this by the bodily disturbances we create as an unsought-for accompaniment of many of our modern therapies. In effect, an unfortunate by-product of our life-saving and life-prolonging procedure is to create a favourable market for staphylococci.

This favourable market is being created in several ways. First, our modern therapies are permitting the survival of people who are less able, in various undefined ways, to cope with bacterial infections. Examples of this sort are the insulin-treated diabetics, the children who have had splenectomies for various haematological disorders, the adults who have had total gastrectomies, and perhaps even some who have had partial pulmonary resections. Second, certain of our commonly used treatments such as cortisone, hydrocortisone and corticotrophin, the more widely acting antimicrobials, and *x*-ray irradiation are known to create circumstances which at times facilitate the development of infection. It is conceivable that on certain occasions treatments such as the antihistamines or the anticoagulants might unfavourably influence infection. Finally, in order to manage many of these modern treatments properly, it is necessary to perform venepunctures and skin punctures with unusual frequency on these very patients who for one reason or another are more liable to the development of infection.

To be sure, this increased congregation of more susceptible hosts in our hospitals is not necessarily the only reason for the apparent increase in staphylococcal infections developing in the hospital. Nevertheless, it does seem to be the principal factor which is *different* in our situation to-day from that of a decade or so ago. Moreover, if it is happening in the hospitals to-day, it is reasonable to expect that it will happen outside the hospitals in the future as these various forces become active on a wider scale.

If we assume the validity of this analysis, how can the situation be improved? It would be pointless to think in terms of attempting to oppose many of the forces which are contributing to this situation, because so many of these forces are such notable scientific achievements for the common good. Moreover, as staphylococci are so ubiquitous, an approach based on attempts to eliminate them from the environment would not seem hopeful. In the same way, it does not appear that antimicrobial drugs *per se* would play an important part. Chemoprophylaxis is a two-edged sword at best. In the present situation, the necessity for protecting the patient for such very long periods against a number of microbial species in addition to staphylococci makes the use of drugs impracticable.

Two approaches exist which seem reasonable. The first is for us all to have a continuing awareness of the fact that our hospitalized patients to-day are on the whole less able to cope with staphylococci than was formerly the case. This means that we should review and probably intensify our aseptic practices not only in the operating-room but especially in connexion with the ordinary "puncture" procedures used in the wards.

The second approach is the major one—namely, to find means for increasing bodily defences against staphylococci and means to restore these defences when they have been reduced. The logic of this approach is evident if you agree with me that the crux of to-day's staphylococcal problem lies not so much in changes in our staphylococci as it does in changes in the status of our hosts. Our difficulties with this second type of approach arise immediately, however, and stem from the fact that we are almost wholly ignorant of the mechanics of staphylococcal infection and disease. Until we can discover more than we now know concerning what determines the pathogenicity of certain staphylococci and how the healthy host manages to live in peace with them, it is not likely that our situation will materially improve.

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THE TRANSMISSION OF STAPHYLOCOCCUS AUREUS

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There is now a great deal of evidence that a high proportion of the staff of many hospitals are nasal carriers of penicillin-resistant *Staph. aureus*, that they soon acquire them after coming into residence (Barber, Hayhoe, and Whitehead, 1949; Rountree and Barbour, 1951; Barber and Burston, 1955), and that similar strains are responsible for sporadic infections of clean operation wounds and for outbreaks of conjunctivitis, mastitis, and pemphigus neonatorum in hospital nurseries. Although this suggests that the nasal carrier is primarily responsible for such infections, it is possible that transfer of organisms from minor staphylococcal infections such as boils, styes, or acne pimples on the person of members of the staff who have remained on duty may be equally important.

Attempts to prevent transfer of infection from either of these two sources are, however, hampered by our lack of knowledge of the methods by which *Staph. aureus* is transmitted from person to person. Except for the work of Duguid and Wallace (1948), little attention has been paid to this. The experiments reported in this paper were designed to throw further light on this question.

Experimental Methods

The manner in which experiments were carried out is given in the appropriate place in the text. It is, however, necessary to give some general details of the methods employed.

Media and Identification of Colonies.—The medium consisted of 1% Lemco agar, and in some of the early experiments an attempt was made to pick out colonies of *Staph. aureus* by their colour, consistency, and behaviour in coagulase tests on slides. In most of the experiments, however, phenolphthalein diphosphate (0.01%) was incorporated in the medium at the time the plates were poured. The majority of strains of *Staph. aureus* (Barber and Kuper, 1951) produce arylphosphatase, with liberation of free phenolphthalein in and around the colonies, which can be detected by a red colour developing when the culture plate is held over the open neck of a bottle of strong ammonia. All plates were examined in this way after incubation for eighteen to twenty-four hours, and counts made of colonies which had a red coloration and which resembled those of *Staph. aureus*. When necessary, subcultures were made in broth, coagulase tests being carried out by the tube method (Fisk, 1940).

Total colony counts were made after incubation for a further 24 hours.

Expression of Results.—The time of exposure of the plates varied in different experiments, and in order to secure uniformity the results are expressed as the number of organisms (or *Staph. aureus*) falling on to 1 square foot (930 square cm.) of medium in one minute.

Transmission of Staph. aureus Originating in the Respiratory Tract of Carriers

Except in very exceptional circumstances, it is improbable that *Staph. aureus* in the respiratory tract of a carrier comes directly into contact with that of normal persons, the eyes of newborn babies, or open wounds. Transfer must therefore occur by a more indirect route involving (1) egress from the respiratory tract, (2) transportation to the recipient, and (3) entrance into his tissues.

1. Egress from the Respiratory Tract

Staph. aureus occurs so infrequently in the throat that egress from the mouth need not be considered as an important factor in the dissemination of this organism. Large numbers are, however, present in the anterior nares of about half the population, and such organisms may reach the outside world by (*a*) expulsion, (*b*) excretion in the faeces, or (*c*) outflow on to hands, etc.

Expulsion in Expired Air

In order to study the number of *Staph. aureus* emitted from the nose, and under what conditions they emerge, experiments were carried out with a thin plastic sheet, holding a culture plate horizontally in such a position that its outer zone was only a few millimetres below the nasal orifice of normal adults. The edge of the plastic was cut away into such a shape that it fitted against the upper lip, and prevented organisms from the mouth reaching the culture medium. Subjects sat upright in an armchair in a laboratory, with as few draughts as possible, and carried out certain standardized activities. At intervals during this process the culture plate was rotated a few degrees, to bring a new area of medium below the nose. After exposure the plates were incubated, and both the total number of colonies and those identified as *Staph. aureus* were counted.

These experiments were carried out with known carriers of *Staph. aureus,* and also with individuals from whom this organism had not been obtained on nasal swabs. The results are given in Table I. Contrary to what might have been supposed, *Staph. aureus,* even when present, was generally not expelled. Only as a result of "snorting" did large numbers of organisms emerge; if the individual was a carrier a high proportion were *Staph. aureus.* Snorting is an unusual type of activity which generally occurs into a handkerchief. These results are similar to those obtained by

TABLE I.—*Number of Colonies Isolated on Culture Plates held below the Nose during Different Types of Activity*

Subject	Presence of *Staph. aureus* in Nose	Mouth Breathing 5 Mins.		Nose Breathing 5 Mins.		6 Coughs		Counting 5 Mins.		One Sneeze		12 Snorts	
		Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*
Fid	+	6	0	7	0	7	4	9	2	2	0	44	37
Bew	+	9	0	5	0	10	0	9	0	5	0	2,500	300
Irv	+	1	0	7	0	4	0	7	0	1	0	1,200	162
Cop	+	8	0	6	0	2	0	10	0	20	0	10	1
Win	+	2	0	3	0	0	0	3	0	1	0	131	55
Ric	−	11	0	15	0	6	0	22	0	2	0	44	0
Geo	−	18	0	13	0	1	0	16	0	4	0	71	0
Mar	−	10	0	4	0	1	0	42	0	2	0	81	42
Fos	−	4	0	1	0	1	0	1	0	1	0	6	0
Pri Nov. 4	−	9	0	3	0	2	0	15	0	3	0	67	0
Pri Jan. 9	+	16	0	4	0	4	0	10	0	12	0	760	184

Duguid and Wallace (1948), and suggest that expulsion in droplets or "droplet nuclei" from the nose is not a very successful method for obtaining the egress of *Staph. aureus* into the outer world.

Excretion in Faeces

Brodie, Kerr, and Sommerville (1956) have suggested that nasal carriers of *Staph. aureus* swallow this organism, and have shown that it may reach the faeces, but it is improbable that this is the principal reason for the wide dissemination of staphylococci among hospital staffs.

Outflow in Nasal Discharges

The nasal secretions flow towards the nasal orifice, and eventually reach the skin of the upper lip or face in the liquid condition or as dried crusts. Thence they may be transported by the hands or handkerchief to other parts of the body or to objects in the vicinity. Observation of a group of nine students during a lecture of one hour showed that they touched their mouth or nose on 23, 19, 15, 15, 14, 11, 10, 7, and 6 separate occasions. Fluorescent patches (in the light of Wood's lamp) could also be detected on the fingers and many areas of the body, desk, etc., if small quantities of the zinc chelate of 8-hydroxyquinoline were previously placed in the nostrils.

To show that *Staph. aureus,* if present in the nose, may be carried in similar fashion, surveys (using sweep plates for clothing and saline-soaked swabs for skin) were made of healthy individuals working in the hospital. The results are given in Table II, showing that *Staph. aureus* was present

TABLE II.—*Presence of Staph. aureus on Skin or Clothing of Nasal Carriers and Non-carriers*

	Har	Fid	Bew	Irv	Cop	Ric	Win	Fos	Pet	Sch	Mar	Pri, Nov. 15	Pri, Dec. 22	Pri, Feb. 20	Geo, Nov. 15	Geo, Jan. 26
Nose	+	+	+	+	+	+	+	−	−	−	−	−	+	+	−	+
Throat	−	−	−	−	+	−	+	−	−	−	−	−	−	−	−	−
Hair	−	−	+	+	−	−	−	−	−	−	−	−	+	−	−	−
Face	+	+	+	+	−	+	+	+	−	+	−	+	+	+	−	+
Wrist	−	+	+	−	−	+	+	−	−	−	−	+	+	+	−	+
Fingers	+	+	+	+	−	+	+	−	−	−	−	−	+	+	−	+
Chest	+	+	+	+	−	−	−	−	−	−	−	−	+	+	−	−
Abdomen	+	+	−	+	−	−	−	−	−	−	−	−	+	+	−	−
Back	−	−	+	+	+	−	−	−	−	−	−	−	+	−	−	−
Legs	−	+	−	+	+	−	−	−	−	−	+	−	−	−	−	+
Front coat	+	+	+	+	+	+	+	−	−	−	−	+	+	+	−	+
Back ,,	+	+	+	+	+	+	+	+	−	+	−	−	−	+	−	+
Handkerchief	+	+	+	+	+	+	+	−	+	−	+	−	+	+	+	+
,, pocket	+	+	+	+	+	+	+	−	−	−	+	+	+	+	+	+
Trousers or skirt	+	+	+	+	+	+	−	−	−	−	−	+	+	+	−	+
Shirt or blouse	+	+	+	+	+	+	−	−	−	+	−	−	+	+	−	−
Socks or stockings	+	−	−	+	+	+	−	−	−	−	−	+	+	+	−	−

+ = *Staph. aureus* isolated. − = *Staph. aureus* not isolated.

on the majority of the sites on the skin and clothing of nasal carriers of this organism, but was found only infrequently on the same areas of individuals who were not carriers.

Swabs taken from the nose of one subject, Pri, on November 1, and on four subsequent occasions, failed to yield *Staph. aureus* until December 22, when a heavy growth was obtained. During the period he was known not to be a carrier—that is, on November 15—examination of his skin and clothing showed that only small numbers of *Staph. aureus* were isolated from a few of these areas. On December 22 this organism was present in large numbers on all areas examined, except one on the skin and one on the clothing. This change in the flora of his nose, skin, and clothing was not accompanied by clinical signs of any description on his part or in his family. This state has persisted. A similar, though less marked, change was also observed with subject Geo.

Sensitivity tests with antibiotics suggested that, in general, strains recovered from the skin and clothing of a carrier were similar to those in the nose. Phage-typing determinations were carried out in detail with strains isolated from the two carriers Ric and Pri. In the case of Ric, his left nostril contained type 52/52A/80, and this strain was found on his face, wrist, and fingers, the back and front of his coat, his pocket, handkerchief, trouser leg, shirt, and socks. His right nostril contained type 3A/3B/55/71+, but this strain was not detected on skin or clothing. The carrier Pri had type 29 in both nostrils, and this type was found on the fingers, abdomen, the front and back of his coat, his handkerchief, trouser leg, and socks. Type 53 was found on his

face, wrist, chest, shirt, and handkerchief. It would thus seem probable that the majority of the staphylococci found on skin and clothing of carriers have been derived from the individual's own nose.

Because of the wide dispersion of *Staph. aureus* on the skin and clothing, it is to be expected that other objects, such as bedding, with which the individual comes into close contact, will be similarly polluted. Five known carriers and five non-carriers took samples of their own bedding, using large woollen swabs moistened with saline. From Table III

TABLE III.—*Presence of Staph. aureus on the Bedding of Carriers and Non-carriers*

	No. Studied	No. of Individuals with *Staph. aureus* on:				
		Lower Sheet	Upper Sheet	Blanket	Counter-pane	Pillow
Nasal carriers ..	5	3	2	1	2	2
Non-carriers ..	5	0	0	0	0	1

it is clear that the bedding of carriers was often contaminated by *Staph. aureus*, whereas that of non-carriers was generally free. It is also of considerable interest that the sheets, counterpane, or pillow were quite as likely to possess *Staph. aureus* as the blankets.

2. Transport of Staph. aureus to Other Individuals

In view of the wide dissemination of *Staph. aureus* on the skin, clothing, bedding, etc., of carriers, it is possible that other individuals may acquire the organisms as a result of direct contact with such surfaces. It can, however, be shown that the organisms may be liberated into the atmosphere by different forms of activity, so that transportation by air currents is an obvious alternative. This may be demonstrated in a variety of ways.

(a) From Skin

Both nasal carriers of *Staph. aureus* and non-carriers rubbed their hands together, and used the handle of a sterile scalpel to rub their chins or hair over an open culture plate immediately below. From Table IV it is clear that most of the carriers were able to dislodge some *Staph. aureus* from their skin or hair by these activities.

TABLE IV.—*Release of Staph. aureus from Friction on the Skin*

	No. of Persons	No. of Persons from Whom *Staph. aureus* was Obtained as a Result of:		
		Rubbing Hair	Rubbing Chin	Rubbing Hands
Nasal carriers ..	8	2	4	2
Non-carriers ..	6	0	0	1

Other experiments were carried out in a smaller version of the cubicle employed by Duguid and Wallace (1948). It was 6 ft. (183 cm.) high, the walls being 2 ft. 9 in. (84 cm.) and 2 ft. 6 in. (76 cm.) wide—that is, 41.25 cubic ft. (1.168 cubic metres). The walls consisted of plastic curtaining, the roof of three-ply wood, and the floor of moist butter muslin covering the hard surface of the laboratory floor. The whole of the interior surface was wiped down with cetrimide (1%), and the cubicle was left undisturbed for fifteen minutes before the experiments began. In each corner of the cubicle three culture plates were held horizontally, one being at floor level, another 1 ft. 9 in. (53 cm.) and a third 3 ft. 5 in. (104 cm.) above the floor. The temperature of the cubicle was usually 20–25° C. and the relative humidity 95 to 100%.

Control experiments showed that air movement *per se* does not bring to plates exposed in these situations more organisms than when it is still, the number of organisms obtained on culture plates exposed while a sterile gown, suspended from a coat-hanger from the ceiling of the cubicle, was agitated by pulling on pieces of string attached halfway down the sides, being approximately the same as on plates exposed while the gown was still.

TABLE V.—*Release of Organisms into Free Air from Skin or Clothing as a Result of Movement*

Subject	Presence of *Staph. aureus* in nose	Subject Clad Only in Bathing-trunks, Sterile Cap, Mask, and Sterile Boots				Subject's Clothes Agitated for 15 Mins.		Subject Fully Clothed Exercising for 15 Mins.	
		Sitting Still for 15 Mins.		Exercising for 15 Mins.					
		Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*
Bew ..	+	43·2	0·15	86·4	0·3	197·2	2·1	300·0	1·17
Pri ..	+	33·4	0·27	85·2	11·7	1,030·0	21·1	720·0	47·4
Ric ..	+	9·9	0·14	193·1	0·21	378·0	1·57	444·9	0·68
Scho ..	−	36·7	0·06	80·5	0·0	870·2	0·61	788·2	0·21
Geo ..	−	9·6	0·0	17·0	0·0	382·6	0·28	215·2	0·14

In this and the subsequent tables the figures give the total number of organisms or *Staph. aureus* falling on to 1 square foot (930 square cm.) in one minute. They are calculated from colony counts on 12 culture plates of the same size exposed horizontally at three different levels in the cubicle.

Subjects clad only in sterile bathing trunks, but with a mask over nose and mouth and a sterile cap over the hair, sat still for fifteen minutes in the cubicle while plates were exposed in the four corners. The plates were changed and the subjects then exercised by marking time and waving their arms about for a further fifteen minutes. After incubation, the total number of colonies and of *Staph. aureus* were counted. The results are given in the first part of Table V.

It is evident from this that during exercise some organisms are liberated into the atmosphere from the naked skin, and that if the individual is a carrier *Staph. aureus* may appear in appreciable numbers.

Staph. aureus may also be liberated into free air in droplets of water in the act of washing. Preliminary experiments showed that the relatively small amount of agitation of the skin and clothing resulting from the motion of the arms did not increase the number of bacteria in the atmosphere to any appreciable extent. But when the hands and arms were washed and scrubbed with toilet soap for five minutes, using clean water in a sterile bowl, the total number of organisms isolated on culture plates standing in the four corners of the cubicle were greatly increased. If the individual was a carrier, a large proportion of the colonies isolated were *Staph. aureus* (Table VI).

TABLE VI.—*Release of Organisms from the Skin of Hands and Forearms into Free Air while Washing*

Subject	Presence of *Staph. aureus* in Nose	Standing Still in Cubicle for 5 Mins.		Standing While Scrubbing for 5 Mins.		Standing While Washing Only for 5 Mins.	
		Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*
Ric	+	12·2	0	670·7	363·2	591·6	237·8
Win	+	35·4	0	998·5	6·56	680·8	38·75
Pri	+	25·8	0	1,762·2	323·9	1,456·1	300·5
Geo 1	−	16·4	0	607·6	0	669·9	0
2	−	6·4	0	383·7	0	421·5	0·41
Fos	−	21·1	0	983·2	0·21	712·8	0·42

Inspection of the plates immediately after exposure showed that many of them had actual droplets on the agar surface, and if the individual was a carrier large numbers of *Staph. aureus* appeared on these areas after incubation. Further experiments were carried out in which the subjects merely washed their hands without scrubbing. Almost identical results were obtained.

Thus friction, movement, and, perhaps most important of all, washing may disseminate large numbers of *Staph. aureus* from the skin of carriers into the neighbouring atmosphere.

(b) From Clothing

Previous workers (Green, Challinor, and Duguid, 1945; Bourdillon and Colebrook, 1946; Hare and Mackenzie, 1946; Duguid and Wallace, 1948) have shown that bacteria may be released into the atmosphere on particles of fluff or dust when clothing is shaken, but further experiments were undertaken to investigate the importance of this with staphylococcal carriers.

The clothing of carriers or non-carriers was accordingly suspended from a coat-hanger attached to the roof of the experimental cubicle. It was agitated for fifteen minutes by means of strings attached to the elbows of the coat and the knees of the trousers. The cubicle having been aired and its walls wiped down again with antiseptic, the subject then donned his clothes and exercised in it for fifteen minutes. The number of colonies developing on culture plates exposed during these activities is given in the second half of Table V.

It is evident from these experiments that while *Staph. aureus* and other organisms may be liberated into the atmosphere when the naked subject exercised in the cubicle, very much greater numbers reach free air from his clothing when agitated by itself or on the person of its owner.

Other experiments have been carried out in which the clothed subject sat still for 7½ minutes and then, for a further 7½ minutes, undressed and dressed again in the cubicle (Table VII). These experiments confirm the results

TABLE VII.—*Release of Organisms into Free Air while Undressing and Dressing*

Subject	Presence of *Staph. aureus* in Nose	Subject Fully Clothed Sitting Still for 7½ Mins.		Subject Undressing and Dressing Again in 7½ Mins.	
		Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*
Ric ..	+	14·7	0	435·6	20·0
Pri ..	+	25·8	0	1,957·3	187·8
Jac ..	+	37·5	0·14	354·5	1·09
Fos ..	−	19·4	0·14	467·4	0·14
Scho..	−	37·3	0·14	859·0	0·70

obtained in the previous experiment, showing clearly that large numbers of organisms are liberated by agitation of ordinary clothing, and by dressing and undressing.

It is of some importance that the amount of air pollution by *Staph. aureus* from the clothing carriers, although always greater than that coming from non-carriers, varied considerably. The clothing of the carrier Pri, for example, consistently produced many more staphylococci than that of the other carriers. Indeed, in his case, *Staph. aureus* accounted for nearly 10% of the total organisms released into the atmosphere.

Phage-typing experiments with the strains isolated when the carrier Ric dressed and undressed in the cubicle showed that type 52/52A/80, which was present in one nostril and widespread on his clothing, was also the predominant type released into the atmosphere. With the carrier Pri, on the other hand, who had type 29 in his nostrils and which was widespread on his clothing, it was found that only a few colonies on the plates belonged to this type. The majority were type 53, which was also found on some areas of his skin and clothing but which was not found in his nose.

In view of the large number of organisms liberated into free air from the clothes, further investigations were carried out to determine whether carriers wearing the type of clothing usual in operating theatres could contaminate the atmosphere.

Carriers and non-carriers accordingly exercised in the cubicle wearing trousers and shirt, or frock in the case of women, over which was placed a sterile gown with short sleeves, open at the back but secured by a tape round the waist. As will be seen from Table VIII, large numbers of organisms reached the exposed plates. This suggested that the gown conferred very little, if any, protection. For this reason, some of the subjects exercised while wearing their ordinary clothing and no gown. As will be seen from Table VIII, approximately the same number of organisms were liberated. Thus it must be concluded that the gowns worn by most persons on the floor of an operating theatre do not imprison the organisms on their clothing.

Those nearest to the patient in operating theatres leave their underclothing outside the theatre and wear clean, if not sterile, pyjamas under the gown, thus eliminating the source of some of the airborne organisms. Experiments were therefore carried out in which the subjects wore sterile pyjamas, covered by a sterile gown, and with sterile cap over the hair, mask over the face, and sterile boots on the feet. The results obtained are also given in Table VIII.

Fewer organisms were liberated than when the same subjects wore their own underclothing, but it is of some importance that the carrier Pri, to whom attention has already been drawn, was still potentially dangerous in that as many as 6.82 *Staph. aureus* were reaching 1 square foot (930 square cm.) in one minute in his vicinity.

(c) From Bedding

If, as shown in Table III, the bedding of carriers is contaminated by *Staph. aureus*, it is to be expected that this organism will be liberated into free air when the bed is made or is agitated in any way. Some provisional observations of ours confirm that this is so, but we have not investigated this problem in detail.

It is clear from these experiments that friction on the dry skin, washing or scrubbing with water, and agitation of the clothing may liberate comparatively large numbers of *Staph. aureus* from skin or clothing into the atmosphere if the subject is a nasal carrier.

3. Entry of Staph. aureus into the Tissues of the Recipient

This may occur as a result of direct contact between the organisms on the hands of a carrier or clothing, the respiratory tract of a normal person, an open wound, or the eyes and skin of newborn babies. But it is extremely probable that in most instances the organisms reach these areas by way of the atmosphere, particularly if the donor is a heavy carrier in active movement, with much shaking of the clothing.

Transmission of Staph. aureus from Septic Processes in Members of the Hospital Staff

When a localized infection of the skin, such as a boil or acne pustule, bursts or is opened *Staph. aureus* will almost certainly spread on to the skin in its immediate neighbourhood, and into whatever dressing may be applied. It is

TABLE VIII.—*Release of Organisms from Theatre Clothing*

Subject	Presence of *Staph. aureus* in Nose	Wearing Ordinary Underclothing, Trousers or Skirt, Cap, Mask, and Boots *with* Sterile Gown				Wearing Ordinary Clothing, Cap, Mask, and Boots but *Without* Gown		Wearing Sterile Pyjamas, Gown, Cap, Mask, and Boots			
		Sitting Still		During Exercise		During Exercise		Sitting Still		During Exercise	
		Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*	Total Orgs.	*Staph. aureus*
Ric: Oct. 25 ..	+	46·7	0·07	445·1	0·75	226·0	0·31	—	—	—	—
Nov. 24 ..	+	32·0	0·07	165·7	0·70	—	—	26·7	0·07	104·6	0·38
Pri: Oct. 25 ..	−	31·0	0·23	336·9	0·38	303·9	0·31				
Nov. 29 ..	−	42·4	0·21	183·0	0·87	—	—	17·6	0·14	67·0	0·21
Dec. 19 ..	+	26·4	1·98	209·0	19·00	—	—	12·8	0·86	61·7	6·82
Geo	−	17·3	0	74·1	0	—	—	11·6	0	19·2	0
Sch	−	25·7	0	364·0	0·07	—	—	25·6	0	218·0	0
Mos	+	32·1	0·70	484·1	0·3	507·8	2·86	—	—	—	—
Sus	−	31·4	0·15	64·0	0·31	66·4	0	—	—	—	—
Mar	−	9·5	0·15	99·0	2·82	102·5	3·52	—	—	—	—

extremely improbable that the infected area will come directly into contact with susceptible tissues in patients, or members of the staff, but the organisms may become widespread on the person in the same way as can *Staph. aureus* originating in the nose. Release as a result of friction or activity and transportation to others by air currents is therefore a possible alternative.

Skin and clothing surveys were made of 10 patients attending the casualty department with minor staphylococcal infections which, if on the person of members of the nursing or medical staffs, might not have necessitated their standing down from duty. All the lesions were discharging pus and none of the patients had received antibiotics. A comparable series of 14 patients without pyogenic infections were examined at the same time. The results are given in Table IX.

TABLE IX.—*Presence of Staph. aureus on Skin and Clothing of Patients with and without Mild Local Sepsis*

	With Sepsis	Without Sepsis	With Sepsis	Without Sepsis
Nose	+ + + + + +	+ + + + + + + +	− − − −	− − − − − −
Throat	− − + − − −	− − + + − − + −	− − + −	+ − − − − −
Hair	− + + − − −	+ − + + − − + +	− − − +	− − − − − −
Face	+ + + + + +	+ + + − + − − −	+ − − −	− + − − + −
Wrist	+ + + + − −	+ − − − + − − −	− − − −	− + − − − −
Fingers	+ + − − + +	+ − + − + − − −	+ − − −	− + − − + −
Chest	+ + − + − −	+ − − − − − − −	+ + − −	− − − − − −
Abdomen	+ + − + − −	+ − + + − − − −	− − − +	− − − − − −
Back	− − − − − −	− − − − − − − −	+ − − −	− − − − − −
Legs	− + − − − −	− − − − − − − −	− − − −	− − − − + −
Front coat	+ + − + + +	+ − + + + + − −	− − + −	− + + − − +
Back ,,	− + + − − +	+ + − + + + − −	− + + −	− − − + + +
Handkerchief	+ + + + + +	+ + + + − + + +	+ + + −	− + − − + −
,, pocket	+ + − + + +	+ − − − − − + +	+ − − −	− − − − + −
Trousers or skirt	+ + + − + +	+ + − − + + − −	− − + +	+ + − − + −
Shirt or blouse	− + + + + +	+ − + + + − − −	− + − +	− − − − − −
Socks or stockings	− + − + + −	+ − − − − − − −	− + − +	+ − − − − −
Site of lesion:	Lip, Finger, Wrist, Thigh, Eye, Finger		Axilla, Toe, Chin, Foot	
Presence of *Staph. aureus*	+ + + + + +		+ + + +	
Lesion discharging (in days)	5 3 1 1 1 7		1 4 1 3	

Six of the infected group and eight of the uninfected were nasal carriers of *Staph. aureus*, and many of them had this organism on different areas of skin and clothing. Although there was a tendency for the clothing in particular to be more widely contaminated when there was infection as well, it cannot be said that the difference was at all marked. There was much less contamination of the skin and clothing of the two groups who had no *Staph. aureus* in the nose, and no very definite evidence that the presence of a purulent infection increased this contamination to any extent.

An investigation comparable to the above was also carried out on a series of infants, aged 5–10 days, in a maternity ward. The results were similar—namely, that heavy staphylococcal contamination of the skin, clothes, and bedding occurred to about the same extent with healthy nasal carriers as with babies suffering from some form of sepsis.

Thus, although there is a possibility that *Staph. aureus* from a septic focus may be more pathogenic than when it is derived from a healthy nasal carrier (Barber and Burston, 1955), there is no evidence that particularly heavy contamination of the skin and clothing occurs.

Discussion

The results obtained in the experiments reported in this paper confirm those of Duguid and Wallace (1948), and show that the mechanism by which *Staph. aureus* is transmitted from the nasal cavity of carriers to other persons is very similar to that suggested for respiratory tract organisms in general by Hare and Mackenzie (1946).

This mechanism does not depend, primarily, on the expulsion into free air of *Staph. aureus* in droplets or droplet nuclei coming from the anterior nares, but on outflow of this organism in the nasal secretions on to the upper lip or alae nasi. Its subsequent transfer to other persons then involves three separate and distinct steps.

The first step is the transport of the staphylococci by hands, handkerchief, or any object coming into contact with the nose to the skin, clothing, bedding, and other objects in the immediate vicinity of the carrier. The second step is the release of the organisms into the atmosphere. This may result from friction and dislodgment of dried particles from the skin or hair, from the spattering of water droplets in the act of washing, and from shaking of the clothing during activity. This may obviously occur anywhere in the hospital.

The third step involves the transport of these infected particles by air currents to other individuals in the neighbourhood. In this way the organisms may reach the anterior nares of normal persons to produce the carrier state in them, highly susceptible tissues such as the conjunctiva of the newborn infant, or, as probably occurs in operating theatres, open wounds, to produce, in due course, post-operative infection.

There is evidence that some carriers produce a much greater degree of air contamination in their vicinity from friction and movement of their clothing than do others. Such a carrier is probably much more dangerous in the hospital environment than is the member of the staff suffering from a minor staphylococcal lesion of the skin.

The application of these results to the prevention of staphylococcal infections in general is outside the scope of this paper, but, whatever alterations in technique be contemplated, cognizance should certainly be taken of the fact that direct expulsion of *Staph. aureus* into free air in droplets or droplet nuclei from the anterior nares is of much less importance than the almost inevitable presence of this organism on the skin and clothing of carriers, and its release on air-borne particles when the contaminated surfaces are subjected to friction and movement.

Summary

Experiments carried out with nasal carriers of *Staph. aureus* suggest that this organism is not transported from person to person by droplets or droplet nuclei but by an indirect route involving egress in nasal secretions, contamination of the skin, clothing, or bedding, release of the organisms by friction, movement, or washing, and transportation to others by air currents.

There is evidence that some carriers can contaminate the atmosphere in their neighbourhood with much larger numbers of *Staph. aureus* than the majority of carriers. Such individuals wearing a sterile gown over their ordinary underclothing may cause potentially dangerous degrees of air contamination during activity on their part; even when wearing a complete set of sterile operating clothes large numbers of *Staph. aureus* may still be detectable in the surrounding atmosphere.

These carriers are probably more dangerous in the hospital environment than the member of the staff suffering from a minor degree of skin sepsis.

We are grateful to the members of the medical and nursing staffs of this hospital for their help and co-operation, to the experimental subjects who have assisted us, and to Dr. R. E. O. Williams, of the Central Public Health Laboratory, for determining the phage-types of some of our strains.

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