J. Hyg., Camb. (1976), **76**, 23
Printed in Great Britain

Investigation of cross-infection in isolation wards of different design

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(*Received* 24 *April* 1975)

SUMMARY

A survey was conducted in seven hospitals to assess the risk of cross-infection with the highly infectious air-borne diseases, varicella-zoster and measles, in isolation wards of different design. Existing wards and isolation techniques were found to afford a high degree of protection, but there was considerable variation in the incidence of cross-infection related to ward structure, ward practice and the availability of trained staff. Recommendations are made for the design of new isolation wards and for safe practice.

INTRODUCTION

Isolation wards vary greatly in design, largely according to the particular ideas and prejudices of individual planners. Although some work (Parker, John, Emond & Machacek, 1965; McMath & Hussain, 1960) has been done on the spread of infection within such units, a search of the literature has failed to reveal any scientific attempt to confirm the merits of different designs. Gardner and colleagues (1973) found that the cross-infection rate with respiratory syncytial virus and influenza A virus was lower in paediatric wards consisting entirely of single-cot cubicles than in those combining some cubicles with an open area, but did not give detailed plans of the ward design.

The present project was, therefore, set up to try to determine the risks of cross-infection in different types of isolation wards. Varicella-zoster and measles, two highly infectious aerial-spread diseases, were chosen as markers. The difficulty of containment of the former is well known and both diseases have striking clinical features which are easy of diagnosis.

Four hospitals were chosen for the pilot study:

Hospital 1. A 26-bedded ward with 13 cubicles opening on to a long straight corridor with wings of 7 rooms at one end and 6 at the other; 4 rooms at either end face each other. Ventilation of all rooms is direct to the outside or direct to the corridor.

Hospital 2. The ward consists of 4 × 5-bedded wings each with a closed corridor. Each room is ventilated direct to the outside in two directions, firstly from the main window and secondly above the service corridor. In addition, air circulates to the corridor when the door of a room is open.

Hospital 3. A ward with 3 wings, each containing 5 rooms opening to a roofed but otherwise entirely open verandah.

Hospital 4. A ward basically similar to that in Hospital 1 with 28 rooms, but having more facing cubicles in the wings and only 6 cubicles in the main corridor.

After the pilot study had been in progress for a year three more hospitals were included:

Hospital 5. A 15-bedded ward with 6 single rooms on either side of a central corridor and a 3-bedded room in the annexe. No window communication from the rooms to the corridor. The doors are spaced so as not to be opposite each other.

Hospital 6. The ward design is similar to Hospital 1 with slightly more rooms in the wings, making a total of 28 beds.

Hospital 7. A ward with one long straight corridor off which open 26 rooms. No windows from rooms to corridor.

For ward plans – see Figs. 1, 2 and 3.

One research worker was appointed to the pilot study and a second for the extension of the project. They kept accurate day-to-day records of the index cases of marker diseases, all susceptibles admitted, state of the ward from the point of view of nursing shortage, decorating or any other event likely to affect the normal standard of barrier-nursing technique. All susceptibles were visited at home following discharge from hospital. The survey continued for five years.

METHODS

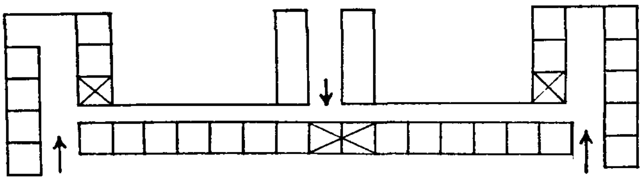
A research worker visited five days a week and recorded the following information:

(i) The distribution of susceptible contacts and index cases by completing the ward plan daily (patients were often moved from one room to another during their hospital stay). The index cases were shown in red ink and a note against their first entry would indicate the day of disease of that patient on his admission to the hospital.

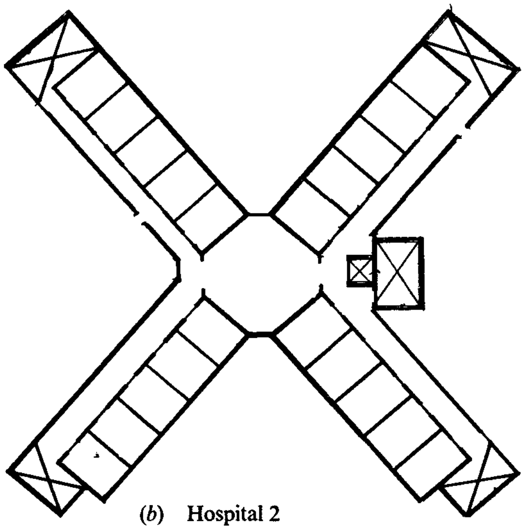
(ii) The names, ages and addresses of all susceptible contacts were kept on a separate list. On discharge of the contact from hospital the date of the home visit was added. This was usually the last day of the expected incubation period of the disease (or diseases) from the time of last contact. If the index case was still an in-patient, the incubation period was dated from the contact's discharge; if not, it was dated from the discharge of the index case.

(iii) Information from the ward sister concerning patients, visitors and staff behaviour (e.g. any 'illicit' room visiting, or any recognized breakdown of the standard barrier nursing techniques).

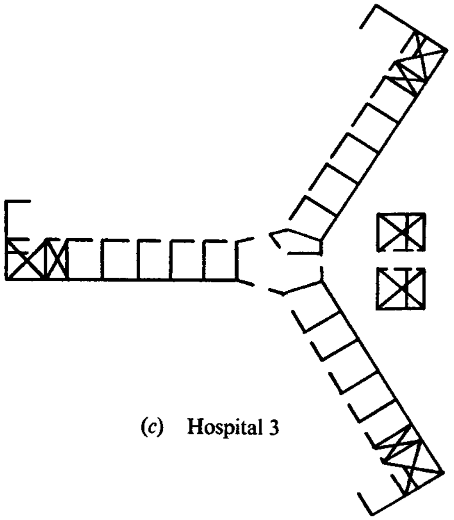
(iv) On discharge of contacts a printed notice outlining the reason for the proposed home visit was included in the letters to the patient's doctor and the medical officer of health.



(*a*) Hospital 1



(*b*) Hospital 2



(*c*) Hospital 3

Fig. 1. Hospitals 1, 2 and 3. The plans of the hospitals in the survey are not to the same scale, and are intended to show the general layout of the wards. Rooms not used for patients are marked with a cross.

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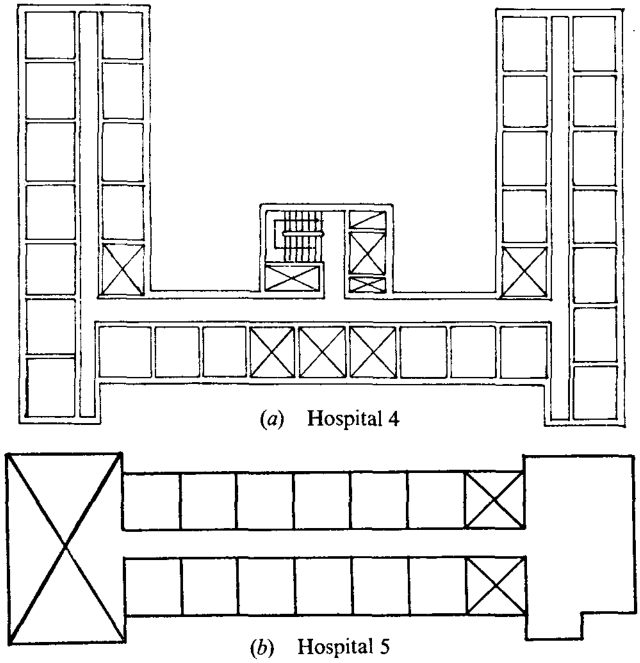

Fig. 2. Hospitals 4 and 5. See note for Fig. 1.

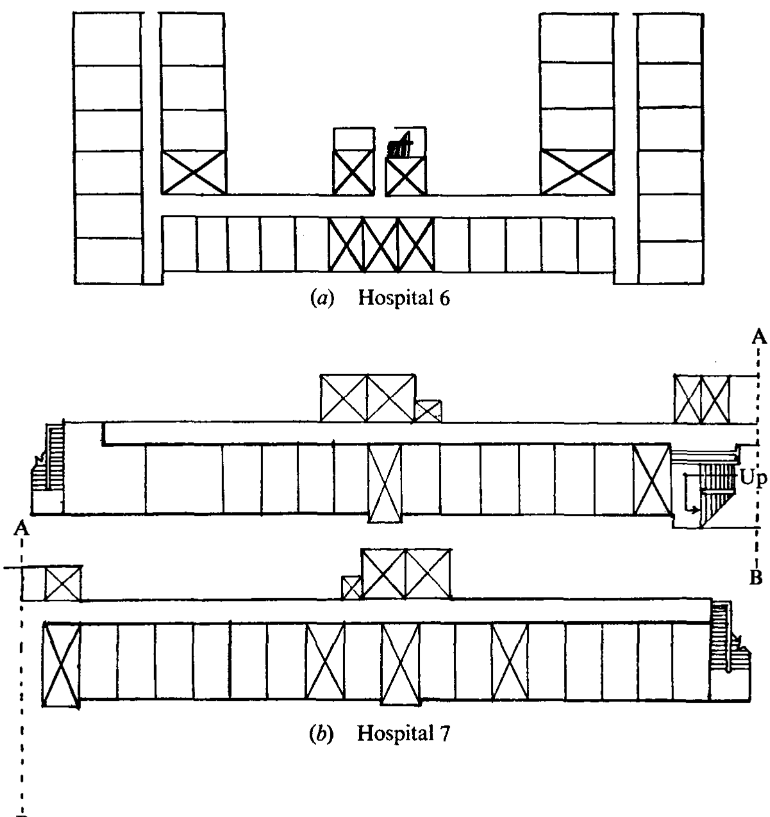

Fig. 3. Hospitals 6 and 7. See note for Fig. 1.

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Table 1. *Visiting statistics*

Number of home visits	5489
Number of patients seen	3049
Number of patients not seen but replied to letter	1941
Number of patients not seen and who did not reply to letter	499

Incubation period

The maximum incubation period of measles was taken as 15 days and of chicken pox as 21 days. Home visits were therefore made by the research worker at the appropriate time and usually within 1 day either side of these timings from the last 'contact'.

Duration of infectivity

Measles was regarded as being possibly infectious for 14 days from the onset, counting the appearance of the rash as day 4 if the onset of the prodromal illness was uncertain. Varicella-zoster was also regarded as potentially infectious for 14 days from the onset.

RESULTS

It can be seen from Table 1 that the research workers were successful in visiting 55·5% of the susceptible contacts after discharge and in obtaining information by letter from a further 35·4%. In approximately 9% of contacts it was not possible to ascertain the outcome.

Details of the number of susceptibles, the extent of exposure, the degree of risk and the infection load are given in Tables 2 and 3. It can be seen from these tables that there were 65 cases of cross-infection with chicken pox among 3861 patients completing the trial. For measles there were 21 cases among 2635 susceptibles. Thus the incidence of cross-infection was very low, 1·68% for chicken pox and 0·8% for measles. Many of these cases were not reported to the hospitals concerned and would have remained undetected without follow-up visiting. Comparison of ward design and analysis of index and cross-infected patients revealed a number of factors which appear to have a bearing on the spread of infection.

(1) *Ward design*

From Table 4 it can be seen that there is a higher incidence of cross-infection with both chicken pox and measles in large wards (1, 4, 6 and 7) where there is ventilation directly into the corridors. In contrast, three hospitals (2, 3 and 5) with a low incidence of cross-infection had small ward units with no ventilation into the corridors. Hospital 2 with an enclosed corridor had no cross-infection with measles and a low incidence with chicken pox. The infecting load in this hospital was greater than in Hospital 3. There was no cross-infection with chicken pox and only two cases of cross-infection with measles in Hospital 3, where the rooms opened directly on to an open verandah. Hospital 5 had no cross-infection with either chicken pox or measles but had the smallest number of index and susceptible patients.

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Table 2. *Varicella-zoster survey*

	Hospital 1	2	3	4	5	6	7	Total
Susceptibles								
No. at entry	1,131	903	435	411	125	426	843	4,274
No. completing trial	1,037	789	410	360	108	382	775	3,861
No. of cases of cross-infection	38	6	0	7	0	3	11	65
Days of exposure								
All cases	11,135	6,655	2,203	3,127	566	2,490	5,381	31,557
Cases of cross-infection	560	36	0	46	0	10	147	799
Degree of risk								
Average days exposure of those not infected	10·6	8·4	5·3	8·7	5·2	6·5	6·9	8·1
Average days exposure of those cross-infected	14·7	6·0	0	6·5	0	3·3	13·4	12·3
Infectious load on ward								
No. of index cases	228	285	60	111	17	72	105	878
Total no. of days index cases remained infectious	2,055	2,488	524	1,302	87	616	885	7,957
Average no. of days index cases remained infectious	9·0	8·7	8·7	11·7	5·1	8·6	8·4	9·1
Cases of cross-infection per 1000 patient/days of exposure	3·4	0·9	0	2·2	0	1·2	2·0	2·1

(2) *Sex incidence of cross-infection*

Although an equal number of male and female patients were admitted to hospital there was a far greater incidence of cross-infection in males susceptible to chicken pox and measles (Table 5). It should be noted that a higher rate of male patients were observed to leave their cubicles without permission – 15 males to 6 females.

(3) *Wandering by patients*

Wandering by susceptible patients, index cases and other patients was associated with cross-infection in 28 out of 65 episodes with chicken pox and 6 out of 21 with measles. It was found that index cases of measles wandered less frequently, presumably because the illness tends to be more severe and patients are confined to bed.

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Table 3. *Measles survey*

	Hospital 1	2	3	4	5	6	7	Total
Susceptibles								
No. at entry	789	541	375	257	256	263	478	2,959
No. completing trial	727	471	355	231	195	222	434	2,635
No. of cases of cross-infection	9	0	2	5	0	2	3	21
Days of exposure								
All cases	8,802	4,026	2,975	2,151	1,305	1,331	2,985	23,575
Cases of cross-infection	209	0	9	50	0	12	13	293
Degree of risk								
Average days exposure of those not infected	12·1	8·5	8·4	9·3	6·7	6·0	7·0	9·0
Average days exposure of those cross-infected	23·2	0	4·5	10·0	0	6·0	4·3	13·4
Infectious load on ward								
Number of index cases	289	285	105	127	58	101	69	1,034
Total no. of days index cases remained infectious	2,647	1,862	840	1,003	288	757	537	7,934
Average no. of days index cases remained infectious	9·2	6·5	8·0	7·9	5·0	7·5	7·8	7·7
Cases of cross-infection per 1000 patient/days of exposure	1·0	0	0·7	2·3	0	1·5	1·0	0·9

Table 4. *Relation between ward layout and cross-infection*

	Size of		Corridor				Cases of cross-infection per 1000 patient/days	
Hospital	Ward (beds)	Ward units (beds)	Lateral	Central	Not enclosed	Ventilation into corridor	Chicken pox	Measles
1	26	26	+	+	−	+	3·4	1·0
2	20	5	+	−	−	−	0·9	0
3	15	5	+	−	+	−	0	0·7
4	28	28	+	+	−	+	2·2	2·3
5	15	15	−	+	−	−	0	0
6	28	28	+	+	−	+	1·2	1·5
7	24	24	+	−	−	−	2·0	1·0

(4) *Open doors*

Doors were reported to be left open in 9 out of 65 patients cross-infected with chicken pox but not in those cross-infected with measles.

(5) *Relative positions of index cases and susceptibles*

The risk of cross-infection was greatly increased when index cases were nursed very near to susceptibles. In 27 out of 65 patients who developed measles the index case was within three cubicles on either side of the susceptibles.

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Table 5. *Sex of patients cross-infected*

Disease	Males	Females	Total
Varicella	45	20	65
Measles	15	6	21

(6) *Admission of index cases*

Admission of index cases past cubicle doors of susceptibles seemed to be a likely explanation of cross-infection in six patients with chicken pox and five with measles. This appeared to be the source of infection in the two patients who developed measles in Hospital 3, spoiling an otherwise perfect record.

(7) *Duration of stay of susceptibles*

In Hospitals 1 and 7, where there was a high incidence of cross-infection with chicken pox, the average days of exposure of susceptibles was considerably greater than in those not infected (Tables 2, 3). The reverse pattern was recorded in Hospital 4.

(8) *Staff shortages*

Shortages of nurses and particularly of experienced nurses were frequently reported from Hospital 1, which had the highest incidence of cross-infection with chicken pox. There was also a temporary shortage of gowns in this hospital.

(9) *Measles/chicken pox/herpes zoster*

The same general pattern was found in the spread of infection with measles and chicken pox with the exception that measles index cases tended to wander less and fewer doors were left open. Herpes zoster was thought to be the source of infection in six cases of chicken pox.

DISCUSSION

From this study covering seven hospitals it would seem that the existing wards and isolation techniques afforded a high degree of protection with an incidence of cross-infection of 1·68% for varicella and 0·8% for measles. There was considerable variation between the hospital units, the largest discrepancy being for varicella, with 3·4 cases of cross-infection per 1000 patient/days in Hospital 1 compared with nil in Hospitals 3 and 5 (Table 4). The serious shortage of trained staff in Hospital 1 was likely to be an important factor in this and the much greater incidence of cross-infection with chicken pox in susceptible males (Table 5) indicates conclusively that air-borne spread of this virus was not the sole factor. Table 6 confirms that wandering by patients or susceptible contacts was important, particularly in chicken pox. This could be due to ward design or inadequate staff supervision, the large ward increasing the chance of the latter. The general discharge policy in all the hospitals was similar but discharges were much affected by social conditions. In Hospitals 1 and 7 there were more long-stay patients, including healthy excretors who could not be returned to over-crowded residential care. These patients were difficult to isolate on the ward where they contributed to

Table 6. *Factors associated with cross-infection*

	Chicken pox	Measles
Males	45/65	15/21
Females	20/65	6/21
Susceptible patients wandering	12/65	5/21
Index patients wandering	8/65	0/21
Other patients wandering	8/65	1/21
Index case admitted past door of susceptible	6/65	5/21
Susceptible admitted past door of index case	0/65	0/21
Susceptible discharged past door of index case	1/65	0/21
Staff shortage	18/65	2/21
Gown shortage	4/65	0/21
Index case close to susceptible (within 3 cubicles either side)	27/65	16/21

the spread of chicken pox. Table 4 clearly shows an increased risk associated with large isolation wards. Central corridors, as in the wings of Hospitals 1, 4 and 6, should be avoided. Table 6 confirms the danger of nursing susceptibles in adjacent cubicles and also the risk of infection being spread through an open door to a susceptible when an infected case is admitted past a cubicle.

We conclude that the following factors should be considered when new isolation units are planned. Ward units should be small, with lateral and not central corridors. Ventilation should not take place into the corridor but directly outside the building. Rooms should be entered through an air-lock or ante-room with two sets of automatic closing doors and there should be adequate provision for admitting patients directly to each section of the ward. It is essential to have adequate numbers of trained staff.

We are indebted to the Department of Health and Social Security for the grant to undertake this study and also to the South East Thames Regional Hospital Board and to the Board of Governors of St George's Hospital for the permission to visit their hospitals. We are most grateful to our colleagues – Dr E. H. Brown, Hither Green Hospital, Professor H. Lambert, St George's Hospital, Dr J. M. Medlock, Eastern Hospital, and Dr E. O'Sullivan, Joyce Green Hospital – for allowing us to study their patients. We also wish to thank sincerely the Research Workers – Mrs D. J. O'Toole, Mrs M. Penry and Mrs F. M. Smith – for their careful record keeping on which the whole project depended.

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