One patient who had a primary removal of a tumour in January, 1947, followed by deep x-ray therapy in June was slowly deteriorating, until Dr. Douglas McAlpine treated him with tetraethyl-pyrophosphate, since when he has steadily improved.

Conclusion

The treatment of myasthenia gravis by thymectomy has been called "empirical," and so it still is in the sense that there are a number of questions to be answered concerning the intimate details of the disease. The connexion between myasthenia and an abnormal thymus gland is now well established, but there is no clue to how or why the gland acquires its abnormal function. The chemistry of the secretion which is producing myasthenia is still quite unknown, and no active principle has yet been isolated.

Fundamental knowledge, such as the truth about the physiology of the neuromuscular junctions, is still lacking, so it is not surprising that understanding of abnormal functions is still defective. Surgery may help to provide an answer to these questions, which are far from being purely academic. In the meantime surgery, with the help of neostigmine, has undoubtedly made a practical advance in being able to alleviate the lot of many of the unfortunate sufferers from myasthenia gravis. There are few more pathetic sights than an otherwise perfectly healthy girl or youth reduced to a state of dependence and physical helplessness, and few more gratifying sights than their dramatic restoration to normal activity, a feat which surgery can now on many occasions claim to have achieved.

Summary

From February, 1942, to July, 1949, 155 patients with myasthenia gravis have been treated by surgical extirpation of the thymus gland.

Of 120 patients who did not have thymic tumours and survived the operation, 79 (65%) have shown a complete or almost complete remission of the symptoms. These could not be accounted for as "spontaneous remissions."

The operative mortality in our hands is at present 4.2%.

The results are influenced by the duration of the disease before operation: the shorter the history the better the results.

Early operation is indicated by the above fact, and by the 11.6% incidence of tumours, the development of which should, if possible, be anticipated.

REFERENCES

- Bratton, A. B. (1948). *B.M.A. Proc. Annual Meeting*, p. 159. London.
 Castleman, B., and Norris, E. H. (1949). *Medicine, Baltimore*, **28**, 27.
 Greene, R. (1949). *Proc. R. Soc. Med.*, **42**, 263.
 Griffith, A. (1949). *British Medical Journal*, **1**, 759.
 Harvey, A. M. (1948). *Bull. N.Y. Acad. Med.*, **24**, 505.
 Kennedy, F. S., and Moersch, F. P. (1937). *Canad. med. Ass. J.*, **37**, 216.
 Keynes, G. (1946a). *Brit. J. Surg.*, **33**, 201.
 — (1946b). *Proc. R. Soc. Med.*, **39**, 600.

A statistical study by V. A. Fenger and J. Nielsen¹ shows that in the period 1908-15 the average duration of life of a Danish doctor aged 25 was 3 years shorter than that of his opposite number in the general population. In more recent years this difference has diminished considerably. This study, brought up to 1944, shows that the mortality among Danish doctors is lower than that among the whole population with regard to tuberculosis, cancer, and accidents. But it is higher with regard to suicides, and more than 40% higher with regard to heart disease. A comparison is made with the studies of Dublin and Spiegelman in the U.S.A., and a table is drawn up by the Danes showing how the Danish and American findings compare with each other in respect of each important cause of death.

¹ *Ugeskrift for Laeger*, June 30, 1949, p. 737.

INCIDENCE OF CROSS-INFECTION IN CHILDREN'S WARDS

BY

A. G. WATKINS, M.D., B.Sc., F.R.C.P.

Paediatrician, Cardiff United Hospitals

AND

E. LEWIS-FANING, B.Sc.Econ., Ph.D.

Statistician, Department of Preventive Medicine, Welsh National School of Medicine

In 1945 the British Paediatric Association began to interest itself in the problem of cross-infection in children's wards in hospitals, and an *ad hoc* committee was set up to consider the matter. Its report was published in the *British Medical Journal* of May 4, 1946 (p. 673). During the committee's deliberations it became obvious that the views and experience of individual paediatricians differed widely. There was not only little information on the incidence of cross-infection but also little evidence of the effect of the common methods used to prevent or control it. The result was a report in very general terms "in the nature of a preliminary discussion," and the collection of evidence on the incidence of cross-infection and the evaluation of methods for its control were left for later investigation. This report is the result.

It is not easy to give an adequate definition of cross-infection in this context, but that suggested by the above-named committee was accepted and used—namely, "To denote any infection acquired by a patient in the hospital environment. Clinically, it is an infection arising during the course of another illness for which the patient was originally admitted to hospital, and may attack the respiratory tract, gastro-intestinal tract, wound, skin, or mucous membrane, or be manifested as one of the specific fevers." This definition places the final onus of diagnosis on the paediatrician, who may or may not have help from bacteriological investigation. This does leave room for a difference of personal opinion, but it was felt that experienced paediatricians would hold relatively uniform views, especially as nearly all those taking part in the investigation had preliminary discussions in committee with their colleagues.

The main objects of the inquiry were to determine: (1) the incidence of cross-infection in children's wards (nurseries for the newborn were excluded); (2) the effect of cross-infection on morbidity and mortality; (3) the part cross-infection played in increasing the length of stay in hospital; and (4) the methods used to prevent cross-infection and their relative efficiency.

Information Sought

Fourteen hospitals were selected as representing a cross-section of children's wards in which patients were under the clinical charge of an experienced paediatrician. The hospitals included examples of children's wards in a general hospital, wards in hospitals for children only, wards in teaching and non-teaching hospitals, and wards taking long-stay cases. In all, the records of 26 different wards were utilized.

Special cards were prepared and issued to each ward for recording the information in respect of every patient admitted. These asked for details of the age, sex, diagnosis on admission, how the child was disposed in the ward on admission and during its stay (e.g., bed in open ward, cubicle), and method of dispersal (e.g., transfer to another ward, transfer to isolation hospital, home). If cross-infection took place its date was to be noted, together with

the suspected source of infection and any relevant bacteriological investigation. Any increased length of stay in the ward as the result of cross-infection was to be estimated, and a special comment was asked for if it was felt that the death of a patient was in any way attributable, either partly or wholly, to cross-infection. The types of cross-infection were divided broadly into: acute specific fevers, upper respiratory infections, lower respiratory infections, gastro-enteritis, and other infections.

A record card was filled in for each child on admission and observations made during the children's stay were dated as at noon of each day. In this way 9,619 cases were covered in the survey. Records were kept from March 1, 1946, to February 28, 1947, but, for reasons to be explained later, analysis was made for only 11 months—i.e., from April 1, 1946, to February 28, 1947.

In addition to the individual patient's record each ward unit was supplied with a questionnaire form. This asked for information on the following:

- Official number of cots in ward.
- Upper and lower age limit of children admitted.
- Type of case admitted (e.g., medical, surgical, tonsillectomy, skins).
- Ward design.—Open ward; length, breadth, height, and distance between cot centres. Number of cubicles, distinguishing single, double, and multiple, giving length, breadth, and height of each cubicle and stating whether it was open or closed.
- Quality of ventilation in wards or cubicles.
- Method (if any) of isolating new admissions.
- Whether a special room is available for dressings.
- Method of ward heating.
- Number of sluices, lavatories, and wash-basins in each ward or cubicle.
- Provision for bed-pan sterilization, napkin disposal, dressings disposal, and refrigerators.
- Whether or not a special room and/or special staff is available for preparing feeds.
- Method of ward-cleaning—dry sweeping, wet or oiled sweeping, oiled floors, oiled blankets, vacuum-cleaning.
- Method of air sterilization (if any).
- Status and qualification of staff: ward sister, number of trained nurses, number of student nurses.
- Number of nurses per ward—average and minimum per day and night.
- Whether "runners" are employed at night.
- Whether the nursing staff are immunized against (a) diphtheria, (b) other infections.
- Number of maids per ward.
- Whether masks are worn by nurses, doctors, students, and maids.
- When masks are worn.
- Whether visiting is allowed—how often, how long, how many per bed, and whether children visitors are excluded.
- Whether acute fevers are transferred or nursed in the ward.
- Any other relevant information.

Data Received

Of the total of 9,619 cases surveyed in the 11 months under review, 679 showed evidence of cross-infection during their hospital stay. This represents an overall incidence (irrespective of length of exposure in hospital) of 7.1%. The frequency of the individual types of infection is shown in Table I.

It is interesting to note that 92 of these children experienced at least two cross-infections and 20 at least three. Tabulation of the acute specific fevers by ward age showed that 23 of the 80 cases of measles were "acquired" before the 10th day, which means that the disease was in the incubation period when the child was admitted to hospital. Similarly three of the five cases of mumps developed before

the 21st day in hospital, five of the 24 cases of whooping-cough developed before the 10th day, and three of the 20 cases of chicken-pox developed before the 14th day. It might be objected that these were not strictly examples of cross-infection and should therefore be excluded from analysis. The objection rests entirely on the interpretation of the word "acquired" in the definition of cross-infection; if these were to be excluded many other infections, both of the upper and of the lower respiratory tract, which were not traceable because the length of their incubation is not known would also have to be excluded. It may be added that admission during the incubation period of an infectious disease was in no way confined to one hospital. In point of fact it has been shown that the cross-infection rates at the individual ward ages would have been little affected if these cases had been omitted.

TABLE I

Type of Infection	Total No.	Percentage Distribution
Upper respiratory infections	257	37.8
Acute specific fevers	155	22.8
Measles	80	11.8
Whooping-cough	24	3.5
Chicken-pox	20	2.9
Scarlet fever	14	2.1
Dysentery	11	1.6
Mumps	5	0.7
Diphtheria	1	0.1
Gastro-enteritis	141	20.8
Lower respiratory infections	57	8.4
Other infections	69	10.2
Total	679	

This evidence strengthens the view expressed in the previous report that an essential barrier to cross-infection is a senior medical officer who shall be responsible for all admissions to the ward.

Effects of Cross-infection

On the record card of each patient an estimate was given of the increased length of stay in the ward attributed to cross-infection. No additional stay was occasioned to 65%, up to an additional week was necessary for 17%, up to two weeks for 14%, and up to three or more weeks for 3.6%. The average additional length of stay in the whole series was 4.59 days, and for those 225 children who did have to stay longer their average increased stay was 12 days. This is an important economic aspect of the problem, for in addition to the increased bed occupation in the original hospital there must be added the days spent in an isolation hospital, home, or other institution. This increased occupancy of beds is a strong argument which may be used in favour of administrative or structural measures that may be adopted to lessen cross-infection, as any means which will reduce the length of hospital stay will therefore increase the total annual occupancy of the beds.

Hospital infection may not only increase the length of a child's illness but contribute materially to a fatal issue. We all know of the patient with pyloric stenosis who is successfully operated upon but who dies later from a gastro-enteritis developed whilst in the ward recovering from the operation. Information was sought by the specific question, "Did the observer consider death was attributable in part or whole to cross-infection?" The answer was in the affirmative in 41 of the 50 deaths which occurred in children developing an infection while in hospital (death wholly attributable to cross-infection, 13; death partly attributable to cross-infection, 28), so that of 587 patients who incurred an infection in hospital 7% died wholly or partly because of that infection. As illustrative of deaths wholly due to cross-infection may be cited two patients admitted for

repair of hare-lip, both of whom died of gastro-enteritis. The infections in this group were as follows:

Gastro-enteritis		17 cases (1 Sonne, 1 Flexner Z)
Pneumonia		16 "
Pneumonia and enteritis		2 "
Upper respiratory infection		2 "
Measles		1 case
Meningitis		1 "
Staphylococcal pyaemia		1 "
Stomatitis		1 "
Total:		41 cases

Only seven of these children were over 2 years old, and of the remaining 34 cases no fewer than 24 occurred in babies under 3 months old, thus illustrating the dangers of hospitalization to small babies.

Statistical Problems

The main statistical problems presented were (a) to calculate an index suitable for comparing the incidence of cross-infection in the various hospitals and wards; (b) to select a suitable standard of comparison; and (c) assuming that the incidence would be found to vary between the wards, to determine whether the rates showed any association with the architectural and administrative factors of the ward. One inherent deficiency in the data was that only infections which became manifest during the patient's stay in hospital were recorded. No provision had been made for following patients up, with the result that the number of cross-infections which occurred in hospital but which developed after discharge was unknown, and the value of the inquiry is lessened to that extent. This once again stresses the advisability of giving careful consideration to the statistical aspects when investigations of this nature are in their initial stage.

No index of cross-infection would be adequate which failed to take into account the differing lengths of time each child was exposed to risk—i.e., the duration of stay in hospital. From the information provided the numbers of patients exposed to risk of infection in each ward at each ward-age (i.e., age 1 = 1 day after entry, age 2 = 2 days after entry, etc.) were obtained. The numbers of cases occurring in each ward were also tabulated, and by relating the total number of cross-infections which occurred at each age in all the wards combined to the aggregate exposures at the relative ages a cross-infection rate at each ward-age for the aggregate of all wards was obtained. These are the standard rates. In calculating them one difficulty which must be recounted necessitated a change in the initial date of the experience. All children admitted for treatment during the period of the survey are admitted at ward-age 0, but the investigation also covered patients who were in hospital

when the inquiry started. To overcome this difficulty it was decided that the experiences should begin on April 1, 1946, instead of March 1. This reduced the length of the inquiry to 11 months, but from the March records the length of stay in hospital previous to April 1 could then be calculated for the majority of children who were in hospital on that day.

The smoothed values of these standard rates (Table II) show that the rate of cross-infection in all hospitals combined rose from 3 per 1,000 in the first four days after entry to 4.9 per 1,000 patients who were in the wards on the 20th–24th days, fell to 3.5 per 1,000 for days 55–59, and was as high as 6.8 per 1,000 for those exposed to risk in days 85–89.

Standard Cross-infection Ratio

For each ward the number of patients exposed to risk at days 0, 1, 2, 3, 4, etc., was known and the number of cross-infections which would have been expected amongst the numbers exposed to risk at each ward-age if the standard rates (all wards combined) had been effective could be calculated for each ward:

$$\frac{\text{Exposed} \times \text{standard cross-infection rate}}{1,000}$$

The numbers expected at each age, aggregated to 91 days or 183 days or 365 days, gave the total number of cross-infections expected in every ward for the respective periods at the standard rates. The number of infections which actually occurred expressed as a percentage of the number expected in the same period provided a comparable index of cross-infection for the different wards. If the actual number was in accordance with expectation the ratio would of course be 100. This index has been termed the "Standard Cross-infection Ratio," because the method of its construction is the same as that of the standardized mortality ratio used by the Registrar-General for comparison of the mortality experienced in different occupations.

When the wards investigated are arranged in order according to the magnitude of the standard cross-infection ratio they may be divided into three groups: those with a high incidence, in which the ratio lies between 140 and 350; those with a moderate incidence of between 60 and 140; and those with a low incidence, below 60, even dropping as low as 29 for a stay of up to 91 days. There are nine wards in the group with a high incidence, eight wards in the moderate group, and nine in the low-incidence group (Table III). It is interesting to observe the extreme

TABLE III.—Wards Arranged in Order According to the Magnitude of the Standard Cross-infection Ratio, Forming Three Groups with High, Moderate, and Low Incidence

S.C.R.	Ward	Stay Up to 91 Days
High (140 or over)	Hospital A, Ward 1	350
	" B, " 1 (infants)	205
	" C, " 1 (medical, babies)	190
	" D, " 1 (infants)	188
	" E, " 1 (convalescent)	185
	" F, " 1	148
	" G, " 2	146
	" H, " 1	145
	" I, " 3 (surgical, babies)	140
Moderate (60–140)	" C, " 1	133
	" J, " 1	123
	" K, " 4	111
	" E, " 2 (convalescent)	90
	" J, " 1	88
	" E, " 3 (convalescent)	84
	" K, " 1 (infants)	73
	" L, " 1	72
	" A, " 2	58
Low (60 or under)	" M, " 1	56
	" K, " 2	55
	" B, " 2	49
	" G, " 2	47
	" L, " 2	38
	" L, " 3	34
	" D, " 2	33
	" N, " 1	29

TABLE II.—Cross-infection Rates (smoothed*) per 1,000 Child-days Exposure (5-day groups); All Wards Combined; Both Sexes. Limited to 91 Days After Admission to Hospital.

Ward Age Groups	Cross-Infection Rate per 1,000 Exposures	Child-days Exposure in Each 5-day Group
0–	2.96	37,306
5–	3.88	30,065
10–	4.47	20,106
15–	4.79	13,981
20–	4.89	10,655
25–	4.81	8,341
30–	4.61	6,641
35–	4.33	5,355
40–	4.03	4,377
45–	3.75	3,560
50–	3.55	3,030
55–	3.48	2,611
60–	3.58	2,274
65–	3.91	2,056
70–	4.52	1,815
75–	5.46	1,568
80+	6.77	1,383

* $y = 2.358 + 0.259x - 0.00801x^2 + 0.0000669x^3$
where y = cross-infection rate, x = ward-age in days.

variation in the wards, all of which were under the supervision of expert paediatricians. To note a specific example, one hospital which is modern and with isolation facilities has a high cross-infection rate in its babies' ward but a low one in its older children's ward, both wards being identical in design. The paediatric supervision, both senior and registrar, is the same for both wards, the recording of cross-infections was done by the same individual, and the nursing staff was drawn from the same training school. It is interesting to note that no fewer than four different hospitals are represented in both the high and the low group.

The amount of material for survey was inadequate for calculation of standard cross-infection ratios based entirely on patients who on admission were under 1 year old, 1 to 4 years, 5 to 9 years, and so on. All that was possible was to distinguish 10 wards which excluded entirely children under 1 year of age. Table IV compares the standard cross-infection ratio of those wards with that of wards to which infants were admitted.

TABLE IV

Type of Ward	S.C.R.			
	Low	Moderate	High	Total
Wards excluding infants under 1 year ..	6	3	1	10
Wards admitting infants	3	5	8	16
Total	9	8	9	26

A statistical test showed significant association between the standard cross-infection ratio ($\chi^2=5.8$; $P<0.05$) and the admission of children under 1 year of age. This increased danger in infancy is a fact well known to all practising paediatricians.

This relation between age and cross-infection is the only "statistically significant" result of our attempt to correlate incidence with environmental influences. Other factors which were statistically investigated but gave no conclusive results were: type of case admitted (surgical, medical, etc.); relation between standard cross-infection ratio and architectural features of cubicles; average square feet per cot; quality of ventilation; employment of "runners"; method of ward-cleaning; and patients' visitors and frequency of visiting-days. (Because of their negative findings these analyses are not recorded in full.) The unit for these analyses was the ward, and with only 26 units it was hardly to be expected that many significant relationships would appear.

The difference between the wards with regard to cross-infection remains difficult to explain fully. There is no doubt that imponderables must play an important part—namely, the quality of the medical and, particularly in this problem, the nursing care. We have noticed that there has been an increase in infection when there has been a change of nursing staff, though we have no figures to support this, and it would seem that there is still a tendency to under-staff babies' wards at night. Thus all the careful work done by the day staff can be undone through a shortage of nurses at night to do the common tasks with adequate care and time.

Another factor which is difficult to assess is the question of immunity of a child admitted to a strange bacterial or viral environment. Bacteriological studies were not undertaken in this review except in a few instances, for in one of the commonest of the infections, gastro-enteritis, there is no specific organism to act as an indicator. It is well known that babies are slow in acquiring an immunity

reaction, and this may well be a factor in the increased infection found in the very young.

Conclusion

On the whole we feel that this inquiry, which entailed a great deal of work for many people, has been disappointing in that it has not resulted in our being able to give advice to hospital planners on the value of the common architectural practices in preventing cross-infection. Further inquiry on these matters which will stand up to statistical scrutiny is desirable. We feel, however, that we have at least obtained some figures that are of interest if only in showing for the first time the extent of cross-infection in a sample of hospital wards in this country and in drawing attention not only to its prevalence but also to its dangers.

It should be recalled that the wards chosen were all under expert paediatric supervision and therefore the number of cross-infections was, or should have been, minimal. However, the very fact of the inquiry taking place in a ward helped to draw attention to the condition and so in itself may have reduced the incidence a little. If, then, hospitals of this status have a cross-infection rate as high as 7% it may be suspected that other hospitals with less facilities and less expert staff have a higher rate.

In this respect it has been interesting to note the reaction in some hospitals visited outside the scope of this inquiry to the question, "How much are you troubled by cross-infection?" In many instances the reply has been given that cross-infection has never occurred, from which it seems likely that the problem has not been acknowledged or recognized. If, then, this paper can do something to interest those responsible for the care of children in hospital in this aspect of their work we feel we may have accomplished something of value.

Summary

Records of all children admitted to hospital during the year March 1, 1946, to February 28, 1947, were provided by 26 children's wards in 14 hospitals in Great Britain. From these records information was obtained as follows: (a) The overall incidence of cross-infection in 9,619 admissions was 7.1%. (b) The average length of increased stay in hospital of these cases that developed a cross-infection was 12 days. (c) In 41 children death was attributable partly or wholly to cross-infection. (d) An index for the rate of cross-infection was calculated for each ward (standard cross-infection ratio) and was found to vary widely for the different wards even within the same hospital. (e) Attempts were made to correlate factors which might be related to the variations, which included ward architecture, equipment, nursing, staffing, visitors, type of case admitted, and the age of the children. The only "significant" finding was that cross-infection was commoner in wards which admitted infants.

The data on which this paper is based have been produced by the helpful co-operation of many sisters and registrars in the hospitals concerned and of the paediatricians who had the children under their care. The following hospital centres have contributed, and we are grateful to all who have helped: Belfast, Birmingham, Cardiff, Glasgow, Guy's, Great Ormond Street (including Tadworth), King's College, Leeds, Liverpool, Newcastle-upon-Tyne, St. Bartholomew's, and Warwick.

We wish to acknowledge many helpful suggestions made by Professor R. M. F. Picken during the course of the analysis. Our thanks are due to Miss Kathleen Davies and Miss Betty Goode, on whom has fallen the burden of the heavy tabulation and computing work, not all of which has been produced in this paper. We are also indebted to the members of the *ad hoc* Committee of the British Paediatric Association on Cross-infection for much valuable advice in the carrying out of this inquiry, and to the British Paediatric Association for a grant towards the computing expenses.