

## Carriage patterns of *Staphylococcus aureus* in a healthy non-hospital population of adults and children

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**Summary.** Bacteriological examination of healthy school children and adults for *Staphylococcus aureus* by weekly swabbing of nose, throat and hands over extended periods demonstrated a general transition from persistent to transient carrier status between 10 and 20 years of age. Adult transient carriers were commoner among manual than office workers and frequently yielded biochemically atypical isolates, possibly because of acquired resistance to typical strains. Nasal carriage was commonest, but children frequently yielded the organism from both nose and throat.

### 1. Introduction

The bacterial flora of the body surfaces and alimentary tract of healthy persons may include a variety of potential pathogens, among them the common pyogenic bacterium of the human species, *Staphylococcus aureus*. Studies on the carriage, or frequency of occurrence, of such organisms may either be cross-sectional (a large, hopefully representative, sample population is examined on one or a few occasions) or longitudinal (chosen individuals are sampled repeatedly over a period), involving one or several body-sites in each individual.

Many investigations of staphylococcal carriage have been cross-sectional ones on populations, such as staff, in-patients or out-patients of hospitals, persons attending general practice surgeries or the inmates of boarding schools or military establishments, which are readily accessible to sampling but in which special factors may appertain; for example, carriage is likely to be more frequent because of inter-contact. Nevertheless, there is good evidence that staphylococcal carriage inclines in some individuals to be sporadic, in others constant (Williams, 1946; Ruys and Willems, 1955; Hutchinson, Green and Grimson, 1957); also, carrier rates tend to be highest at some stage of childhood and fall thereafter (Cunliffe, 1949; Noble, Valkenburg and Walters, 1967; Doig, 1971).

The purpose of the present study was to investigate the current incidence of *Staph. aureus* in samples of the population-at-large, namely adults attending their place of work and children at day schools, each person being examined repeatedly over an extended period. This paper reports on the patterns of transient and persistent carriage, the relative importance of nose, throat and hand carriage and the incidence of biochemically typical and atypical forms of *Staph. aureus*.



## 2. Subjects and methods

### Study population

This comprised 50 non-resident manual or office employees of the University of Surrey and 50 day school children living in or near Guildford, Surrey. At the time of recruitment, none was receiving medical treatment nor showing any obvious sign of disease. None of the adults had significant contact with each other during work; the children were drawn from two local primary schools and, within each, contact was mainly during school hours.

### Sampling plan

The work involved in weekly swabbing prohibited surveillance of a group of 100 persons at any one time. During 1970-71, 50 persons (25 adults, 25 children) were examined; in 1971-72 this was repeated on a comparable sample population of different individuals. The children could readily be contacted only whilst at school and, to obviate discrepancies, swabbing of both adults and children was carried out during school time only. Subjects away from school or work because of temporary illness were not swabbed.

### Bacteriology

Each week, the left and right nostril, throat and right hand of each participant was separately swabbed. Swabs were placed in 5 ml 10 per cent NaCl broth and incubated overnight at 37°C; a loopful of the resulting culture was subcultured onto 5 per cent blood agar plates. (When plates were overgrown by *Proteus* spp. a further subculture was made onto 0.2 per cent chloral hydrate blood agar.)

Colonies which were pigmented, haemolytic and which otherwise resembled *Staph. aureus* were subcultured and purified and the resultant isolates tested for free coagulase, bound coagulase, mannitol fermentation and phenolphthalein diphosphatase production; only those positive to two or more of these tests were recorded as *Staph. aureus*, following the convention of Baird-Parker (1965).

## 3. Results

Three children were withdrawn by their parents. The remainder, and the adults, were swabbed on an average 27 occasions (range 9-30) each and yielded a total of 3836 isolates of *Staph. aureus*, 2479 from children and 1357 from adults. One adult never yielded the organism.

No differences related to sex were found whatever, and results for both sexes have throughout been pooled.

### Isolation rates

Table 1 shows, for each group, the percentage of swabbing occasions on which *Staph. aureus* was isolated from different sites and thus indicates likely carrier rates had the study been a cross-sectional one of a correspondingly larger population. Isolation rates were consistently higher in children than adults and, in both, nose isolation rates were highest. Similar isolation rates occurred in both years except that, in children, nose isolations were more frequent and throat isolations less frequent in 1971-72 than in the preceding year.

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Year	Group	No. sampled	Av. no. sampling occasions	Percentage isolation rates			
				Hand	Nose	Throat	Overall
1970-1	Children	24	28.5	25.0	61.8	55.4	78.2
	Adults	25	27.5	18.0	39.9	22.8	54.4
1971-2	Children	23	27.7	23.3	69.4	34.2	77.4
	Adults	25	25.6	16.2	39.9	15.4	52.6

Table 1. Isolation rates of *Staphylococcus aureus* among school-children and adults in two consecutive years.

Isolation rates calculated as percentages of samples from which *Staph. aureus* was isolated from hand, nose, throat or, in the case of the overall rates, any combination of these sites.

#### Transient and persistent carriage

Some individuals yielded *Staph. aureus* only occasionally; others showed alternating periods of carriage and non-carriage and others still were regularly positive over extended periods. An arbitrary classification of individuals into transient carriers (*Staph. aureus* isolated on less than 70 per cent of sampling occasions) and persistent carriers (70 per cent or more sampling occasions positive) shows that the former were commoner among adults and the latter among children (table 2); this largely accounts for the higher isolation rates in children shown in table 1.

Year	Group	No. sampled	Av. no. sampling occasions	Distribution of individuals according to percentage of sampling occasions positive						Ratio N:T:P
				0-9	10-29	30-49	50-69	70-89	90-100	
1970-1	Children	24	28.5	0	0	2	5	9	8	0:29:71
	Adults	25	27.5	1	7	4	3	5	5	4:56:40
1971-2	Children	23	27.7	0	0	4	3	6	10	0:30:70
	Adults	25	25.6	0	8	5	5	3	4	0:72:28

N=non-carriers

T=transient carriers

P=persistent carriers

Table 2. Non-, transient and persistent carriers of *Staphylococcus aureus* among school-children and adults in two consecutive years.

A positive sampling occasion was one on which *Staph. aureus* was isolated from nose, throat, hand or any combination of these sites. Transient carriers were individuals with less than 70 per cent positive sampling occasions, persistent carriers those with 70 per cent or more positive.

Retabulation according to 10 year age groups (table 3) shows that the change from predominantly persistent to transient carrier status began in the 10-19 years group and was apparently complete in the 20-29 group: higher age groups were too small to reveal any subsequent trend.

There was a significant difference between the adult groups sampled in 1970-71 and 1971-72: transient carriers, somewhat commoner in the first year, were markedly commoner in the second ( $P < 0.05$ ). The mean age was similar in both years (33.9 and 34.0 years). However, in the first year the adult group had happened to comprise 8 manual and 17 office workers; to create some kind of balance



Age group	Number examined	Number of carriers	
		Transient	Persistent
0-9	12	2	10
10-19	38	14	24
20-29	22	14	8
30-39	12	8	4
40-49	5	2	2
50-59	5	4	1
60-69	3	2	1

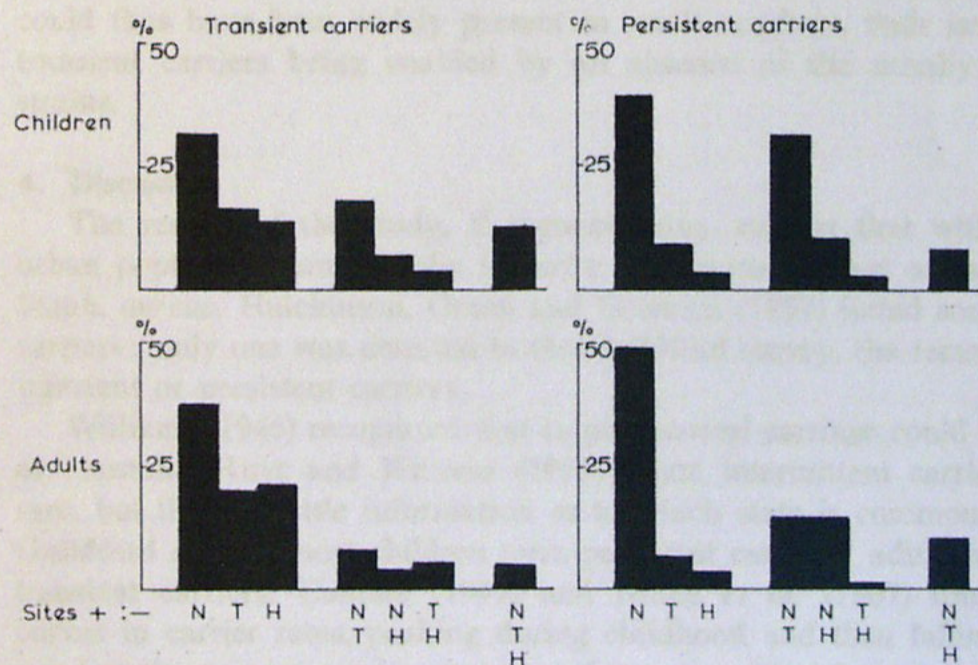
Table 3. Distribution of transient and persistent carriers of *Staphylococcus aureus* among different age groups.

One adult in the 40-49 age group was a non-carrier.

in the second year 17 manual and 8 office workers had been recruited. Most of the manual workers (20 out of 25) were transient carriers whereas among the 25 office workers only 12 were transient carriers, 12 being persistent and one a non-carrier ( $P < 0.05$ ).

#### Isolation patterns

Culturing from nose (N), throat (T) and hands (H) allowed seven possible patterns of isolation and, excluding negative samplings, their overall order of frequency was N (35.7 per cent), NT (22.2 per cent), HNT (13.4 per cent), T (10.7 per cent), HN (8.9 per cent), H (6.4 per cent) and HT (2.7 per cent). Both in children and adults there was a statistically significant correlation between isolations from nose and throat ( $P < 0.001$ ) and nose and hand ( $P < 0.01$ ) and  $P < 0.001$  respectively) and children also showed a hand and throat correlation



Distribution of different isolation patterns of *Staphylococcus aureus* from nose, throat, hands or combinations of these sites, shown as percentages of positive sampling occasions.

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( $P < 0.001$ ). A given individual tended, particularly if a persistent carrier, to display a similar pattern over a period.

The figure shows that isolation from the nose alone was the commonest pattern in each group, but reveals interesting differences: transient carriers quite often yielded the organism from throat or hand alone, a finding rare among the persistent carriers; the nose and throat isolation pattern was distinctly commoner in children than adults and, in child persistent carriers, approached the nose-alone pattern in frequency.

Type of carrier	Strains from children					Strains from adults				
	Typical		Atypical		Total	Typical		Atypical		Total
	No.	Percentage	No.	Percentage		No.	Percentage	No.	Percentage	
Transient	332	82.6	73	18.2	405	151	41.4	214	58.6	365
Persistent	1897	91.5	177	8.5	2074	936	94.4	56	5.6	992

Table 4. Proportions of biochemically typical and atypical *Staphylococcus aureus* isolated from transient and persistent carriers.

A typical strain was positive for free coagulase, bound coagulase, mannitol fermentation and phenolphthalein diphosphatase; an atypical strain was positive to two or three of these tests; other strains excluded.

#### Typical and atypical strains

All of the *Staph. aureus* isolations from which the tables have been constructed were of strains positive to at least two of the four tests employed. It seemed reasonable to distinguish between "typical" (positive to all four tests) and "atypical" forms (positive to two or three tests only). By these criteria, "typical" isolates were commonest by far and predominated in all groups except the adult, transient carriers, from whom more than half of the isolates were "atypical" (table 4); the difference between adult transient and persistent carriers was statistically significant ( $P < 0.001$ ). Interpretation needs some care; the swabs were cultured by a method which tends to isolate only the most abundant strain. Atypical strains could thus have been widely present in small numbers, their isolation from adult transient carriers being enabled by an absence of the usually abundant typical strains.

#### 4. Discussion

The results of the study, if representative, suggest that within the particular urban population sampled the majority of persons at least occasionally harboured *Staph. aureus*. Hutchinson, Green and Grimson (1957) found some persistent non-carriers: only one was detected in the Guildford survey, the remainder being either transient or persistent carriers.

Williams (1946) recognized that staphylococcal carriage could be either sporadic or constant; Ruys and Willems (1955) found intermittent carriage by no means rare, but there is little information as to which state is commoner. In the present Guildford survey, most children were persistent carriers: adults were more usually transient carriers. Cunliffe (1949) and Noble *et al.* (1967) found age-associated curves in carrier rates, peaking during childhood and then falling with increasing age but the present results suggest rather a transition from persistent to transient

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carrier status occurring somewhere between 10 and 20 years of age (Doig (1971) found somewhat higher carriage rates in paediatric in-patients than in adult patients). The finding that adult transient carriers tended to yield biochemically atypical isolates is apparently unique.

Higher carrier rates among children may be partly due to their close contact at school allowing ready interchange of bacterial flora; their usual state of persistent carriage may also be partly explained by repeated re-infection. But it seems likely that children are also intrinsically more susceptible than adults to staphylococcal colonization. The lower carrier rates and comparative infrequency of persistent carriers among adults suggests that many (the transient carriers) may have developed resistance mechanisms, perhaps local to the nose or throat. Conceivably, such resistance might derive from the acquisition of a well-adapted nose or throat flora not including *Staph. aureus* and so stable as to preclude intrusion by it. But the transient adult carrier's resistance would appear quite selective in suppressing the biochemically typical *Staph. aureus* and relatively inoperative against atypical forms. Such a degree of specificity points to an immunological basis and a comparison of secretory immunoglobulin levels in adult transient and persistent carriers might well be illuminating. Also, since there is evidence that staphylococcal skin and wound infections are, except for hospital infections, generally endogenous (Martin, 1942; Miles, Williams and Clayton-Cooper, 1944; Rebell, 1947; Williams, Blowers, Garrod and Shooter, 1960), it would be valuable to study the relative frequency of such disease among transient and persistent carriers.

It is difficult to understand the higher incidence of transient carriers among manual workers. Verification of the apparent difference is needed, together with a search for factors conducive to the development of resistance, affecting manual workers more than office workers.

Elek (1959) believed the primary site for *Staph. aureus* carriage to be the nose, other sites being contaminated from this source. The present results (see figure) support this view, at least in the case of persistent carriers: isolation patterns which included nasal isolation were much commoner than patterns which did not. Other workers have found many carriers who simultaneously yielded the organism from nose and skin (Gillespie, Devenish and Cowan, 1939; Smith, 1941). Such findings are consistent with the hands generally receiving infection by contact with the nose and, indeed, it is known that nose and skin isolates from a given person are often of the same phage type (Williams, 1946; Ridley, 1959; Noble *et al.*, 1967). The throat presumably becomes infected by mucus drainage from the nose, particularly it would appear in children, in whom the nose-and-throat isolation pattern was common.

The more nearly even frequency of isolation from nose, hand or throat alone found among transient carriers (see figure) suggests that initial infection may occur at any of these sites, either by the respiratory route or by direct or indirect hand transmission. The same probably holds for persistent carriers, but these are characterized by the subsequent establishment of the regular pattern of predominantly nasal carriage.

#### Acknowledgment

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**Zusammenfassung.** Die bakteriologische Untersuchung gesunder Schulkinder und Erwachsener auf *Staphylococcus aureus* durch wöchentliche Nasen-, Kehlen- und Handabstriche über längere Zeit zeigte einen allgemeinen Übergang vom dauernden zum vorübergehenden Trägerstatus zwischen 10 und 20 Jahren. Erwachsene vorübergehende Träger waren unter Handarbeitern weiter verbreitet als unter Büroarbeitern und zeigten häufig biochemisch atypische Isolate, möglicherweise wegen der erworbenen Resistenz gegen typische Stämme. Nasenbefall war am weitesten verbreitet, aber Kinder zeigten den Organismus häufig in Nase und Kehle gleichzeitig.

**Résumé.** L'examen bactériologique d'écoliers et d'adultes bien portants pour détection de *Staphylococcus aureus* par écouvillonnage hebdomadaire du nez, de la gorge et des mains durant de longues périodes a mis en évidence un passage général du statut de porteur persistant à celui de porteur transitoire entre les âges de 10 et 20 ans. Les porteurs transitoires adultes étaient plus communs chez les travailleurs manuels que chez les employés de bureau et véhiculaient plus souvent des isolats biochimiquement atypiques, peut-être à cause d'une résistance acquise aux souches typiques. La localisation nasale était la plus commune, mais les enfants ont fréquemment livré l'organisme à la fois du nez et de la gorge.