

unlikely to have been a significant factor, since it fails to explain the interval of normality which preceded the onset of symptoms in all our cases.

Embolism from the carotid artery into the middle cerebral artery or direct extension of the thrombosis to that vessel are two possibilities which account for this interval satisfactorily. The former is unlikely, since Schorstein (1940) has pointed out that such emboli are a rare finding at necropsy of patients who develop hemiplegia following ligation of the carotid artery. The latter is supported by the necropsy findings in the case recorded by Caldwell (1936). This case is the only one resembling ours which we encountered in the literature, and many of the details are strikingly similar to those reported above.

Caldwell's patient, who was 16 years old, received a penetrating wound of the soft palate following a fall on to a hedge. The immediate result was local pain and swelling but no loss of consciousness. Four hours after his injury he was seen by his doctor, who recommended hot gargles. A few hours later he became drowsy and could not talk, though he apparently understood what was said to him. He was admitted to hospital in this state 10 hours after the injury. The abnormal findings on examination were a right hemiplegia and a diminished corneal reflex on that side. There were twitching movements of both lips on the right side of the face. A jagged wound 2 cm. in diameter was seen in the roof of the mouth at the junction of the hard and soft palate slightly to the left of the midline. The findings on lumbar puncture were normal. While in hospital his stupor increased, and he died six days after admission. At necropsy the left internal carotid artery contained a well-formed thrombus which extended from the cervical portion of the artery into the cranial portion and on into the middle cerebral and Sylvian arteries. The left cerebral hemisphere was softer than the right, and on section a haemorrhagic infarct was found in the central portion.

The part played by failure of the systemic circulation in our cases is difficult to assess. Irreversible anoxic changes in the brain may result from a fall in the systemic blood pressure due to shock or as a result of an increase in pressure in the carotid sinus (due to distal occlusion of the internal carotid artery) acting reflexly (Rogers, 1947). In our cases there was no evidence of serious impairment of the general circulation, except in the initial episode in Case 1, which may well have been of this nature.

A word or two may be added on the subject of prevention. Similar catastrophes could be largely avoided by the application of simple common-sense measures. The rarity of the clinical picture described should not detract from the importance of enforcing these measures. Whenever possible, pointed objects should be kept out of the reach of young children, and they should be strongly discouraged from holding any such object in the mouth. In the case of older children the dangers of holding pointed objects in the mouth should be explained. Finally, it would seem a wise precaution for practitioners to keep under close surveillance for a period of two or three days any child who suffers a potentially penetrating injury in the region of the soft palate. In this way neurological symptoms will be detected early and treatment started promptly.

Summary

Three cases of penetrating injury in the region of the soft palate followed by hemiplegia believed to be due to traumatic thrombosis of the internal carotid artery are described.

The possible pathogenesis of the symptoms is discussed.

Recommendations regarding treatment and prevention are made.

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COAGULASE-POSITIVE STAPHYLOCOCCI

A SERIAL SURVEY FOR NASAL CARRIERS DURING THE FIRST SIX MONTHS OF NURSING TRAINING

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A feature of the epidemiology of staphylococcal disease acquired in hospital which is rather puzzling is the relative infrequency of outbreaks of manifest disease in wards staffed by nurses who show a high nasal carrier rate for coagulase-positive staphylococci. This puzzle prompts the question, Are there *within* the group of coagulase-positive staphylococci a few types which are responsible for outbreaks of disease? If this is so it is obviously desirable in the interests of prevention that we should be able to identify such types. Type differentiation of the genus *Staphylococcus* by both phage and serological methods at present lacks precision owing to our lack of knowledge of the fine antigenic structure of the organism. Nevertheless serological typing of staphylococci has proved to be of value in the study of epidemiological problems of staphylococcal disease (Hobbs, 1948; Oeding, 1954; Brodie *et al.*, 1955, 1956). Serological typing has the great advantage over phage typing in that it takes less time and is simpler to carry out.

The objects of the present investigation were to determine, by serial observations, the influence of nursing training on the nasal carrier rate of coagulase-positive staphylococci, to ascertain the prevalence of antibiotic resistant strains in nurses, and to study the serological types which might have colonized the hospital.

The analysis is based on a six-months serial survey for staphylococcal carriage of a group of 30 student nurses from the start of their training. The examinations of the nasal staphylococci of each nurse were made at weekly intervals. The survey began in October, 1954, and ended in March, 1955, during which time the student nurses spent three months in the preliminary training school of a general hospital followed by three months on duty in the wards of the hospital.

Methods

The methods used in this study for the isolation, selection, and typing of staphylococci have been previously described (Brodie *et al.*, 1955).

Serological typing was based on slide agglutination tests with absorbed sera prepared from Hobbs types. We used seven "factor" sera a, c, e, f, h, i, and k, based on the antigenic formula given by Oeding for Hobbs types (Oeding 1952, 1953a, 1953b, and 1954).

A comparative table showing our formula for Hobbs types is as follows :

Our formula	Hobbs types
acei/-	1
-/h	2
ac/-	3, 4, and 12
a/-	5 and 6
ace/h	8 and 13
ac/h	9
auto/h	11

With our sera we were unable to type Hobbs types 7 and 10.

Sensitivity testing by the plate and tablet method was also done, using penicillin (P), chlortetracycline (C), chloramphenicol (Ca), oxytetracycline (O), streptomycin (S), and erythromycin (E). These antibiotics are represented in the text and tables by their initials for brevity.

Typing Scheme.—The combined results of the antigenic analysis by slide agglutination and sensitivity testing were used to type each strain examined. For example, ac/-P.O.C.S.Ca. represents a strain which agglutinated in the live state with absorbed sera "a" and "c" only, failing in the autoclaved state to agglutinate with all absorbed sera (-/-), and was resistant to penicillin, oxytetracycline, chlortetracycline, streptomycin, and chloramphenicol (P.O.C.S.Ca.)

Evidence of Cross-Infection to Nurses in Wards

This section presents the evidence that cross-infection of nasal staphylococci to the nurses takes place *after* they have entered upon their duties in the wards. It also analyses the types of "hospital" staphylococcus isolated during the survey.

The frequency of isolation of coagulase-positive staphylococci increased *after* the nurses began ward duties. During the preliminary training period the number of isolations of coagulase-positive staphylococci was 73 out of 274 specimens examined (27%), while during the period of ward work it was 133 out of 234 specimens examined (57%).

The frequency distribution of the common serotypes of the coagulase-positive staphylococci during both periods is set out in Table I. Comparison is made of the serotypes

TABLE I.—Frequency Distribution of Common Serotypes of Coagulase-positive Nasal Staphylococci of Nurses while in Preliminary Training School and in Wards

While in P.T.S.			While in Wards		
No. C. + Examined*	Serotype	No. Positive	No. C. + Examined	Serotype	No. Positive
71*	ac/-	10 (14%)	133	ac/-	40 (30%)
71	acei/-	28 (40%)	133	acei/-	24 (18%)
71	ac/h	2 (3%)	133	ac/h	19 (14%)
71	-/h	10 (14%)	133	-/h	6 (4%)
71	Misc.	21 (29%)	133	Misc.	44 (34%)

* Two of the coagulase-positive strains isolated were not examined serologically.
-/- Indicates inagglutinable in both live and autoclaved states.

ac/-, acei/-, ac/h, the inagglutinable strains, and a miscellaneous group. This last group includes a variety of serotypes, each of which is numerically small, and a number of strains which were autoagglutinable and therefore could not be typed.

The interesting features which emerge are : (a) the increase in the numbers of serotype ac/- from 10/71 (14%) to 40/133 (30%) after entry to the wards, and for serotype ac/h from 2/71 (3%) to 19/133 (14%) after entry to the

wards ; (b) a corresponding decrease in serotype acei/- from 28/71 (40%) to 24/133 (18%) and for inagglutinable strains from 10/71 (14%) to 6/133 (4%) ; and (c) the similarity in the frequency of the miscellaneous group before and after entry to the wards. The decrease in the numbers of inagglutinable strains isolated from the nurses after entry to the wards is not surprising when it is recalled that the antisera were prepared from Hobbs types which were originally isolated largely from hospital communities. The decrease of frequency of serotype acei/- is difficult to explain and may perhaps best be left to be dealt with in the discussion.

Table II illustrates the increase in the numbers of strains which showed resistance to various antibiotics after entry to the wards.

TABLE II.—Frequency Distribution of Antibiotic-resistant Types of Coagulase-positive Nasal Staphylococci of Nurses while in P.T.S. and in Wards

While in P.T.S.			While in Wards		
No. C. + Examined	Sensitivity	No.	No. C. + Examined	Sensitivity Group	No.
73	S	28 (38%)	133	S	2 (1.5%)
73	P	38 (52%)	133	P	75 (56%)
73	Px	7 (10%)	133	Px	57 (43%)

S=Strains sensitive to penicillin, chlortetracycline, chloramphenicol, oxytetracycline, streptomycin, and erythromycin.

P=Strains resistant to penicillin but sensitive to the five other antibiotics used.

Px=Strains resistant to penicillin, and to one or more of four other antibiotics but not to erythromycin.

TABLE III.—Example of Individual Variations to Infection with Coagulase-positive Staphylococci

Date	"Insusceptible" (Nurse 24)	"Low Susceptibles" (Nurse 4)		"Persisters" (Nurse 30)		Multiple Serotype Carriers (Nurse 21)					
		Serotype	Resistance	Serotype	Resistance	Serotype	Resistance				
9/10/54	No isolations	No isolations	}	ac/-	P	acei/-	Nil				
19/10/54								ac/-	P	acei/-	Nil
27/10/54								ac/-	P	acei/-	Nil
3/11/54								ac/-	P	acei/-	Nil
9/11/54								ac/-	P	-/-	Nil
16/11/54								ac/-	P	ac/-	Nil
23/11/54								ac/-	P	ac/-	Nil
30/11/54								ac/-	P	ac/-	Nil
7/12/54								ac/-	P	ac/-	Nil
15/12/54								ac/-	P	ac/-	Nil
12/1/55	a/-	PSCa	No swab	No swab	No swab	P					
19/1/55	a/-	PSCa	ac/-	POC	ac/h	P					
26/1/55	ac/-	POCSCa	ac/-	P	a/-	P					
2/2/55	-/auto	POCSCa	ac/-	P	No swab	P					
9/2/55	ac/-	POCSCa	ac/-	POC	ac/-	P					
16/2/55	ac/c	POCSCa	No swab	POC	ac/-	P					
23/2/55	ac/-	PSCa	ac/-	POC	ac/h	P					
2/3/55	ac/-	PSCa	ac/-	P	ac/h	P					
9/3/55	No swab	No swab	No swab	P	ac/-	P					
16/3/55	"	"	ac/-	P	-/h	P					
6/4/55	"	"	ac/-	P	ac/-	POCS					

This analysis shows that, after entry to the wards the sensitive strains decrease from 28/73 (38%) to 2/133 (1.5%) and the cross-resistant strains increase from 7/73 (10%) to 57/133 (43%). There is, curiously enough, little change in the frequency of strains resistant to penicillin only, the figures being 38/73 (52%) and 75/133 (56%).

An analysis was made to determine which, if any, of the common serotypes accounted for the general increased frequency of antibiotic-resistant strains after entry to the wards. Serotype ac/- was the only type containing cross-resistant strains among the "pre-ward" isolations. The general increase of cross-resistant strains after entry to the wards was accounted for by an increase in each of the four common serotypes encountered during the survey. The increase for the cross-resistant strains, after entry to the wards, was for type ac/- from 3/10 (30%) to 22/40 (55%), for type acei/- from 0/28 to 10/24 (42%), for ac/h from 0/2 to 6/19 (32%), and for inagglutinable strains from 0/10 to 4/6 (66%).

Variability Among Individual Nurses

The variability of isolation of staphylococci, from the viewpoint of both serotype and antibiotic-resistance pattern, was considerable in this group of nurses. For purposes of description, the group is divided into four categories—namely, “insusceptible,” “low susceptible,” “persisters,” and “multiple serotype carriers.” In Table III a typical case card is shown for each category, giving the serotypes and antibiotic-resistance patterns for each. One nurse is regarded as “insusceptible” because of failure to isolate coagulase-positive staphylococci from her nose at any time during the whole period of the survey. Five show “low susceptibility.” In each of these no isolation was obtained in the pre-ward period, but isolations were obtained after beginning ward duties. There were seven in the “persisters” group, being those who carried the same serotype before and during duty in the hospital wards. It was striking that, in this category, although the serotype remained constant, the type of resistance pattern varied. The “multiple serotype carriers” were more numerous than all the other categories put together. In all, 15 nurses were so classified because they carried different serotypes at different times during the course of the serial survey.

Multiple Infection

It may be appropriate at this stage to anticipate the discussion and to state that two explanations were possible for the “multiple serotype carrier.” These were (a) that infection with one serotype might be followed by superinfection with a second, third, or fourth type, or (b) that multiple infection with two or more serotypes might be present at the same time. If this latter explanation is correct it would be possible by selection to pick a colony of one serotype on one occasion and a second serotype on a subsequent examination. To test the validity of the latter view, six colonies were picked from a series of plates at the time of primary isolation and their serotypes and antibiotic patterns defined. Of the 23 nurses examined in this way, 12 yielded coagulase-positive staphylococci. Pigmentation of the colonies was found to be of great value when isolating coagulase-positive strains. Examination of the selected strains demonstrated that multiple infection with different serotypes having different resistance patterns does occur.

In this survey 3 out of 12 nurses were carriers of more than one serotype. One nurse, indeed, harboured three distinct serotypes, each of which had a different antibiotic-resistance pattern. The other two nurses carried two distinct serotypes, again with different resistance patterns. The remaining nine were carriers of single serotypes, each with a constant resistance pattern.

Cross-Infection in Preliminary Training School

Scrutiny of the data covering the three-months pre-ward period failed to show any satisfactory evidence of cross-infection between nurses during that period. Within the limits of the methods of study employed, cross-infection during the period of preliminary training is minimal and thereafter of little significance. This is in marked contrast to the problem of acquired infection which undoubtedly arises when the nurses take up duties in the wards.

Discussion

Brodie *et al.* (1955), in a study of staphylococcal complications arising during the treatment of bacillary dysentery with broad-spectrum antibiotics, drew attention to the value of “typing” strains of staphylococci by combining serological typing with sensitivity testing. By this means they were able to demonstrate a close relationship between the occurrence of complications and the isolation of a defined type of staphylococcus (ac/- P.O.C.S.T.) which on this evidence seemed to be the cause of the complications. These authors put forward the view that the control of staphylo-

coccal disease in hospitals might be more readily achieved by the recognition of carriers of certain defined types of staphylococci. This approach to the problem of control might conveniently be called “type sanitation.”

A prerequisite to the application of type sanitation is a knowledge of the important types of staphylococci which produce diseases most frequently in hospitals. The value of the present study lies not so much in the confirmatory observation that nurses on entry to the wards became carriers of staphylococci in general, but in the demonstration that a relatively small number of “types” of staphylococci had colonized the hospital. It is clear that a great deal more work is required to test the validity of the concept of type sanitation, and success will undoubtedly be linked to studies of the classification of the genus *Staphylococcus*. It seems not unreasonable to suppose that the history of control of staphylococcal disease will be the history of the classification of staphylococci.

A striking feature of the present observations is the changeover of predominant types after the nurses enter the wards. Types ac/- and ac/h appear to gain ascendancy in the wards over type acei/-. It certainly looks as if types ac/- and ac/h have a greater ability to spread more rapidly in a hospital population than type acei/-, but whether this is due to their faster rate of growth or to the production of an inhibitor for type acei/- said at present. It is, however, an interesting subject for study.

While the evidence points clearly to the nurse as a potential source of infection, the serial observation indicates that infection of the nurse is contracted during her duties in the ward. The failure to demonstrate cross-infection of staphylococci during preliminary training, when the nurses are living as a semi-closed community, suggests that infection is “picked up” during some point in the handling of the patients during nursing.

There is a pressing need for an “index” which would measure, even if only in a rough-and-ready way, the extent of staphylococcal cross-infection in a hospital. The present study suggests that the “nurse nasal index” for staphylococci provides an indication of the extent to which a hospital has been colonized by the “hospital” staphylococcus. Such an index should also prove useful as a means of assessing methods of control. We would suggest that to be of value the nurse nasal index for staphylococci should not only record the frequency of carriers of coagulase-positive staphylococci but should also include the frequency of carriers of different “types” based on the combined use of serological typing and sensitivity testing. The present experience serves to demonstrate that further observations along similar lines would be worth while.

Summary

A serial survey of nasal coagulase-positive staphylococci in a group of student nurses during their first six months of training showed that cross-infection did not take place during preliminary training, but only after they began duty in the wards. The survey demonstrated that the “hospital” staphylococcus consists of a relatively small number of “types.” The proposal is put forward that the “nurse nasal index” for staphylococci might serve as a useful measure of the extent of staphylococcal cross-infection in a hospital.

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