterial virulence in a changing population.

There are, however, at least two special circumstances in which, undoubtedly, blankets may be important fomites.

Urinary infections

Kirby, Corpron & Tanner (1956) investigated urinary tract infections caused by antibiotic resistant coliform bacilli and pointed out that the objects with which the patient comes into close contact, particularly mattresses and blankets, may be heavily contaminated with resistant coliform bacteria. The bacteria may then cover the patient's skin and the in-dwelling catheter and may gain access to the bladder when it is irrigated.

Payne (1959) applied this suggestion to an outbreak of staphylococcal cystitis in a gynaecological ward. In 5 months, there had been 37 cases of cystitis, 20 of them staphylococcal, in 138 patients. Following redecoration of the ward, modification of the catheterization technique and disinfecting blankets with 'Lissapol' and 'Cirassol OD', there was only one case of staphylococcal cystitis in 384 cases in the succeeding 17 months.

It seems possible that the reduction in post-prostatectomy urinary tract infections in this hospital (Caplan, 1959) was due, in part at least, to the prevention of transmission of infection by direct contact between catheters and bedding, as suggested by Kirby and his colleagues.

Inter-relation of ward and theatre infection

Gillespie, Alder, Ayliffe, Bradbeer & Wypkema (1959) noted a diminution in the rate of theatre infection among patients in one of their wards, the improvement seeming to start with the introduction of blanket disinfection by moist formalin vapour. This, they say, 'is consistent with the widely held belief that contamination of the patient's skin by bacteria-laden blankets and baths is an important means of conveying staphylococci to the theatre'. They comment that 'it was not surprising that a reduction in the ward load of staphylococci brought about a decline in theatre infection, since about a third of the theatre infections were caused by staphylococci prevalent in the wards'.

The one situation in which air-borne infection of wounds seems to be established is in the operating theatre (Williams, 1960) and it is possible that both the indirect air-borne route and direct skin contamination play parts in the transmission of infection in the theatre. If this is so, then only sterile blankets should be taken into the operating theatre suite.

SUMMARY AND CONCLUSIONS

A planned experiment to gauge the effect of regular blanket disinfection on bacterial, especially staphylococcal, contamination and infection in an acute geriatric unit is described.

With formalinization of blankets, the total colony counts of sweep-plates of blankets in use fell to 43 and 34 % of the control period counts on two test wards respectively. The staphylococcal counts fell to 20 and 25 % of their previous levels on the two test wards. Ordinary laundering with soap and water did not significantly alter the degree of bacterial contamination of the blankets.

Colony counts of slit-sampler plates taken during bed-making fell, with formalinization, to about one-third and one-half of the control period counts on the two test wards respectively. Staphylococcal colony counts fell to about one-fifth and one-third of their previous levels.

Staphylococcal contamination of patients was measured by the nasal carrier rate, there being very little sepsis on the unit. The gross figures for nasal carriage of *Staph. aureus* showed little variation attributable to blanket disinfection. The number of patients acquiring a new strain of staphylococcus after admission tended to increase as the investigation continued. This trend was reversed on both test wards coincident with the introduction of blanket disinfection, and it would seem that this measure may have the effect of lessening the chances of the hospitalized patient becoming a nasal carrier of *Staph. aureus*, but the results are not formally statistically significant.

There appears to be a lack of parallelism between the degree of environmental contamination and cross-infection rates. It is considered unlikely that contaminated blankets may cause infection except in two special circumstances: (*a*) in the wards, by direct contact with the patient's skin or in-dwelling catheter, and (*b*) in the operating theatre suite, either directly by contact with the patient's skin, or indirectly via the air.

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REFERENCES

BARBER, M. & KUPER, S. W. A. (1951). *J. Path. Bact.* **63**, 65.
BLOWERS, R. & WALLACE, K. R. (1955). *Lancet*, i, 1250.
BOURDILLON, R. B., LIDWELL, O. M. & THOMAS, J. C. (1941). *J. Hyg., Camb.* **41**, 197.
CAPLAN, H. (1959). *Lancet*, i, 1088.
COLBECK, J. C. (1960). *Amer. J. publ. Hlth*, **50**, 468.
GILLESPIE, W. A., ALDER, V. G., AYLIFFE, G. A. J., BRADBEER, J. W. & WYPKEMA, W. (1959). *Lancet*, ii, 781.
HINTON, N. A., MALTMAIN, J. R. & ORR, J. H. (1960). *Amer. J. Hyg.* **73**, 343.
HUTCHINSON, J. G. P. & GREEN, C. A. (1956). *Brit. med. J.* **2**, 1364.
KIRBY, W. M. M., CORPRON, D. O. & TANNER, D. C. (1956). *J. Amer. med. Ass.* **162**, 1.
Lancet (1958). *Annotation*, ii, 736.
PAYNE, D. J. H. (1959). *J. clin. Path.* **12**, 286.
REPORT (1959). *An Interim Report on the Cleansing and Sterilization of Hospital Blankets.* King Edward's Fund for Hospitals, London.
WILLIAMS, R. E. O. (1960). *Ann. rev. microbiol.* **14**, 43.
WILLIAMS, R. E. O., BLOWERS, R., GARROD, L. P. & SHOOTER, R. A. (1960). *Hospital Infection: Causes and Prevention.* London: Lloyd Luke.