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AN INQUIRY INTO THE EPIDEMIOLOGY OF PEMPHIGUS NEONATORUM

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In recent years there has been a considerable increase in the incidence of pemphigus neonatorum, especially in nurseries in maternity hospitals and units. Cases and outbreaks have in the main been mild, with a very low mortality, but this does not lessen the administrative problems of isolation, quarantine, and ward closure. The rise in incidence of infection due to *Staph. pyogenes* not only in infants but also in nursing mothers, and bacteriological studies of infection in surgical operation wounds, war wounds, and industrial dermatitis, have led to an increased interest in the epidemiology of staphylococcal infections in general. The study of the epidemiology of pemphigus neonatorum and of other staphylococcal infections is rendered difficult by the ubiquity of the causative organism, and it is obvious that the application of any method whereby strains of *Staph. pyogenes* can be differentiated into types must inevitably lead, as in the case of *Str. pyogenes*, *Str. pneumoniae*, the typhoid bacillus, and *Salmonella* organisms, to more accurate knowledge of the sources and paths of spread of infection.

The most generally accepted criterion of actual or potential pathogenicity of staphylococci at present is the ability to produce coagulase, and as staphylococci may be golden, yellow, off-white, or white we have applied the term *Staphylococcus pyogenes* to coagulase-positive strains regardless of pigment production. The first acceptable differentiation of *Staph. pyogenes* into types was described by Cowan (1939), using a slide-agglutination technique whereby most strains of *Staph. pyogenes* were found to fall into three types and an atypical group among which he tentatively recognized five subtypes (personal communication). Differentiation of the subtypes is often difficult, as they are not always clear-cut, and a considerable amount of cross-reaction may occur owing to the presence of common antigens. In 1940 Christie and Keogh, using the same technique, succeeded in differentiating nine types, including Cowan's original three; their observations were based on reactions with absorbed and unabsorbed sera, and the organisms were classified according to the presence of major and minor agglutinogens, but they did not find it possible to eliminate the considerable antigenic overlap between different strains. A further development occurred in 1945, when Wilson and Atkinson described a method of differentiating types among *Staph. pyogenes* by means of bacteriophage action, evolved from the original observations of R. T. Fisk (1942) and

R. T. Fisk and Mordvin (1944); by this method they were able to recognize 21 types or subtypes and to apply the technique successfully to the investigation of several outbreaks of staphylococcal infection, in particular food-poisoning due to staphylococcal enterotoxin.

In the course of investigations to confirm and extend the work of Cowan and of Christie and Keogh, and to explore the possibility of obtaining more clear-cut results by agglutination methods, we were called upon to investigate outbreaks of staphylococcal infection causing pemphigus neonatorum and breast abscess in nursing mothers (Hobbs, 1944), food-poisoning due to staphylococcal enterotoxin (Murphy and Edward, 1944), and cases of sycosis barbae (Hobbs, Carruthers, and Gough, 1947). This provided an opportunity for testing experimental sera and for carrying out investigations on the epidemiology of staphylococcal infections, in particular pemphigus neonatorum.

In November, 1943, we were asked to investigate an outbreak of pemphigus neonatorum, affecting eight infants, in the main nursery of the maternity unit, City Lodge Hospital, Cardiff. This marked the beginning of a series of observations on the epidemiology of pemphigus neonatorum in the unit, which continued uninterruptedly for two years till November, 1945. During this period 2,719 infants were born in or admitted to the unit, of which 111 (4.1%) developed pemphigus neonatorum; all strains of *Staph. pyogenes* isolated from these patients were investigated serologically.

In addition, there occurred during the period of investigation 25 cases of staphylococcal conjunctivitis ("sticky eye"), either alone or associated with pemphigus neonatorum; cultures were taken from the infected conjunctivae for bacteriological and serological examination.

Procedure and Technique

(a) *Collection of Specimens.*—The specimens examined came from the lesions, nose, eyes, and occasionally umbilicus of infected infants, from the nose of healthy infants in infected nurseries, from likely sources of infection such as the nose, throat, and skin of infants' mothers, nursing, domestic, and medical staff, from air and dust in the nursery, and from infants' blankets and gowns. New patients were visited as early as possible in order to collect fluid from intact bullae by aseptic puncture with sterile Pasteur pipettes drawn out to a fine capillary. If the lesions were already open and discharging, swabs

were taken from the exudate after initial cleansing with sterile gauze. Nasal and eye swabs for infants were made from a fine pliable copper wire with a very small pyriform pledget of cotton-wool. Specimens for culture from skin were taken from the thumb, the terminal phalanges of the index and middle fingers, and the palmar and dorsal surfaces of the hand with swabs previously moistened with quarter-strength Ringer solution. Dust samples consisted of floor sweepings, which were collected in sterile test-tubes and shaken up in quarter-strength Ringer solution; cultures were made from tenfold dilutions. For air-sampling, blood-agar plates were exposed for one to three hours in the air of the ward during both quiet periods and periods of greatest activity. Blankets and infants' gowns were tested by soaking two small areas of about 12 sq. in. (75 sq. cm.) of each article in nutrient broth, cultures being made from the broth and from dilutions of the broth.

(b) *Laboratory Procedures.*—Agar plates containing 10% horse blood were the basic medium used for the culture and isolation of strains of *Staph. pyogenes*, but specimens from lesions were often cultured also on gentian violet (1/500,000) blood agar, especially if the presence of *Str. pyogenes* was suspected. Swabs still moist were inoculated direct on to blood-agar plates, but any which appeared to be dry were moistened with broth or quarter-strength Ringer solution. An ideal procedure was to incubate the swab in broth after inoculation of the plates. The broth culture after 18 hours' incubation was used for the tube-coagulase test (Gillespie, 1943), and if the direct plate showed no staphylococci the enrichment broth was plated out on to blood agar. By this method small numbers of staphylococci often missed by direct plating were isolated in almost pure culture. Following overnight incubation of the direct plate at 37° C. observations were made on the amount of growth, the types of organisms, and the proportion of colonies of *Staph. pyogenes*. From all cultures showing the presence of staphylococci at least two colonies were tested for their ability to produce coagulase by the slide-coagulase test introduced by Cadness-Graves *et al.* (1943), using human plasma. Pigmented strains which were coagulase-negative by the slide technique were re-tested by the tube method (A. Fisk, 1940). At least two coagulase-positive colonies from each culture were sub-cultured for serological typing. It was found advisable to leave the blood-agar plates on the bench for a few days to allow the full development of pigmentation and colony morphology. By so doing differences between types of colony became more obvious, and such differences were frequently found to correspond with different serological types, and often more than one type was present on a plate. Serological typing was carried out by means of the slide-agglutination technique described by Cowan (1939), using crude and absorbed sera from rabbits inoculated with vaccines prepared from Cowan's original three strains and from strains of additional types described by Christie and Keogh (1940). Agglutinating sera were also prepared against a number of freshly isolated strains which did not appear to fit into any of the hitherto identified types; these strains were cultured from various staphylococcal lesions during the course of the investigation. Many of the strains of *Staph. pyogenes* type Ib isolated from lesions during the second outbreak of pemphigus were typed by the bacteriophage method at the Public Health Laboratory, Oxford, and were regularly lysed by the same phage filtrates.

Prevalence of Pemphigus Neonatorum during the Period of Investigation

The maternity unit was housed in a 2-story block and consisted of a main nursery (Nursery 10) with 32 cots (later reduced to 16), a nursery for premature infants (10 cots), another 10-cot nursery, and five isolation nurseries (10 cots). In three of the six wards mothers and infants were nursed together. The unit had maximum accommodation for about 90 infants with their mothers, including isolation cases.

Prior to November, 1943, cases of pemphigus neonatorum in the unit had been rare, and had occurred singly and sporadically. Between November, 1943, and October, 1945, 132 cases of pemphigus neonatorum and staphylococcal

conjunctivitis occurred in the unit, and their distribution in the various wards and nurseries is shown in Table I. It will be seen that 93 cases (70.5%) occurred in infants in Nursery 10, attached to Wards 10 and 11, while 29 cases (22%) occurred in infants in Wards 8 and 9; there were only two cases in premature infants. It is also to be noted

TABLE I.—Distribution of Cases

No. of Ward or Nursery	No. of Cases of			Total Cases
	Pemphigus Neonatorum	Staphylococcal Conjunctivitis	Pemphigus Neonatorum + Staphylococcal Conjunctivitis	
2	4	—	—	4
6A	2	—	—	2
7	2	—	1	3
8/9	25	4	—	29
10	73	17	3	93
14	1	—	—	1
Totals:	107	21	4	132

that all 21 cases of staphylococcal conjunctivitis and three of the four cases of combined pemphigus and staphylococcal conjunctivitis occurred in Wards 8 and 9 and Nursery 10. As over 70% of the cases were among infants in this nursery the epidemiological investigations carried out were centred round it.

The present investigation began when three cases of pemphigus occurring in Nursery 10 were reported to the laboratory during the first week of November, 1943, and the unit was visited to take specimens for bacteriological examination. During the two succeeding weeks five further cases of pemphigus developed in this nursery, and as serological methods of identifying the infecting strains of *Staph. pyogenes* had already proved successful in tracing the source of a small outbreak of pemphigus neonatorum in a private nursing home it was decided to widen the scope of the inquiry in order to discover the source of infection and the mode of spread.

Investigations and Results

Coagulase-positive staphylococci, usually in pure culture, were isolated from the lesion of every case investigated, including both pemphigus and "sticky eye." Swabs from the lesions of many cases were examined on repeated occasions, and in infants with multiple lesions sometimes several swabs were taken from different infected areas of the body. All the strains were subjected to serological examination, and the infecting organism was typed in all but one of the 132 cases.

Distribution of Serological Types in the Lesions of Infected Infants

Fig. 1 shows the distribution month by month of the serological types of *Staph. pyogenes* isolated from all the cases in the maternity unit during the period of investigation. The total number of infants born in the maternity unit month by month during the period is also shown, and varied from 84 to 144, with a mean of 113.7. The number of cases of pemphigus and staphylococcal conjunctivitis per month varied from 0 to 22, with a mean of 5.5. In broad outline the chart shows a small sharp outbreak due to *Staph. pyogenes* type I which occurred early in November, 1943 (8 cases: 6 type I). This was followed by an outbreak due to type Ib which began in January, 1944, and continued with varying intermissions and recrudescences until May, 1945 (119 cases: 101 type Ib). Following an intermission of three months during which no cases occurred, there were indications of a third outbreak starting early in October, 1945 (5 cases: 4 type I), just as the investigation had to be terminated.

The first outbreak involved eight infants, all in Nursery 10, who were infected over a period of two weeks in November, 1943. *Staph. pyogenes* type I was isolated from the lesion of six infants; of the remaining two, one was infected with *Staph.*

pyogenes type I/II and the other with type IIIc. The latter infant was later reported to have been discharged from the unit with no evidence of pemphigus and to have been brought back one week later suffering from pemphigus and staphylococcal conjunctivitis. Type IIIc was also isolated from pus from the infected eyes and from the nose. During December no cases

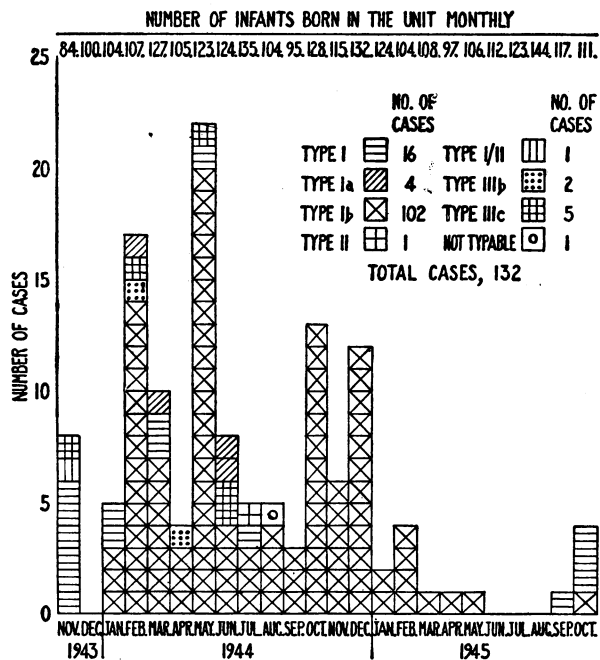


FIG. 1.—The serological types of *Staph. pyogenes* causing pemphigus neonatorum and staphylococcal conjunctivitis among infants in a large maternity unit month by month from November, 1943, to October, 1945.

of pemphigus occurred, but in January, 1944, there were five cases, in two of which infection was due to *Staph. pyogenes* type I. From the three remaining cases *Staph. pyogenes* type Ib was isolated, and this type became the prevailing cause of pemphigus neonatorum in the unit during the remainder of the period of investigation. In February there were ten cases of pemphigus, all due to type Ib, and seven cases of staphylococcal conjunctivitis, of which four were caused by type Ib. During March no cases of pemphigus occurred in Nursery 10, but there were seven cases of staphylococcal conjunctivitis, of which four were due to type Ib, two to type I, and one to type Ia. A sharp rise in the incidence of pemphigus took place in May, mainly affecting Nursery 10 in which 21 cases occurred, 20 due to type Ib and one to type I. The one case of staphylococcal conjunctivitis in May was due to type IIIc. Following this outbreak in May, Nursery 10 was closed for a few days at the beginning of July and was thoroughly washed and cleansed. The nursery was reopened under less crowded conditions and there were no further cases of pemphigus in it in July, but six occurred during August and September, all due to type Ib. A further rise in incidence in this nursery took place between October and December, when type Ib caused 17 cases of pemphigus, one case of pemphigus and conjunctivitis, and two cases of conjunctivitis alone. The next five months produced nine cases, all due to type Ib, of which seven occurred in Nursery 10; but no more cases of staphylococcal conjunctivitis were observed up to the end of the investigation. There were no cases of pemphigus during June, July, and August, 1945, but in September there was one case due to type I. When the investigation was terminated in October there had been three more cases in Nursery 10 all due to type I.

Table II gives the numbers of cases of pemphigus and staphylococcal conjunctivitis which occurred throughout the investigation in the various nurseries and wards, and also shows the type distribution of the strains of *Staph. pyogenes* isolated from the lesions. It demonstrates, as already pointed out, that

TABLE II.—Distribution of Serological Types of *Staph. pyogenes*

No. of Ward or Nursery	Illness	Serological Type							Total	
		I	Ia	Ib	II	I/II	IIIb	IIIc		Not Typed
2	P	2	1	1	—	—	—	—	—	4
	P	—	—	2	—	—	—	—	—	2
	P	—	1	1	—	—	—	—	—	2
6A	P	—	—	—	—	—	—	—	—	—
	P	—	—	—	—	—	—	—	—	—
	P	—	—	—	—	—	—	—	—	—
7	P	—	—	—	—	—	—	—	—	—
	P	—	—	—	—	—	—	—	—	—
	P	—	—	—	—	—	—	—	—	—
8/9	P + C	—	—	1	—	—	—	—	—	1
	P	—	—	23	—	—	—	—	—	23
	P	—	—	3	—	—	—	—	—	3
10	P + C	10	—	59	1	1	—	2	—	73
	P	3	1	9	—	—	—	2	—	15
	P	—	—	2	—	—	—	1	—	3
14	P	—	—	1	—	—	—	—	—	1
	P	—	—	2	—	—	—	—	—	2
	P	—	—	1	—	—	—	—	—	1
All	P	13	2	87	1	1	—	2	1	107
	P	3	2	12	—	—	—	2	—	21
	P + C	—	—	3	—	—	—	1	—	4
Total		16	4	102	1	1	2	5	1	132

P = Pemphigus neonatorum. C = Staphylococcal conjunctivitis.

type Ib, isolated from 102 (77.3%) of the 132 cases, was responsible for the great majority of the infections. It may also be noted that 73 (68.2%) of 107 cases of pemphigus and 17 out of 21 cases of staphylococcal conjunctivitis occurred in Nursery 10; between 50 and 60% of the infants born in the unit occupied Nursery 10.

Staphylococcal Conjunctivitis

A study of Table II shows that 87 (81.3%) out of 107 cases of pemphigus were caused by type Ib, and only 12 (57.1%) out of 21 cases of staphylococcal conjunctivitis were due to the same type; three out of four cases of combined pemphigus and conjunctivitis were due to type Ib. It would appear, therefore, that in an outbreak of pemphigus due to a particular serological type of *Staph. pyogenes* associated cases of conjunctivitis due to the epidemic type may occur, but there may also arise sporadic cases of conjunctivitis due to other serological types of *Staph. pyogenes* not prevalent as the cause of pemphigus, or indeed in the absence of pemphigus.

Swabs were taken from both eye and nose of nine cases of conjunctivitis, and seven showed the same type in eye and nose, the types being different in the remaining two. Swabs from four patients with coincident pemphigus and conjunctivitis yielded the same type from eye and lesion in each case, and in two cases from which nasal swabs were also taken the infecting type was found in the nose as well. When pemphigus and conjunctivitis occurred in the same patient, therefore, the double infection was caused by the same serological type of *Staph. pyogenes*. Also when conjunctivitis alone occurred the same type of *Staph. pyogenes* was present in the infected eyes and in the nose of a high proportion of cases.

Serological Types of *Staph. pyogenes* Isolated from Nursery Staff

Swabs were taken from the noses, hands, and occasionally the throats of the nursery, domestic, and medical staffs of the unit three times during the course of the investigation (Table III). The first of these occasions was in November, 1943, two days after starting the investigation of the first outbreak of pemphigus neonatorum in Nursery 10. Nose, throat, and hand swabs were taken from 15 members of the medical and nursing staff of the infants' nursery, and 10 (66.7%) were found to be harbouring *Staph. pyogenes* in one or more of the three sites. Four carried the epidemic type I, two harboured type IIIb, two type IIIc, and one each types Ia and Ib, all in the nose. *Staph. pyogenes* was isolated from the hands of seven members of the nursing staff, and all the strains belonged to the same serological types as were present in the noses of the individuals.

The second swabbing of the staff took place in February, 1944, when cases in the second outbreak due to *Staph. pyogenes* type Ib were increasing in number. Fig. 1 shows that the peak of this outbreak was reached in May, 1944. Nose, throat, and hand swabs were taken from 40 persons, including doctors, sisters, nurses, pupil midwives, and ward cleaners—the entire

TABLE III.—Summary of Results of Serological Examination of *Staphylococcus pyogenes* isolated from Infants and their Environment in Nursery 10 during Three Consecutive Outbreaks of Pemphigus Neonatorum (1943-5)

Source of Specimens	1st Outbreak— <i>Staph. pyogenes</i> Type I			2nd Outbreak— <i>Staph. pyogenes</i> Type Ib			3rd Outbreak— <i>Staph. pyogenes</i> Type I		
	Total Examined	No. showing		Total Examined	No. showing		Total Examined	No. showing	
		<i>Staph. pyo.</i>	<i>Staph. pyo.</i> Type I		<i>Staph. pyo.</i>	<i>Staph. pyo.</i> Type Ib		<i>Staph. pyo.</i>	<i>Staph. pyo.</i> Type I
Infants with pemphigus	7	7	6	56	56	52	3	3	3
Lesion ..	7	7	6	56	51	29	3	2	2
Nose ..	6	4	3	56	46	30	3	3	2
Eye ..	—	—	—	20	20	11	—	—	—
Infants with conjunctivitis	—	—	—	—	—	—	—	—	—
Eye ..	—	—	—	—	—	—	—	—	—
Healthy infants	32	28 (87.5%)	11 (34.4%)	—	—	—	18	11 (61.1%)	2
Nose ..	—	—	—	—	—	—	—	—	—
Nursery staff	15*	10 (66.7%)	4 (26.7%)	40†	29 (72.5%)	12 (30%)	48‡	33 (68.8%)	18 (37.5%)
Hands ..	15	7	4	40	41	6	48	10	5
Nose ..	5	2	2	—	—	—	3	3	1
Mothers	4	2	1	—	—	—	—	—	—
Milk ..	4	2	1	—	—	—	—	—	—
Skin ..	2	1	1	—	—	—	—	—	—
Nursery dust	—	Present	28% of 18 colonies	—	—	—	—	Present	Present
Nursery air	—	—	Present	—	—	—	—	—	—
Blankets and gowns	8	6	1	—	—	—	—	—	—

* One nurse (6.7%) harboured *Staph. pyogenes* type Ib in her nose. † Two nurses (5.0%) harboured *Staph. pyogenes* type I in the nose. ‡ Two nurses (4.2%) harboured *Staph. pyogenes* type Ib in the nose.

staff of wards and Nurseries 8, 9, 10, and 11. It appeared that most of the junior nursing staff had altered since the previous swabbing in November, 1943, as a regular change-over of pupil midwives took place every three months. Of 40 persons 29 (72.5%) harboured *Staph. pyogenes*; 28 of these were nasal carriers and one had a positive throat culture only. The epidemic strain, type Ib, was harboured by 12 persons (30%), type Ia by six persons, types IIIa and IIIb by three persons each, type I (5%) by two persons, type IIIc by one person, while two persons carried unidentified types. Ten members of the staff had *Staph. pyogenes* in both nose and throat, and in eight the organisms in both sites were of the same type. Eleven persons showed *Staph. pyogenes* both in the nose and on the hands, and in nine instances the types were the same in both sites.

It was apparent that the percentage of the staff harbouring the first epidemic strain, type I, had declined from 26.7% to 5%, and that the second epidemic, type Ib, was now prevalent to a degree (30%) shown formerly by type I; in the first swabbing type Ib was found present in the nose of only one nurse (6.7%). These findings suggested that a high carrier rate among the staff of an infective strain of *Staph. pyogenes* would render the infant population of a nursery highly exposed to infection by that strain, and be followed by the appearance of clinical cases of pemphigus neonatorum and of staphylococcal conjunctivitis. An opportunity to test this hypothesis was provided by the occurrence of a small number of cases of pemphigus due to *Staph. pyogenes* type I in September and October, 1945. Following three isolated cases caused by type Ib in March, April, and May there had been a lull in the incidence of pemphigus throughout the unit during June, July, and August. Alterations in the technique of routine procedures that may have been responsible for this decline in cases are described in a later section. At the beginning of October, 1945, nasal and hand swabs were taken from 48 members of the maternity staff, more than half of whom were pupil midwives who had recently joined the staff and had not been swabbed previously; 33 (68.8%) were found to be harbouring *Staph. pyogenes* in the nose and 10 on the hands. Eighteen of the nasal carriers carried type I, eight harboured type IIIb, three type I/II, two type Ib, and two type II. Again the most prevalent type present in the noses of the staff was that giving rise to the fresh cases of pemphigus in the nursery. Of the total staff 18 (37.5%) harboured type I, and only two individuals (4.2%) carried type Ib, which had been responsible for cases throughout 1944 and the early part of 1945 and which was present in the noses of 30% of the staff in February, 1944. The first two swabbings of the staff had been carried out during the height of outbreaks of pemphigus, and it was impossible to decide whether the high nasal carrier rate of the epidemic strain was a cause or a consequence of the outbreak. The third swabbing, however, was carried out after a case due to a different type had occurred, following a period of three months during which there had been no cases of pemphigus or staphylococcal conjunctivitis. The presence of a high proportion of

nasal carriers of the infecting type among the staff at this early stage strongly suggests that a build-up of nasal carriers of a potentially infective strain occurs among the staff before the appearance of cases of pemphigus.

Twelve members of the nursery staff were swabbed on two or more occasions. Nasal swabs from five either showed non-epidemic types of *Staph. pyogenes* or were negative. Of the remaining seven, four harboured the prevalent epidemic type once, while the remaining three yielded the prevalent epidemic type each time they were swabbed. The numbers are too small for any deductions to be drawn regarding the frequency of change of serological type of *Staph. pyogenes* in the nose in relation to the prevalent epidemic type.

Staph. pyogenes in Noses of Healthy Infants in the Infected Nursery

In addition to swabbing the staff, nasal swabs were taken from all the healthy infants in Nursery 10 on two occasions (Table III). First in November, 1943, at the time of the outbreak due to *Staph. pyogenes* type I, nasal swabs were taken from 32 healthy infants in the nursery; 28 (87.5%) were found to be harbouring *Staph. pyogenes* and 11 (34.4) carried the epidemic type I and were free from clinical infection. Type Ia was isolated from six infants, type Ib from three infants, and type II from two infants, while 13 strains could not at that time be typed. Seven of the infants harboured more than one serological type of *Staph. pyogenes*. The infants harbouring type I were scattered throughout the nursery and there was no concentration of infants in neighbouring cots showing the same serological type in their noses.

When, in October, 1945, after a period of three months' freedom from infection, cases of pemphigus due to *Staph. pyogenes* type I began to appear in Nursery 10, nasal swabs were again taken from all of 18 infants in the nursery. Swabs from five of the infants, ranging in age from 5 hours to 2 days, failed to yield staphylococci; of the remaining 13 infants, aged from 4 days to 2 months, 11 (61.1%) were heavy carriers of *Staph. pyogenes*. The types were fairly evenly distributed, no single type being predominant, and the high nasal carrier rate of type I among the staff was not at this stage present among the infants.

Staph. pyogenes in the Nursery Air and Dust

Blood-agar plates were exposed in Nursery 10 on two occasions—first during the outbreak of pemphigus in November, 1943, and again in October, 1945. On the first occasion five plates were exposed at cot level in different parts of the nursery from 2 to 5 a.m. and a second series from 7 to 10 a.m., periods of least and greatest activity respectively in the nursery. A total of approximately 3,000 colonies, representing bacteria-containing particles, were counted on plates exposed from 2 to 5 a.m. Plates exposed from 7 to 10 a.m. were too overcrowded for counting. The organisms on the plates were predominantly saprophytic cocci and bacilli, but *Staph. pyogenes* was present in small numbers. Of three colonies of *Staph.*

pyogenes subcultured for examination two were identified as type I. The second exposure of plates in the nursery in October, 1945, yielded approximately 2,000 colonies during the early morning period and approximately 10,000 colonies during the active period between 7 and 10 a.m. Again *Staph. pyogenes* was present only in small numbers, but type I, which was at that time the cause of pemphigus, was identified on plates from four different sites.

It was evident, therefore, that the epidemic strain of *Staph. pyogenes* was present in the ward air during both periods of exposure, but it was not possible from these investigations to estimate to what degree, although it appeared to be low.

Two samples of dust from the floor of Nursery 10 were examined in November, 1943. The samples were collected into sterile jars from the routine morning sweepings. Cultures yielded large numbers of organisms, mainly saprophytic; but *Staph. pyogenes* was present in considerable numbers in one sample, while the other yielded scanty colonies. Of 18 colonies of *Staph. pyogenes* examined serologically five were identified as type I, four as type IIIc, one as type Ib, while the remaining eight could not be typed. The epidemic type I therefore represented 28% of a random sampling of *Staph. pyogenes* in the floor dust of the nursery; the remaining identified strains belonged to types which were found in the noses of members of the nursery staff and of healthy infants in the nursery.

Staph. pyogenes in Infants' Blankets and Gowns

Staph. pyogenes was isolated from five out of six blankets from cots in Nursery 10 in November, 1943; type I was found on one blanket and types Ib, II, IIIb, and IIIc on the others. One blanket was re-examined after laundering, and *Staph. pyogenes* type I was isolated from nutrient broth in which part of the blanket had been soaked and also by shaking the blanket over exposed blood-agar plates. Two flannel gowns belonging to infants in Nursery 10 were examined after laundering; one gown yielded *Staph. pyogenes* type IIIb and an untypable strain, while no staphylococci were isolated from the other.

Table III gives a summary of the results of examinations of cultures from material taken in relation to the three outbreaks of pemphigus neonatorum in Nursery 10. It shows the regularity with which the epidemic types were found in the noses of a high percentage of the nursery staff, and elsewhere in the infants' environment, and suggests that widespread distribution of an infecting strain in the nursery environment may bear a causal relationship to the onset of an outbreak. Members of the staff swabbed during the second and third outbreaks included those engaged on nursing duties in other nurseries and wards of the unit, especially Ward and Nursery 8/9, in which 23 out of 24 cases of pemphigus and three out of four cases of staphylococcal conjunctivitis were caused by *Staph. pyogenes* type Ib.

Distribution of Infecting Types of Staph. pyogenes in Eye, Nose, and Umbilicus of Infected Infants

During the course of the investigation swabs were taken from 102 of the 111 cases of pemphigus neonatorum, not only from the lesions but also from other sites on the body, including the nose, eye, and umbilicus. Table IV shows the numbers of

TABLE IV.—Correlation Between Serological Types of *Staphylococcus pyogenes* Isolated from the Lesion, Eye, Nose, and Umbilicus of Cases of Pemphigus Neonatorum (Total Number of Cases Examined—102)

Sites	No. of Cases Examined	Same Serological Types		Different Serological Types	
		No.	%	No.	%
Lesion and nose	102	75	73.5	27	26.5
Lesion and eye	91	64	70.3	27	29.7
Lesion and umbilicus	19	15	78.9	4	21.1
Lesion, eye, and nose	91	55	60.4	36	39.6
Lesion, eye, nose, and umbilicus	16	8	50.0	8	50.0

cases from which the various combinations of swabs were taken and the numbers and percentages of cases in which strains of

Staph. pyogenes were serologically identical or of different serological types. In general it was found that there was a remarkably high association between the serological types of *Staph. pyogenes* present in lesion and nose, lesion and eye, and lesion and umbilicus, with a lower but still notable association between the types when more than one site was swabbed in addition to the lesion. Findings, already quoted, indicated the ubiquity of the infecting strain in the infants' environment, and these figures show that the wide dispersal extends also to the infants' healthy skin, upper air-passages, and exposed mucous surfaces such as the conjunctivae.

Serological Types of Staph. pyogenes Isolated from Mothers of Infected Infants

Apart from the nursery staff, consisting of doctors, nurses, and ward-maids, the only persons with whom the infants came into contact were the mothers, during breast-feeding. It was therefore decided to investigate serologically the staphylococcal flora of a number of mothers as a potential and intimate source of infection.

Swabs from the nose, throat, and in a few cases samples of the breast milk were taken from mothers of infected infants to see what relationship, if any, the serological types of *Staph. pyogenes* isolated from the mother bore to the type isolated from the infant. Swabs from the infants were taken from the lesion and from some or all of the following sites—nose, eye, and umbilicus. Table V shows the results of the examination

TABLE V.—To Show the Relationship Between Serological Types of *Staphylococcus pyogenes* Isolated from Infants with Pemphigus Neonatorum and from their Mothers

No.	Name	Serological Types of <i>Staph. pyogenes</i> Isolated from					
		Lesion	Eye	Umbilicus	Nose	Throat	Breast Milk
1	Mrs. Cl. Baby Cl.	I			I IIIb, IIIc	—	IIIb
2	Mrs. Wo. Baby Wo.	I/II	I/II		I/II, I	—	—
3	Mrs. Co. Baby Co.	I	I		I	—	I
4	Mrs. Jo. Baby Jo.	I*	I		I	I	—
5	Mrs. Je. Baby Je.	I	I		Ib	—	—
6	Mrs. Cr. Baby Cr.	I	Ib	Ib	I, Ib II	Ib	Ib
7	Mrs. Pe. Baby Pe.	Ib	Ib	IIIc	Ib, Ia Ia	II	Ia
8	Mrs. Ba. Baby Ba.	Ib	Ib	Ib, IIId	Ib, Ia	—	—
9	Mrs. de H. Baby de H.	Ib	Ib	Ib	I/II	—	—
10	Mrs. Wi. Baby Wi.	I		—	IIIc II	—	—
11	Mrs. Mo. Baby Mo.	Ib	I	Ib	IIIb	—	—
12	Mrs. O'D. Baby O'D.	Ib	Ib	—	Ib, I Ib	IIIb	IIIb
13	Mrs. Pi. Baby Pi.	Ib†	Ib		IIIc	—	—
14	Mrs. Ph. Baby Ph.	Ib	Ia	—	Ib, I Ia	I	Ia
15	Mrs. Bi. Baby Bi.	Ib	Ib, Ia	Ib, Ia	Ia Ib	Ia	Ia

* Septic finger occurring after infection in her infant.
† Small septic lesion on breast following infection in her infant.

of strains of *Staph. pyogenes* isolated from 15 infected infants and from their mothers. In only six instances—viz., Nos. 1, 3, 4, 10, 13, and 14—was the serological type of *Staph. pyogenes* causing the infection in the infant also isolated from the mother; five of the six mothers harboured the organism in the nose, and in one (Mrs. Co., No. 3) it was found only in the breast milk. In the case of Mrs. Jo. (No. 4) the organism was isolated from the nose, the throat, and from a septic finger which occurred after her infant became infected with pemphigus, so it seems likely that she was infected by her infant. A similar explanation may account for the septic lesion in the breast of Mrs. Pi. (No. 13). If these two are eliminated, or even if not, the correlation of infecting strains in mother and infant is low. These findings, taken in conjunction with the results of the bacteriological investigations in Nursery 10, lend weight to the view that infection was spread in the nursery and was not transmitted to the infants by their mothers.

Discussion

The results of the serological identification of strains of *Staph. pyogenes* isolated from the lesions of 132 cases of pemphigus neonatorum and staphylococcal conjunctivitis occurring in a large maternity unit over a period of two years show that there were three separate outbreaks, each due to a distinct serological type of *Staph. pyogenes*. The organisms causing the outbreaks were isolated not only from lesions but also from the eyes and noses of a large proportion of infected infants, from the noses of healthy infants in the same nursery, and from the noses of a large proportion of the staff. During one outbreak the epidemic type was also isolated from air, dust, bedclothes, and infants' gowns in the nursery. It was evident, therefore, that the epidemic types were widespread in the infants' environment, and the results of different surveys of staphylococcal types found showed that this high concentration of the epidemic type in the noses of the nursery staff was present not only at the height of an outbreak but also in the early stages of an epidemic.

It is accepted that the main reservoir of *Staph. pyogenes* is the upper respiratory tract of man, in particular the nasal passages; but the organisms may also be present on the skin of a considerable proportion of the population (Gillespie, Devenish, and Cowan, 1939; McFarlan, 1942), and higher carrier rates were found among hospital in-patients and nurses than among the general population (Miles, Williams, and Clayton-Cooper, 1944). In the present investigation 72 (70%) of 103 members of the staff swabbed on three different occasions were carrying *Staph. pyogenes* in the nose, and in 34 instances (33%) the strains isolated belonged to the epidemic type; 28 members of the staff who harboured *Staph. pyogenes* in the nose were also hand-carriers, and in 15 instances the strains cultured from the skin were identified as the epidemic type. No hand-carriers of *Staph. pyogenes* were found among the 31 members of the staff whose nasal swabs were also negative. There was therefore confirmation of the close association between nasal carriage and skin carriage of *Staph. pyogenes*. The high percentage of the staff found to be carrying the epidemic types was probably not an accidental congregation of persons harbouring those types, but more likely a gradual build-up of infection by a strain possessing the ability to implant itself and multiply in the nose when spread from person to person.

The possible sources of infection of the infant with *Staph. pyogenes* are those who come into contact with it, either directly or indirectly, and include mother, doctor, nurse, ward-maid, and laundress. The mother may infect her own infant during breast-feeding, but the evidence shows that the spread of infection takes place in the nursery. The contacts between doctor and infant after it has been born are in general irregular and transitory, and there is little or no evidence that he plays any part in the spread of infection. The same conclusion applies to the ward-maid, whose presence in the ward is of short duration with only indirect, if any, contact with the infants. The laundry is a potential source of infection, either through failure to rid blankets and infants' gowns and napkins of staphylococci or by infection during handling. The nurse is in regular and intimate contact with the infants, especially during toilet and hygiene, and the evidence suggests that she is the most important factor in the spread of infection. This evidence is based on the epidemiological, bacteriological, and serological findings, and as a result of visits to different maternity units and nursing homes in order to watch the procedure and technique of infant hygiene and nursing.

The possible paths of spread of infection are represented in Fig. 2, which shows infection spreading from the adult nose at the centre via hand, fomites, air, and dust to the infant's skin, nose, and eye at the periphery. In the present investigation *Staph. pyogenes* has been found to be so ubiquitous in the infants' environment that no precise conclusions could be drawn regarding the mode of spread. The serological types of *Staph. pyogenes* which were the cause of the outbreaks were isolated in cultures on repeated occasions from the sources shown in the centre and radii of the diagram, although infection of dust and air appeared

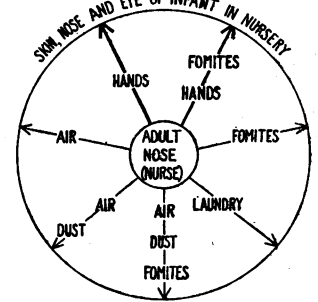


FIG. 2.—Potential paths of spread of infection in nursery outbreaks of pemphigus neonatorum and conjunctivitis.

to be low. The most probable path is via the nose and hands of the midwife or nurse to the infant's skin, but the infant's communal bath and towel also probably play an important part in the transmission of infection.

Knowledge of the possible paths of spread of infection alone will not suffice as a basis for the prevention or control of outbreaks of infection. Factors which facilitate the spread of infection must also be considered and steps taken to eliminate them. During visits to several maternity units and nursing homes in which outbreaks of pemphigus neonatorum had occurred, many such factors were noted. One of the chief among these was overcrowding and bad spacing of cradles or cots: in one large nursery capable of accommodating a maximum of 18, allowing a minimum of 25 sq. ft. (2.3 sq. metres) per cot, there were 32 infants. Insufficient ventilation and light, partly due to black-out conditions and the building of anti-blast walls, were also noted as undesirable factors. In most of the units visited the wards and nurseries were cleaned by dry dusting, a practice which was immediately altered when attention was drawn to it. Associated with the overcrowding of nurseries the nursing staff was often inadequate, and too much of the toilet and hygiene of the infants had of necessity to be carried out by pupil midwives insufficiently supervised and still in an early stage of training with little or no knowledge of the nature of infection and modes of transmission. Other points facilitating the transmission of infection noted in different hospitals were: the communal changing-table covered with a towel on which all infants were placed in turn; failure to disinfect the bath after use for each infant; failure to wash the hands before and after attending to an infant; toilet requisites handled by different nurses and used in common for all infants in the nursery. Masks were employed in all the maternity units and nursing homes visited, but in one large maternity unit masks were often worn covering the mouth only, leaving the nose exposed.

Until more precise knowledge is available of the paths by which staphylococcal infections are spread in nurseries, it is justifiable to recommend measures to prevent and control outbreaks covering a wider range than may later be found necessary. Benians (1943) showed that the mere closure of a ward in which an outbreak had occurred, followed by cleansing and airing, was ineffective in terminating an outbreak, as fresh cases began to appear within three days of reopening the ward. It has also been pointed out by Elliott, Gillespie, and Holland (1941) that the use of masks, gowns, and rubber gloves alone did not have any observable effect on the spread of infection. Most of the

factors already noted as facilitating the occurrence and spread of infection suggest the obvious remedies—avoidance of overcrowding, adequate ventilation and natural light, a proper proportion of trained and untrained nursing staff with more supervision of the latter, and early training in the nature, sources, paths of transmission, and methods of prevention and control of hospital infections.

The ward or nursery should be cleaned by vacuum cleaner or by damp dusting. The infant's bath should be thoroughly disinfected either with undiluted lysol (M.R.C., 1941) or with 1% C.T.A.B. (Barnes, 1942) and washed after use by each infant, and well rinsed before again being used. So far as practicable a separate toilet outfit should be reserved for each infant, including the towel on which it is placed after its bath, if different from that with which it is dried. Consideration should be given to the changing of infants in their cots instead of on a communal changing-table, as is the practice in many maternity units, while the crib bath in an individual bath blanket has much to recommend it.

No member of the nursery staff—medical, nursing, or cleaning—should go on duty or enter the nursery if suffering from any acute upper respiratory infection or skin sepsis. Efficient masks covering both mouth and nose should be worn by all staff when in the nursery. Masks should be changed frequently, as they may become moist, rendering them inefficient and unpleasant to wear. The nurse's hands should be washed in soap and water and dried either with destructible tissue towels, which are again on the market, or on her own towel immediately before and after attending to an infant, and especially after every use of the handkerchief. Hamburger and Green (1946) have pointed out the importance of nose-blowing in the expulsion of *Staph. pyogenes* by nasal carriers, with infection of the hands and transfer from hands to secondary environmental reservoirs, such as clothing, bedding, towels, etc. This may be an important factor in the infant nursery as a source and mode of spread of staphylococcal infection, in view of the high percentage of persons in a semi-closed community, such as a hospital, who harbour *Staph. pyogenes* in the nose.

Members of the nursery staff who are aware that they are heavy nasal or skin carriers of *Staph. pyogenes* should be most meticulous in observing preventive measures even in the absence of staphylococcal infection in the nursery. Attempts to clear profuse nasal carriers of *Staph. pyogenes* with sulphathiazole snuff or ointment have not had the hoped-for success, but the application of penicillin ointment to the nostrils two or three times daily and sniffed in, recommended by Hobbs, Carruthers, and Gough (1947) as an adjunct to the treatment of sycosis barbae, may be more effective.

The numerous administrative and technical procedures necessary to prevent and control the spread of infection among infants in large nurseries in maternity hospitals—procedures which in many instances are not possible or practicable—give rise to consideration of the question whether the large infant nursery should not eventually be discarded in favour of the mother and infant being nursed together in a cubicle or in small wards. Apart from the respiratory and intestinal infections to which the newborn infant is so highly susceptible, it would not be exposed to the high concentration of infection which develops in a nursery in the earliest stages of an outbreak of pemphigus neonatorum, and the number of contacts, direct and indirect, would be very considerably reduced. The primipara, moreover, would have more opportunity for guidance and practice in the feeding, toilet, and hygiene of her infant. In any event the prevention and control of infection should be based on high standards of nursing technique and infant

hygiene as exemplified in Medical Research Council War Memorandum No. 11 (1944).

Summary

An outbreak of pemphigus neonatorum and staphylococcal conjunctivitis affecting 132 infants in a large maternity unit over a period of two years is described.

Serological identification of strains of *Staph. pyogenes* isolated from the lesions of all the cases showed that there were three outbreaks, each due to a distinct serological type of the organism; there were also a small number of sporadic cases due to different serological types of *Staph. pyogenes*.

Investigations in one large nursery in which 93 of the cases occurred showed that the infecting strain was widespread in the infants' environment, and was isolated from the noses of a high proportion of the nursing staff, from the noses of healthy infants, from blankets and gowns, and from dust and air in the nursery.

The findings indicate that the infants were infected in the nursery and not from their mothers.

The evidence suggests that the main reservoir of infection was the nasal passages of the nursing staff, whence infection was spread to the infants, probably via the hands.

Recommendations are made for the prevention and control of staphylococcal infection in infant nurseries.

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There are now 12,000 industrial canteens known to the Chief Inspector of Factories, and more than half of these are in factories employing fewer than 250 workers. The Industrial Welfare Society has produced an illustrated brochure (4s. 6d. post free) entitled *Canteens in Industry*, which takes the form of a guide to the planning and management of these enterprises. It was first published at the beginning of the war and has now reached its sixth edition, incorporating a large amount of wartime experience. Suggestions are made concerning site, accommodation, lay-out, internal construction, lighting, heating, ventilation, furnishing, and colour scheme. There is a chapter on food and diet in which a number of useful hints are given, as, for example, the great food value of oily fish, such as the herring and mackerel; the need for making soups a substantial dish, of nourishing quality and distinctive flavour; the help of the friendly and filling dumpling and other accessories in making the available meat go round; the popularization of vegetables, especially the lesser known varieties; the value of salads, particularly if they include some sustaining ingredient such as a good portion of potato or a sardine or egg, as an alternative to sweets; and also the value of the sweet in supplementing minerals and vitamins.