of patients died from complications of endocarditis at about the time of completion of a six-weeks course of antibiotics adjudged to be curative, and, although no detailed study was made at necropsy concerning the viability of the bacterial colonies seen, their appearance gave no grounds for hope that, in these cases, several weeks less of treatment would have sufficed. In addition a case has already been quoted in which even six weeks was not long enough to effect cure.

For penicillin-sensitive organisms fever that continues despite treatment may be due to systemic reaction to the antibiotic or to inadequate dosage. When considering this latter aspect it must be remembered that, while for streptococci of oral origin the bactericidal and bacteriostatic levels of penicillin are usually very similar, they are not always so, and this may explain failure of otherwise apparently adequate therapy (Berntsen, 1955).

Cure of infection with so-called resistant organisms by the use of bacteriostatic drugs is not to be expected, and a drug or combination of drugs having bactericidal action must be sought (Garrod, 1953). The most generally useful combination at present is penicillin (10 to 20 mega units a day) with streptomycin 2 g. daily. But it is emphasized that treatment of such cases is part of a campaign planned in full co-operation with the bacteriologist, and rapid switching of drugs and dosage schedules merely serves to confuse the issue and may kill the patient. Should sensitivity reactions to the chosen bactericidal drug occur the lethal nature of bacterial endocarditis requires that rapid desensitization should be attempted in preference to reversion to treatment using bacteriostatic antibiotics.

Summary

The results of treatment of bacterial endocarditis from 1945 to 1956 are presented. The immediate mortality has been about 25%. Delay in diagnosis is still considerable, and is discussed. The part played by teeth in the disease is emphasized. So far, there has been a late recurrence rate of some 18%. The disease has its greatest mortality, and is more often missed, among the older age groups.

I am grateful to the medical, surgical, and dental staffs of St. Bartholomew's Hospital for allowing me to follow and report in summary cases treated by them, and to the department of bacteriology, by whose considerable efforts treatment has been guided. This study was started with the encouragement of Professor R. V. Christie and of Dr. G. W. Hayward, who has been kind enough to offer advice, and was continued on the medical unit under Dr. E. F. Scowen. I also wish to express my thanks to Dr. J. E. Cates, who followed cases treated in the first half of the period under review and who facilitated my own work by allowing me access to his records.

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FURTHER STUDIES ON THE TRANSMISSION OF STAPH. AUREUS

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It is now generally assumed that, except for pyogenic infections, the principal reservoir of *Staph. aureus* is the anterior nares of normal humans beings, and that there is a constant passage of this organism from person to person to produce the carrier condition or, when susceptible tissues are available, clinical infection.

The work of Duguid and Wallace (1948) and Hare and Thomas (1956) would suggest that direct transmission from carrier to recipient seldom takes place by means of droplets or droplet nuclei expelled from the nose. An indirect route is more probable, the first step being contamination of the skin and clothing of the carrier. Thence the organisms may reach a recipient who touches the carrier, by carriage on objects such as bedding or towels which have been in close physical contact with the carrier, or by air-borne particles released from his skin or clothing by friction, movement, or washing.

If transmission of *Staph. aureus* occurs in this way the numbers and distribution of the organism on the skin and clothing may govern the ability of the carrier to transmit his organisms to others. Investigation of this forms the first part of our paper. The second part gives details of experiments in which the ability of carriers to transmit their organisms by air-borne particles was assessed.

Experimental Methods

Media.—Isolation of *Staph. aureus* from the nasal cavity, skin, clothing, and air was invariably carried out on nutrient-agar plates containing phenolphthalein diphosphate. Made up in a concentration of 0.5%, it was sterilized by filtration and sufficient added to the melted agar immediately before the plates were poured to give a final concentration of 0.01% (Barber and Kuper, 1951; Hare and Thomas, 1956).

Isolation of Staph. aureus.—After incubation for 24 hours on the above medium, the plates were held face downwards over the neck of a bottle of strong ammonia: colonies of *Staph. aureus* turn red, thus enabling counts to be made of the number present. But, since other organisms may produce a similar coloration, representative colonies were invariably purified by plating and identified as *Staph. aureus* only if they were coagulase-positive and microscopically typical.

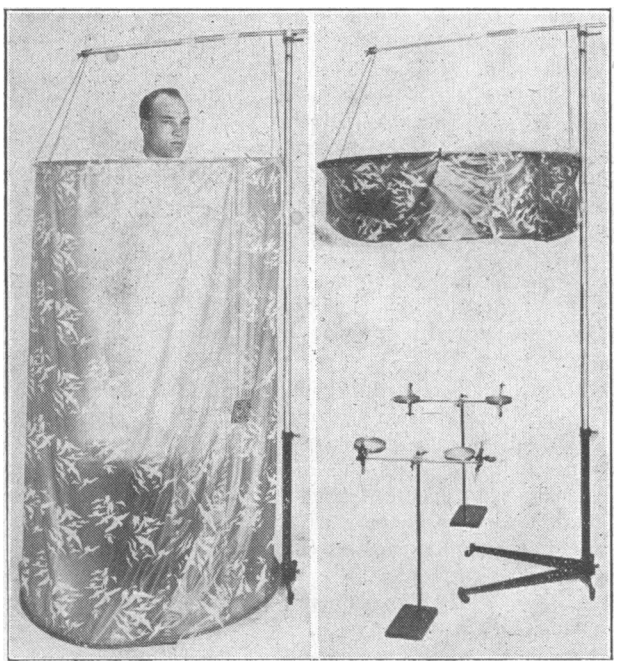
Contamination of Skin.—This was estimated by rubbing large cotton-wool swabs moistened with broth over an area of approximately 16 sq. cm. at each site. The swabs were immediately rubbed over the whole surface of phenolphthalein diphosphate nutrient-agar plates. With some carriers the whole of each finger was sampled, but with the majority one swab was used for the thumb and all the fingers of each hand.

Contamination of Clothing.—Sweep plates were employed (Blowers and Wallace, 1955) to sample the clothing, each plate being made to traverse the whole length of two adjoining areas on each garment. In the case of the handkerchief, it was bunched up and pressed down on the agar

surface. The only pocket sampled was that in which the handkerchief was kept (in the case of women the handbag), and for this purpose a broth-moistened swab was rubbed about in the depths. In some surveys press plates were used —that is, contact between the cloth and the surface of the medium was made by means of a circular wooden slab, slightly smaller in diameter than that of the culture plates, giving an area of 50.2 sq. cm.

Dispersal of Organisms from Skin and Clothing

The cubicle employed in these experiments was tubular, consisting of plastic curtain material hanging from a hoop 3 ft. (91 cm.) in diameter. The hoop itself was filled in with transparent plastic, but had a slit in the centre through which the head of the subject could protrude. There was another slit which could be closed by clips down the side of the cubicle through which the subject entered. The whole arrangement was suspended by guy ropes from a rod supported on a large stand (see Fig.).



Cubicle employed in the experiments. The position of the four culture plates exposed in each experiment is shown on right.

The culture plates were exposed on each side of the subject at about 15 in. (38 cm.) from the ground. Only four plates were employed, experience having shown that larger numbers, such as were used by Hare and Thomas (1956), are unnecessary. Experience has also shown that, except when a carrier is actually exercising in the cubicle, *Staph. aureus* is not likely to be isolated on the exposed plates, and for this reason control estimations of the bacterial contamination of the air with the carrier standing still were not carried out.

The carriers exercised in the cubicle for 15 minutes by marking time and waving their arms about while wearing their ordinary everyday clothing. An attempt was made to use a uniform degree of violence, but this proved difficult.

Both the total number of colonies and those consisting of *Staph. aureus* on the exposed plates were counted, and, assuming that each colony develops from one organism, the results were expressed as the number of organisms falling on 1 sq. ft. (0.09 sq. m.) in one minute.

During November and December, 1956, nasal swabs were taken from 76 technicians, surgical dressers, and final-year medical students. *Staph. aureus* was isolated from 30, giving a carrier rate of 39.4%. Nineteen of these carriers and 12 of the non-carriers were employed as subjects for this investigation.

Contamination of Skin and Clothing

The results obtained in surveys of 15 carriers are given in Table I and show that six (Cer, Ans, Mas, Dle, Ler, Ham) had much less contamination of the skin or clothing than the remaining nine. The latter had *Staph. aureus*, sometimes in considerable numbers, on the skin and usually on sites having fairly direct contact with the nose—that is to say, the face, palms, and fingers. The forearms, probably because they are protected by the sleeves, were seldom contaminated, as, contrary to what is usually supposed, were the wrists. The hair, chest, abdomen, back, and legs were either free or the numbers were small.

The only item of clothing likely to have direct contact with the nose is the handkerchief, and this was usually contaminated heavily. So, too, was the pocket in which it was kept, but staphylococci could also be found on one or other site on the remainder of the clothing, and certainly on that of the front of the body.

There seems to be no doubt that the skin and clothing may continue to be contaminated for months, but whether its intensity varies greatly from day to day was not specifically investigated.

Contrary to expectation there was no correlation between the number of *Staph. aureus* in the nose and the intensity and extent of skin or clothing contamination. Carriers Dle and Ham, for example, had many in the nose but few on their persons, whereas the opposite was the case with Bit and Ell. Nevertheless, if the carriers studied be considered representative of carriers in general, there is no doubt that about three-fifths evidently have enough *Staph. aureus* on various sites of skin and clothing to render them capable of acting as donors of infection.

Source of the Staph. aureus on Skin and Clothing

Following the work of Gillespie, Devenish, and Cowan (1939), Miles, Williams, and Clayton-Cooper (1944), and Williams (1946), it is now assumed that most of the *Staph. aureus* found on skin and clothing are not multiplying there, but are derived from the individual's own anterior nares. Phage-pattern determinations, carried out for us by Dr. Patricia Jevons of the Central Public Health Laboratory, would suggest that with 12 of the 15 carriers this may well have been the case. For the majority of the skin and clothing strains isolated in the surveys carried out over the period December–April had the same pattern as those in the carrier's nose. Of the remaining three carriers, two (Ham, Cer) had staphylococci on the skin or clothing which were different from the nasal strain, but so few were actually isolated that they may have been environmental strains.

This leaves one carrier (Bit) who had no staphylococci in his right nostril when examined on February 14 and only 10 colonies on a plate from the left nostril. One of these colonies had the phage-pattern 52/80. This strain was also found on his face and his left forearm. On the other hand, one colony from each of the other areas—chest, abdomen, leg, left and right palms, one finger of his right hand, shirt, front and back of his coat, socks, and handkerchief—all had the pattern 55/71.

Widespread contamination of Bit, who is a healthy individual with no pyogenic or other lesions of the skin and only a few *Staph. aureus* of a different phage pattern in one nostril, made it appear probable that this organism was derived from some situation other than his nose, where there was sufficient warmth and moisture to enable the organism to multiply. No *Staph. aureus* was isolated at preliminary examinations on May 15 and July 17 from the axillae, but large numbers were obtained from the perineum. It should perhaps be added that there was so heavy a growth of coagulase-negative skin micrococci from the latter area that, without the assistance afforded by the phenolphthalein diphosphate medium, the colonies of *Staph. aureus* might have been missed.

In view of this, a much more detailed survey was carried out on July 25, the results being as follows (the figures give the total number of *Staph. aureus* colonies isolated from

TABLE I.—*Presence of Staph. aureus on Skin and Clothing of 15 Nasal Carriers*

Name	Sex	Date	Left Nose	Right Nose	Hair	Face	Chest	Abdomen	Back	Legs	L. Forearm	R. Forearm	Wrists	L. Palm	R. Palm	L. Hand: Thumb	L. Hand: Finger 1	L. Hand: Finger 2	L. Hand: Finger 3	L. Hand: Finger 4	R. Hand: Thumb	R. Hand: Finger 1	R. Hand: Finger 2	R. Hand: Finger 3	R. Hand: Finger 4	Front Coat	Back Coat	Shirt	Trousers	Socks	Handkerchief	Handkerchief Pocket
Ale ..	M	Feb. 6	∞	∞	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	200	150
		Apr. 4	∞	∞	0	1	0	0	0	–	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	21	3	3	31	0	∞	∞
		June 25	∞	∞	0	∞	0	0	0	0	–	–	0	2	0	←	—	9	—	→	∞	6	0	16	1	11	3	0	1	3	100	∞
Son ..	M	Dec. 12	∞	∞	1	6	0	0	5	0	–	–	0	–	–	←	—	0	—	→	←	—	—	1	→	0	4	0	0	3	1	15
		Feb. 13	∞	∞	2	20	0	0	0	2	1	–	–	0	50	←	—	2	—	→	←	—	—	3	→	1	1	0	6	0	13	4
		June 27	∞	∞	0	20	0	0	0	0	–	–	0	0	8	←	—	0	—	→	3	1	4	∞	30	7	1	0	2	0	17	11
Ray ..	M	Nov. 27	∞	∞	0	1	1	0	1	1	–	–	–	–	–	–	1	2	2	–	–	2	1	1	–	3	1	4	3	0	100	100
		Jan. 31	∞	∞	1	8	2	0	0	0	–	–	0	–	–	–	0	5	1	–	–	2	15	2	–	0	4	0	3	1	100	38
Ips ..	M	Feb. 12	32	35	1	8	3	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	3	1	0	5	0	7	3
		June 26	100	∞	0	2	0	50	0	0	2	0	0	0	1	←	—	1	—	→	0	5	50	0	0	5	2	1	0	3	2	6
Ell ..	F	Feb. 6	0	100	0	2	–	–	–	0	0	0	0	0	1	1	0	0	1	0	1	0	1	1	3	1	0	–	2	–	20	–
		June 26	150	25	0	26	–	–	–	–	0	0	0	–	14	←	—	21	—	→	100	cont.	150	4	0	0	0	1	–	–	26	100
Ret ..	F	Feb. 6	0	100	0	0	–	–	–	0	0	0	0	0	0	0	100	1	0	0	0	4	0	0	0	2	0	–	0	–	20	–
Ett ..	M	Feb. 19	200	∞	6	11	40	3	0	30	26	4	23	40	15	←	—	100	—	→	←	—	4	—	→	2	3	2	4	11	16	12
		Aug. 27		∞	0	60	3	3	–	0	0	1	–	–	–	←	—	100	—	→	←	—	1	—	→	22	2	0	20	–	–	–
Ade ..	M	Feb. 5	∞	∞	1	27	0	0	0	1	2	0	2	0	0	2	0	3	2	3	8	5	36	4	0	0	3	1	1	0	500	17
		July 8	∞	∞	0	0	0	0	0	1	–	–	0	0	5	←	—	0	—	→	1	30	9	0	0	0	0	0	0	0	3	2
Bit ..	M	Feb. 14	10	0	0	2	3	13	0	2	4	0	0	4	1	←	—	0	—	→	←	—	2	—	→	5	4	1	0	15	1	0
		July 25	0	0	0	0	0	2	0	0	0	0	0	0		0	4	0	0	0	0	0	0	0	0	0	0	5	8	2	0	0
Cer ..	M	Dec. 19	∞	∞	4	0	0	5	0	0	–	–	3	–	–	←	—	—	—	0	—	—	—	—	→	1	8	0	0	1	3	2
Ans ..	M	Feb. 11	50	70	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	2	4	1	0	0	0
Mas ..	M	Feb. 7	∞	∞	0	0	0	0	0	0	0	0	0	–	–	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4	0
Dle ..	F	Dec. 12	∞	∞	0	1	1	–	0	–	–	–	0	–	–	←	—	—	—	0	—	—	—	—	→	0	0	0	0	0	6	0
		Jan. 27	∞	0	0	0	0	0	0	0	0	–	–	0	0	←	—	0	—	→	0	0	0	0	0	0	0	0	1	0	0	0
		Feb. 13	∞	∞	0	0	0	0	0	–	–	2	0	0	0	←	—	0	—	→	←	—	0	—	→	0	0	–	6	–	2	0
Ler ..	M	Feb. 11	∞	50	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
		June 27	∞	∞	0	19	0	0	0	0	0	0	0	0	1	←	—	7	—	→	0	2	0	0	3	1	0	0	0	0	4	2
Ham ..	M	Nov. 30	∞	∞	0	0	0	0	3	0	–	–	1	–	–	–	0	0	0	–	–	0	1	0	–	0	0	3	0	0	1	2

Note.—The figures give the number of colonies of *Staph. aureus* isolated from each area. The symbol 0 means that no *Staph. aureus* was isolated, and – indicates no test. In the case of women, the skirt was sampled instead of the trousers, and blouse or pullover in place of shirt. The handbag was sampled instead of the pocket.

approximately 16 sq. cm. of skin by a moistened swab, or on 50.2 sq. cm. of clothing using press plates):

Staph. aureus of Phage Pattern 3C/55/71 Present.—Abdomen (L 1, R 1). Perineum, 150. Fold between scrotum and thigh (L 1,000, R 100). Penis, 1. Front scrotum, 4. Inner thigh (L) 15. Foot: dorsum (L 4, R 1); sole (L) 1. Forefinger (L) 4. Drawers: front (L 3, R 4); inside leg (L 100, R 4); seat (L 47, R 8). Shirt, upper front (L 1, R 4); lower front, 14; sleeve (L 3, R 3); upper back, 3. Trousers, leg (L 2, R 4). Socks (L) 2.

No Staph. aureus Present.—Nostrils (L and R); throat; hair; chest (L and R); axilla (L and R); umbilicus; back (L and R); groin (R); inner thigh (R); outer thigh (L and R); anal fold; leg (L and R); foot, sole (R); forearm (L and R); wrist (L and R); hand, back (L and R), palm (L and R); R thumb and fingers; L thumb and 2, 3, and 4 fingers; faeces; coat; socks (R); handkerchief.

Staph. aureus of phage pattern 52/80 was found on the left groin and lower back, upper back, and left sleeve of the shirt.

On this occasion no *Staph. aureus* was isolated from either nose or throat, but colonies belonging to the same phage pattern as those found in February were obtained from many areas, by far the largest number coming from the perineum and the folds between the scrotum and thighs. The neighbouring areas—that is, the front of the scrotum, the penis, the anal fold, the skin of the inner part of the thighs about 4–6 in. (10–15 cm.) from the perineum, the area over Poupart's ligament, the lower part of the abdomen, and the umbilicus—were either free or much less heavily contaminated. The clothing in apposition to the perineum, such as the legs and seat of the drawers, was heavily contaminated, whereas more distant areas had much fewer organisms.

There was no evidence that the perineum had been contaminated by *Staph. aureus* coming from the faeces. Not only was this organism not found in a sample of faeces, but, as already mentioned, it was not isolated from a swab rubbed along the anal fold and over the anus. *E. coli*, it may be added, was present in fair numbers on this area.

These investigations suggest that the perineum of this particular individual had been the primary source of the *Staph. aureus* on his skin and clothing all along. This implies that this organism was able to multiply on this area of the body. An experiment carried out on July 30 would suggest that such is the case.

The subject defaecated at 8 a.m. and then at 11 a.m. thoroughly washed the whole of the perineum, inner side of the thighs, anal fold, testicles, and penis with soap, using many changes of warm water in a bowl. The area was dried with a sterile towel. He then put on a clean shirt, drawers, and trousers, and went about his work in the usual way, much of it involving sitting at a bench. The weather was warm and humid, so that there was much sweating. That night he put on clean pyjamas and slept between clean sheets. He did not defaecate again until 8 a.m. next day, and great care was taken to avoid touching the perineum or neighbouring areas during the intervening period.

Swabs moistened with broth were employed to take samples from the perineum and adjacent areas immediately after washing and again after 4, 7, 12, and 24 hours. Only a few micrococci and no *Staph. aureus* were isolated from swabs taken after washing; but both organisms, and particularly the micrococci, were present in increasing numbers in the samples taken after four and seven hours. By the 12th and the 24th hour there were so many micrococci that a heavy confluent growth was obtained, but embedded in it were many phosphatase-positive colonies of *Staph. aureus*. The results so far as they concern *Staph. aureus* are given in Table II.

TABLE II.—*Growth of Staph. aureus on the Perineum of Subject Bit*

Time	No. of *Staph. aureus* isolated from: Folds between Thigh and Scrotum: Left	Folds between Thigh and Scrotum: Right	Perineum	Anal Fold
After washing	0	0	0	0
4 hours	96	4	1	0
7 ,, ...	360	160	16	0
12 ,, ...	640	800	176	0
27 ,, ...	1,200	1,200	600	0

Specimens of faeces taken before the experiment and at the 22nd hour were both negative.

A somewhat similar increase in the number of *Staph. aureus* on the skin following removal of most of the surface organisms by washing was observed by Devenish and Miles (1939) in their studies of the flora of the hands during operations. They suggested that the staphylococci were already present in the sweat glands and deeper layers of the skin, and that sweating induced by wearing rubber gloves merely carried them to the surface. It is improbable that this is the explanation for our results. Table II shows, for example, that the numbers present as long as four hours after washing were not very large. In this experiment no attempt was made to promote sweating, but in another in which it was induced by sitting on a space heater for one and a half hours after washing, only 11, 0, and 7 colonies of *Staph. aureus* were obtained from the three areas at the end of that time.

It would therefore seem that *Staph. aureus* was actually multiplying on the perineum of subject Bit. For all practical purposes he was a perineal carrier of this organism, he had been one for several months, and organisms from this reservoir were able to reach other sites on the skin and clothing to much the same extent as with nasal carriers.

Dispersal of Staph. aureus into Free Air as a Result of Movement

With the use of the new form of cubicle illustrated above, in which the head of the subject is outside, the ability of 13 non-carriers and 19 carriers to disperse *Staph. aureus* was investigated. The results obtained with the non-carriers are given in Table III. Very few staphylococci appeared on the plates, the highest number falling on 1 square foot (930 sq. cm.) in one minute during exercise being 1.

TABLE III.—*Dispersal of Staph. aureus by Subjects Without Staph. aureus in the Nose*

Name	Sex	No. of Organisms Falling on 1 sq. ft. in One Minute	
		Total	*Staph. aureus*
Nes	M	484	1·0
Obs	F	55	0·8
Ris	M	340	0·4
Ple	M	135	0·2
Ied	F	294	0·2
Ink	F	39	0·2
Eel	M	115	0·2
Ael	M	350	0·2
Eek	M	47	0·0
San	F	65	0·0
Eld	M	771	0·0
Vis	M	96	0·0
Cis	F	72	0·0

TABLE IV.—*Dispersal of Staph. aureus by Known Nasal Carriers of this Organism*

Name	Sex	Date	Growth on Nasal Swabs		No. of Organisms Falling on 1 sq. ft. in One Minute	
			L	R	Total	*Staph. aureus*
Ale	M	Jan. 8	∞	∞	153	2·4
		Feb. 6	∞	∞	372	10·6
		April 4	∞	∞	494	27·8
		June 25	∞	∞	565	18·0
Son	M	Feb. 13	∞	∞	431	4·6
		April 3	∞	10	520	9·4
		June 27	∞	∞	284	1·0
Ray	M	Jan. 22	150	∞	193	10·8
Ade	M	Jan. 7	150	20	247	5·6
		Feb. 15	∞	∞	120	1·6
		March 21	150	∞	64	1·0
		May 30	∞	∞	N.D.	4·0
		July 11	∞	∞	302	7·8
Ans	M	Jan. 23	300	1	1,133	1·2
		Feb. 11	50	70	93	1·6
		April 4	4	20	520	1·6
Eal	M	Jan. 22	50	300	892	2·2
		May 31	1	0	885	6·5
Ips	M	Feb. 12	∞	∞	179	2·6
Ell	F	Jan. 21	300	300	127	1·2
		Feb. 6	100	0	216	1·2
		June 26	150	25	1,145	6·4
Bit	M	Feb. 14	0	10	276	4·5
		July 25	0	0	124	2·8
Cer	M	Jan. 17	100	300	172	1·4
Ett	M	Jan. 8	300	300	53	1·1
		Feb. 19	∞	200	169	1·0
Mas	M	Jan. 14	300	300	223	0·4
		Feb. 7	∞	∞	350	0·8
		July 8	∞	6	819	10·2
Dle	F	Feb. 13	∞	∞	389	0·6
		June 27	∞	0	279	0·0
Ean	F	Jan. 15	250	300	153	0·4
Per	M	Jan. 24	3	3	93	0·4
Lin	M	Jan. 15	100	20	152	0·4
Ham	M	Jan. 22	100	300	216	0·0
Ret	F	Feb. 6	100	0	38	0·0
Ler	M	Feb. 11	∞	50	488	0·0
		June 27	∞	∞	664	2·0

TABLE V.—*Dispersal of Organisms While Wearing Different Types of Clothing*

Carrier	Wearing Working Clothes		Wearing Best Clothes	
	Total Organisms	*Staph. aureus*	Total Organisms	*Staph. aureus*
Bit	276	4·5	169	2·9
Son	431	4·6	312	3·2
Ray	193	10·8	152	2·5
Ade	302	7·8	164	0·6

The results obtained with 19 known nasal carriers are given in Table IV. Six dispersed either no *Staph. aureus* at all, or less than 1 per square foot per minute. They were therefore in the same category as individuals who are not carriers. The counts obtained with the remaining 13 were higher, and for this reason all must be looked upon as potentially more dangerous than the rest of the population. Nevertheless, it is obvious that some were much more so, and no fewer than seven produced counts of 5 or more *Staph. aureus* per square foot per minute on at least one occasion.

Tests carried out at intervals over several months showed that some carriers, such as Ale, dispersed large numbers on each occasion, but others were much more variable. No adequate reasons for this variation can be advanced, but factors such as type of clothing worn, and the time elapsing between the last bath or change of underwear and the tests, may play an important part. Lower counts were certainly obtained with four carriers when " best clothes " were worn (see Table V).

Since the dispersed organisms must have come from either skin or clothing, it might be assumed that individuals with heavy surface contamination would disperse more organisms. Many of the dispersal experiments were carried out on the same days as the surveys, and comparison between Tables I and IV will show that, on the whole, there was correlation between numbers dispersed and extent of surface contamination. Nevertheless, there were obvious exceptions. One carrier—Ett, for example—was heavily contaminated on each of two occasions, but, probably because he was the most lethargic individual in the cubicle we have encountered, his counts were so low that he could hardly be described as a disperser at all.

On the other hand, there was very little correlation between the number of *Staph. aureus* in the nose and ability to disperse. Two carriers—for example, Dle and Ler—had large numbers in the nose but dispersed no *Staph. aureus* at all, or only a few. Another two, Eal and Bit, had very few in the nose, but the former produced a count of 6.5 and the latter 4.5. The same individual, too, might have approximately the same number in the nose on two occasions when very different results were obtained in the dispersal experiments—for example, Ade and Son.

Source of the Dispersed Organisms

Comparison between the phage patterns of the dispersed organisms and those present in the nose of the same individual in the experiments carried out during the period December–April showed that, excluding three carriers who dispersed none at all (Ler, Ret, and Ham), the pattern was the same in 14 out of the remaining 16. Thus in these instances the primary source of the dispersed organisms may well have been the nose.

Of the remaining two, one (Dle) dispersed only three colonies, which were different from each other and from those in the nose ; the second (Bit) was the perineal carrier already referred to. The strains he dispersed on February 14 and July 25 were of the same phage pattern (3C/55/71) as those on the perineum and clothing. They were therefore different from the strain (52/80) which was present in his nose. It is thus obvious that *Staph. aureus* derived from some primary source other than the nose may be dispersed during exertion as readily as when the primary source is the nose.

Discussion

Although nasal carriers have been looked upon for some time as constituting one of the most important reservoirs of *Staph. aureus* in the community, it is still not known whether all carriers can transmit their organisms to others with equal facility. This is partly due to the fact that very little is still known about the mechanism by which transmission occurs, but from the work of Duguid and Wallace (1948) and Hare and Thomas (1956) it would seem that it occurs by a comparatively circuitous route, the first and most important part being contamination of the skin and clothing of the carrier himself.

Detailed surveys, using numerical methods, were accordingly made of the skin and clothing of nasal carriers of *Staph. aureus*, and these showed that about two-thirds had sufficient numbers of this organism on different sites to render them capable of acting as donors. Some were more heavily contaminated than others, but until much more information is available it is not possible to suggest a line of demarcation between the really dangerous and the less dangerous carrier.

Even so, it is obvious that the number of staphylococcal carriers amongst hospital populations who are likely to have sufficient *Staph. aureus* on various parts of their skin and clothing to enable them to act as donors is considerable. To make matters worse, it is probably even larger than has previously been thought. For evidence has been obtained that some apparently normal individuals may possess areas of skin, such as the perineum, on which *Staph. aureus* can multiply. They may have no staphylococci at all in their nose, or, if they are present, they may be of an entirely different phage pattern. Nevertheless, the organisms from the primary site on the skin can reach areas of skin or the clothing at some distance, and be dispersed during movement in the same way as with individuals whose organisms have come from the nose. Such individuals, therefore, are potentially as dangerous as the nasal carrier.

They may be even more dangerous, for in the paper by Hare and Thomas reference was made to a subject, Pri, whose skin and clothing were heavily and widely contaminated and who dispersed more *Staph. aureus* when exercising (47.4 per sq. ft. per minute) than any of the carriers studied in this paper. The phage pattern of the dispersed organisms was 53, and although he had *Staph. aureus* in his nose they had the phage pattern 29. The primary source of the dispersed organisms was never ascertained, and although it may have been the perineum, as seems to have been the case with the subject investigated in this paper, it is quite possible that other sites, such as the axillae, umbilicus, or even the hands, may be similarly parasitized.

It is thus evident that it is no longer justifiable to assume that only nasal carriers need to be considered when attempts are made to trace the donors during outbreaks of infection. Much more extensive investigations are obviously required.

Nor can it be assumed that most of the *Staph. aureus* found on the skin or clothing, or which are dispersed into free air during movement, have invariably come from the individual's own nose. For this reason, wholesale instillation of antiseptics or antibiotics into the noses of carriers may eradicate part of the reservoir of *Staph. aureus* in hospital communities, but is unlikely to have much effect on that part of the reservoir constituted by those whose *Staph. aureus* are derived from some non-nasal site.

Summary

Extensive surveys of the skin and clothing of nasal carriers of *Staph. aureus* have shown that about three-fifths have sufficient numbers of this organism on certain areas, particularly the hands and the clothing of the front of the body, to enable them to transmit their own organisms to other persons with whom they come into direct physical contact, by means of objects such as blankets or towels which they have touched, or as a result of dispersal into free air during movement.

With many carriers, the primary source of these organisms is the nose, but the number of *Staph. aureus* in nasal swabs gives little indication of the extent of skin and clothing contamination, or ability to disperse this organism. Nevertheless, at least one individual in the series studied in this paper had a primary source which was not in the nose but on the skin of the perineum. *Staph. aureus* from this area could contaminate the skin and clothing and be dispersed during movement to much the same extent as with nasal carriers.

Thus, when possible sources of infection are being sought, the existence of non-nasal carriers of *Staph. aureus* must not be overlooked.

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The establishment of air pollution advisory councils in all countries and legal enforcement of measures to prevent air pollution were recommended by a W.H.O. expert committee on air pollution recently. The committee's meeting was W.H.O.'s first attempt to marshal the facts of air pollution and to establish a programme for preventive and remedial action by national authorities. According to the committee, it was certain that on the basis of existing knowledge much pollution could be avoided at a reasonable cost by careful planning and siting of factories and dwellings, better design of equipment, and better operation based on adequate training of management and employees. With small domestic heating appliances it was not so far economically practicable to burn coal without considerable emission of smoke, and to avoid air pollution new heating systems might have to be introduced into some communities. The committee noted that two processes for removing more than 90% of the sulphur dioxide from the chimney gases had been in use over several years at power stations in England. The cost of the processes was still very high, but experiments were in progress in several countries to find cheaper and more satisfactory systems.