TEMPORARY AND CHRONIC CARRIERS OF *SALMONELLA TYPHI* AND *SALMONELLA PARATYPHI* B

By Th. M. VOGELSANG, M.D., *Gade's Institute, Department of Bacteriology, Bergen, Norway* and Johs. BØE, M.D., *Bergen City Hospital, Department of Infectious Diseases, Bergen, Norway*

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INTRODUCTION

In both typhoid fever and paratyphoid B, man is the original source of infection in the overwhelming majority of cases. *Salmonella typhi* has been found in the faeces of Greenland sleigh dogs which feed on human faeces (Krogh-Lund, 1940), and *S. paratyphi* B has been found in the faeces of cows (Kauffmann, 1941), but such modes of infection play a quite subordinate part. In the few cases which have come to light, the hosts should be regarded rather as vehicles of infection than as sources of it. It is only in the human body that both *S. typhi* and *S. paratyphi* B persist and reproduce themselves. In tracking down sources of infection we therefore ultimately come back to the living human being.

Both *S. typhi* and *S. paratyphi* B are in the main discharged from the human body with the faeces and urine. This process takes place, not only in the course of the disease, but may also continue during convalescence (temporary carriers) and may, under special conditions, persist for the rest of life (chronic or permanent carriers). To prevent further spread of the infection it is, therefore, essential to examine faeces and urine for the specific germ before the patient is declared free from infection.

To throw more light on the frequency with which a delayed or persistent discharge of *S. typhi* and *S. paratyphi* B in the faeces and urine takes place in a large number of cases, an examination was undertaken of the typhoid and paratyphoid B patients treated in the Bergen City Hospital in the period 1920–47. The patients who had discharged other *Salmonella* types than *S. typhi* and *S. paratyphi* B were not included in this investigation. The diagnosis depended partly on serological tests, partly on positive blood culture or the demonstration of the specific germ in faeces or urine during the illness. The present publication deals only with the investigations undertaken after the patients had become afebrile. But it may be noted in this connexion that 208 of the *S. paratyphi* B strains isolated were subjected to more searching bacteriological and serological tests and were invariably shown to be genuine *S. paratyhhi* B (Vogelsang, 1934).

TECHNIQUE

The nutrient media employed for the demonstration of *S. typhi* and *S. paratyphi* B sown directly from faeces and urine were, in the main, as follows:

Lacmus-lactose-agar

Meat broth	1000 ml.
Sodium chloride	5 gr.
Bacteriological peptone (Parke, Davis and Co.)	10 gr.
Agar, granular (Parke, Davis and Co.)	25 gr.
Lacmus solution -Kubel-Tiemann (Schering-Kahlbaum)	150 ml.
Lactose	15 gr.
pH 7·6–7·8	

Brom-thymol-blue-agar

Meat broth	1000 ml.
Sodium chloride	5 gr.
Bacteriological peptone (Parke, Davis and Co.)	10 gr.
Agar, granular (Parke, Davis and Co.)	25 gr.
Lactose	10 gr.
Saccharose	10 gr.
Sodium thiosulphate	1 gr.
0·2% brom-thymol-blue solution	40 ml.
0·1% crystal-violet solution	5 ml.
pH 7·6–7·8	

The brom-thymol-blue solution is prepared thus:

Brom-thymol-blue	1 gr.
Distilled water	475 ml.
N/10-NaOH	25 ml.

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Transfer to bottles and keep in a thermostat at 50–55° C. for several days, shaking several times daily. This gives a 1:500 (0·2 %) brom-thymol-blue solution.

With a Pasteur pipette a couple of drops of urine are dropped on to a Petri dish containing one of the above-mentioned substrates and are distributed over the surface with the help of a sterile glass rod bent at a right angle. During the earlier years, faeces were distributed over several lacmus-lactose dishes with the same glass rod, and since 1928 in the following sequence of four Petri dishes: (1) Lacmus-lactose dish, (2) Brom-thymol-blue dish, (3) Lacmus-lactose dish, (3) Brom-thymol-blue dish.

By this procedure we have succeeded in obtaining well-isolated colonies for examination.

The specific germs were identified by agglutination tests on slides, and by their capacity to ferment the three following sugars: mannit, maltose, glucose, but not saccharose.

For a long time catheter specimens of urine from women were examined. Aperients were given before samples were taken of the facees, the last and most watery portion, which had traversed the intestines rapidly, being examined.

In the period 1920–2, the minimum requirement for a certificate of freedom from infection was two negative faeces and urine tests. Since 1923, this criterion has been supplemented by duodenal tubage with absence of the germ in question also in the bile. Subsequently, duodenal tubage has been omitted in very exceptional cases, for example, young children and a few old folk objecting to this examination. In such cases a greater number of negative faeces tests was demanded.

OCCURRENCE OF TEMPORARY AND CHRONIC CARRIERS

In the period 1920–47, the Bergen City Hospital treated 1468 cases of typhoid and paratyphoid B. As Table 1 shows, there were eighty-one deaths (5·5 %), so the number of temporary and chronic carriers examined was 1387. Barely one-third were infected with *S. typhi* and over two-thirds with *S. paratyphi* B. The former proved to be much more dangerous than the latter, the mortality being 12·8 and 2·7 % respectively.

Table 1. *Typhoid and paratyphoid B cases and deaths*

	No. of cases	Deaths		No. of convalescents
		No.	%	
1920–47	1468	81	5·5	1387
S. typhi	413	53	12·8	360
S. paratyphi B	1055	28	2·7	1027

Table 2 gives the excretion of *S. typhi* and *S. paratyphi* B during convalescence. On the whole, about one-eighth of the patients continued to discharge the specific germ after they had become afebrile. While the percentage of patients found to be temporary carriers was approximately the same for *S. typhi* as for *S. paratyphi* B, the percentage of chronic carriers was higher for the former, the figures being 3·3 and 1·9 % respectively.

Table 2. *Faecal and urinary excreters after the acute stage of the disease*

	No. of cases	Excreters		Temporary carriers		Chronic carriers	
		No.	%	No.	%	No.	%
1920–47	1387	185	13·3	153	11·0	32	2·3
S. typhi	360	55	15·3	43	11·9	12	3·3
S. paratyphi B	1027	130	12·6	110	10·7	20	1·9

(Six temporary carriers both faecal and urinary excreters.)

Without going into detail over the causes of the chronic carrier state, we should like to point out that when a severe and prolonged typhoid infection is associated with meteorism and constipation, the flow of bile may be obstructed with consequent stagnation which helps the specific germ to settle in the biliary passages (gall-bladder).

Among the temporary carriers were six who discharged the specific germ in both faeces and urine. Table 3 shows that there were more than twice as many temporary carriers with infected faeces as with infected urine. In spite of the many statements in the literature on the subject, it is at least very doubtful whether medicinal treatment can influence the discharge of the infectious matter in the faeces. On the other hand, it is possible in almost every case to sterilize the urine by urinary disinfectants. Hence the fact that among our chronic carriers there was only one, a man aged 46, who continued to be a urinary excreter. All the other thirty-one chronic carriers were so by virtue of their infected faeces.

Table 3. *Temporary carriers*

Specific organism	No. of cases	Faecal excreters		Urinary excreters	
		No.	%	No.	%
S. typhi	360	31	8·6	15	4·2
S. paratyphi B	1027	78	7·6	35	3·4
Total	1387	109	7·9	50	3·7

As Table 4 shows, there was a considerable difference in the number of chronic carriers during the first 3 years and the subsequent period. In the period 1920–2, not a single chronic carrier was found among 134 typhoid patients, whereas in the

period 1923–47, 5·3 % were chronic carriers. Since 1923, the proportion of chronic paratyphoid B carriers to the number of patients has risen almost tenfold, the chronic carriers in 1920–2 constituting 0·4 % of the para-typhoid B patients, and 3·6 % in the period 1923–47.

The percentage of temporary urinary carriers was about the same in the two periods. But among the temporary faecal excreters we find the same conditions as among the chronic faecal carriers, though not to such a marked degree. However, since 1922, the ratio of temporary excreters of both *S. typhi* and *S. paratyphi* B to the number of patients was about three times greater than it had been in the period 1920–2.

This great difference in the number of temporary and chronic faecal carriers in the two periods cannot be fortuitous and must assuredly be due to improvements in the technique of our examinations. While our technique for the demonstration of the specific germ in the urine has remained unchanged all these years, contro of faecal excreta has been tightened up. As already mentioned, ever since 1923 practically every patient has undergone duodenal tubage in addition to the examination of the faeces.

The faultiness of the control exercised in the period 1920–2 has subsequently been directly proven by the fact that two women, discharged in 1921 after the then customary negative faeces and urine tests, were later shown to be chronic carriers. One of them, aged 43, was discovered as a carrier in 1923 when several cases of paratyphoid B occurred in her family. During subsequent yearly control examinations she has always discharged *S. paratyphi* B in the faeces.

Another woman, aged 33, was not found to be a chronic carrier until a new servant maid in her home developed paratyphoid B. When cholecystectomy was performed in 1930, the gall-bladder was found to contain fifteen cholesterol stones as large as peas, and a histological examination revealed chronic cholecystitis. The last time *S. paratyphi* B was demonstrable in the faeces was 12 days after the operation.

We have not included in the present study these two women who were not shown to be chronic paratyphoid B carriers till after they had been discharged from hospital. If we include them in our material, then there were twenty-two chronic carriers among 1027 paratyphoid B patients, the percentage of chronic paratyphoid B carriers being thereby raised from 1·9 to 2·1.

In the present study we have included only those temporary and chronic carriers who were found to be such during their stay in hospital. Our figures must, therefore, be regarded as minimum figures. On the other hand, among all the cases of typhoid and paratyphoid B included in the present study there were only these two women who were 'negative' on discharge, and who were subsequently found to have infected other persons. In the period under review in Bergen and adjoining districts in western Norway comprehensive investigations have been undertaken for tracking the sources of infection when typhoid or paratyphoid B has broken out. Altogether, in addition to the thirty-two chronic carriers dealt with in this study and the two women found to be chronic carriers at a late stage, ninety-four other persons were found to be chronic typhoid or paratyphoid B carriers. But none of these ninety-four carriers had been treated for their original infection at the Bergen City Hospital in the period under review.

Table 4. *Temporary and chronic carriers in different periods*

Specific organism	Years	No. of cases	Faecal excreters		Urinary excreters		Chronic carriers	
			No.	%	No.	%	No.	%
S. typhi	1920–2	134	5	3·7	7	5·2	0	—
	1923–47	226	26	11·5	8	3·5	12	5·3
S. paratyphi B	1920–2	526	19	3·6	18	3·4	2	0·4
	1923–47	501	59	11·8	17	3·4	18	3·6

SEX AND AGE

Table 5 gives the age and sex of the typhoid and paratyphoid B patients. Both among the typhoid and paratyphoid B patients, about one-quarter were children under the age of 16. But among the adults there were relatively more young patients suffering from paratyphoid B than from typhoid. The sex distribution of the cases and of the deaths was approximately equal (Table 6). In the case of both typhoid and paratyphoid B, the mortality rose with age, as plainly shown in Table 7 in which the number of deaths is compared with the number of cases. The mortality from paratyphoid B in childhood is shown to be very low, and it is so in young folk also, but it reaches 5 % in the age group over 30. In contrast, we find infection with *S. typhi* even in childhood causing a mortality of 8·5 %, rising to about twice this figure in the age group over 30.

Tables 8 and 9 give the sex and age of temporary carriers. While both the cases and the deaths were approximately evenly distributed between the two

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sexes, the female temporary carriers were much in the majority. This preponderance of women in the present study was particularly marked among the cases of typhoid, only about one-third of the temporary typhoid carriers being males. Our figures according to this classification are, however, rather small. They are larger for the paratyphoid B cases, in which the predominance of females is less marked. The frequency with which patients become temporary carriers rises with age, and in the case of both infections it is about 15% in the age group over 30. women. The same sex inequality is demonstrable in the total material of chronic typhoid and paratyphoid B carriers in western Norway, more than four-fifths of them being women.

Only one of the chronic carriers in the present study was a child. The chance of an adolescent becoming a chronic carrier is also small, but it grows considerably after the age of 30 (Table 11). The chances of an infection with either *S. typhi* or *S. paratyphi* B rendering a patient a chronic carrier are great in the higher age groups. Among thirty-four

Table 5. *Sex and age of typhoid and paratyphoid* B *patients*

		S. typhi			*S. paratyphi* B		
Age	Total	No. of cases	Male	Female	No. of cases	Male	Female
0–5	105	37	14	23	68	37	31
6–10	127	41	25	16	86	53	33
11–15	141	39	23	16	102	50	52
	373 (25·4%)	117 (28·3%)			256 (24·3%)		
16–20	231	41	28	13	190	80	110
21–25	276	58	26	32	218	95	123
26–30	180	47	22	25	133	58	75
	687 (46·8%)	146 (35·4%)			541 (51·3%)		
31–40	213	68	32	36	145	61	84
41–50	111	48	27	21	63	34	29
51–60	50	23	7	16	27	13	14
>60	34	11	3	8	23	7	16
	408 (27·8%)	150 (36·3%)			258 (24·4%)		
	1468	413	207	206	1055	488	567
			50%	50%		46·3%	53·7%

Table 6. *Sex and age at death*

		S. typhi			*S. paratyphi* B		
Age	Total	No. of cases	Male	Female	No. of cases	Male	Female
0–15	11 (13·6%)	10	5	5	1	—	1
16–30	33 (40·7%)	19	8	11	14	7	7
>30	37 (45·7%)	24	14	10	13	6	7
	81	53	27	26	28	13	15
			51%	49%		46·4%	53·6%

Table 7. *Cases and deaths at different ages*

	S. typhi			*S. paratyphi* B		
Age	No. of cases	No. of deaths	%	No. of cases	No. of deaths	%
0–15	117	10	8·5	256	1	0·4
16–30	146	19	13·0	541	14	2·6
>30	150	24	16·0	258	13	5·0
	413	53	12·8	1055	28	2·7

Table 10 shows that the sex difference was still more marked in the case of chronic carriers, three-quarters of the chronic *S. typhi* carriers being women. Nine-tenths of the chronic *S. paratyphi* B were typhoid patients over the age of 50 there were six chronic carriers, and the same number among fifty paratyphoid B patients over the same age. It is of epidemiological significance that chronic carriers are so largely recruited from among elderly women. Among the twelve chronic carriers over the age of 50, there were eleven women.

DURATION OF EXCRETION

In several publications, the duration of the carrier state is calculated as from the beginning of the illness. But a search for the specific germ during the illness is chiefly for the sake of diagnosis, and it is not

till convalescence has set in that it acquires importance with regard to the duration of the excretion of bacilli. An infection with *S. typhi* or *S. paratyphi* B can in certain cases run a light course and be of short duration, and in others it may cause prolonged illness with relapses extending over months. We have, therefore, chosen as our starting-point, when determining the duration of the carrier state, the first day without fever provided the permanent carriers, there was only one typhoid patient out of the total of 1387 typhoid and paratyphoid B patients whose carrier state ceased spontaneously more than 3 months after she had contracted the disease. Aged 61, she had in the course of 7 months been found constantly to harbour *S. typhi* in the faeces. After this interval, *S. typhi* could be found neither in the faeces nor in the bile drawn by duodenal tubage.

Table 8. *Sex and ages of temporary carriers*

		S. typhi			*S. paratyphi* B		
Age	Total	No. of cases	Male	Female	No. of cases	Male	Female
0–5	8	3	—	3	5	2	3
6–10	9	3	1	2	6	4	2
11–15	6	2	1	1	4	1	3
	23 (15·0%)	8 (18·6%)			15 (13·6%)		
16–20	18	3	2	1	15	5	10
21–25	34	4	1	3	30	14	16
26–30	22	10	3	7	12	6	6
	74 (48·4%)	17 (39·5%)			57 (51·8%)		
31–40	32	8	4	4	24	10	14
41–50	11	7	3	4	4	2	2
51–60	7	2	—	2	5	1	4
> 60	6	1	—	1	5	1	4
	56 (36·6%)	18 (41·9%)			38 (34·6%)		
	153	43	15	28	110	46	64
			34·9%	65·1%		41·8%	58·2%

Table 9. *Cases and temporary carriers at different ages*

	S. typhi			*S. paratyphi* B		
Age	Convalescent cases	Temporary carriers	%	Convalescent cases	Temporary carriers	%
0–15	107	8	7·5	255	15	5·9
16–30	127	17	13·4	527	57	10·8
> 30	126	18	14·3	245	38	15·5
	360	43	11·9	1027	110	10·7

temperature remains subsequently normal. In most cases it has not been difficult to fix this day as the temperature is often subnormal at the beginning of convalescence.

In about one-quarter of the temporary carriers it was no longer possible after the first week without fever to demonstrate the specific germ in the faeces and urine (Table 12). After 2 weeks without fever, more than half had ceased to be infectious, and after 4 weeks only one-tenth of the temporary carriers continued to discharge the specific germ. Among the sixteen carriers who discharged germs for more than 4 weeks, there were ten who ceased to be so in the course of the second month of convalescence, and five more in the course of the third month (Table 13). Apart from the thirty-two patients who became

DURATION OF THE CHRONIC CARRIER STATE

Among the chronic carriers there were thirty-one faecal and one urinary excreter. The subsequent fate is unknown of this urinary excreter and of two of the faecal excreters, who were not included in our repeated control of chronic carriers.

Eight chronic carriers died respectively $1\frac{3}{4}$, 3, 3, 3, 5, 7, 10, and 17 years after becoming infected. To judge by the control examinations of these patients carried out at irregular intervals after their carrier state had been detected, it lasted till their death. Now and then a test might be negative, but on further examination the specific germ would again be found in the faeces.

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This was also the case with six of the other chronic carriers who are still under supervision, and who have now discharged the specific germs for 1½, 4, 5, 22, 23, and 25 years respectively.

A woman, aged 52, suffered from typhoid fever in January 1940. During convalescence her faeces continued to contain *S. typhi* which was also demonstrable in the bile on duodenal tubage. An X-ray a series of tests of the faeces failed to reveal *S. typhi*. She would seem, therefore, to have recovered spontaneously between 6 months and 4 years after the cessation of her illness.

Among the chronic faecal carriers in western Norway were some who were willing to undergo cholecystectomy with a view to becoming non-infectious. This operation was not recommended

Table 10. *Sex and age of chronic carriers*

		S. typhi			*S. paratyphi* B		
Age	Total	No. of cases	Male	Female	No. of cases	Male	Female
0–15	1 (3·1%)	1 (8·3%)	1	—	—	—	—
21–25	3	—	—	—	3	—	3
26–30	4	1 (8·3%)	—	1	3	—	3
	8 (21·9%)				6 (30·0%)		
31–40	9	2	—	2	7	1	6
41–50	3	2	1	1	1	1	—
51–60	6	3	1	2	3	—	3
> 60	6	3	—	3	3	—	3
	24 (75·0%)	10 (83·3%)			14 (70·0%)		
	32	12	3	9	20	2	18
			25%	75%		10%	90%

Table 11. *Cases and chronic carriers at different ages*

	S. typhi			*S. paratyphi* B		
Age	Convalescent cases	Chronic carriers	%	Convalescent cases	Chronic carriers	%
0–15	107	1	0·9	255	0	—
16–30	127	1	0·8	527	6	1·1
> 30	126	10	8·0	245	14	5·7
	360	12	3·3	1027	20	1·9

Table 12. *Duration of the temporary carrier state*

		Duration of excretion in convalescence					
Route of excretion	Specific organism	1 week	2 weeks	3 weeks	4 weeks	> 4 weeks	Total
Faeces	*S. typhi*	8	9	6	4	4	31
	S. paratyphi B	20	21	20	12	5	78
	Total	28	30	26	16	9	109
Urine	*S. typhi*	1	5	5	—	4	15
	S. paratyphi B	8	15	6	3	3	35
	Total	9	20	11	3	7	50
		37	50	37	19	16	159

examination of the gall-bladder failed to show any shadows of it after one or two portions of Shadocol. On her discharge from hospital at the end of June 1940, her faeces still contained *S. typhi*. During the wartime conditions of that period, we failed to obtain new samples for examination from her before 1944, when the tests proved negative. She was readmitted to hospital in 1946 for observation. Two examinations of the bile after duodenal tubage and until duodenal tubage had located the specific germ in the bile. The cholecystography undertaken revealed either gall-stones or functional disturbances of the gall-bladder. When its functional activity was found to be normal, it was not operated on.

Among our chronic carriers there were fourteen who underwent cholecystectomy. Three of them were not operated on till more than 2 years after they had recovered from their illness, and in seven

cases this interval was between 1 and 2 years. In all ten cases, calculi were found in the gall-bladder, and a histological examination showed chronic cholecystitis. The specific germ was demonstrable in the bile in pure culture.

Table 13. *Temporary excreters* 1 *month or more in convalescence*

Route of execretion	Specific organism	No. of cases	Duration of excretion
Faeces	*S. typhi*	4	31, 32, 75 days and 7 months
	S. paratyphi B	5	48, 60, 63, 64 and 65 days
Urine	*S. typhi*	4	30, 36, 37 and 44 days
	S. paratyphi B	3	30, 33 and 46 days

The operation proved useless in one case in which *S. typhi* has continued for the past 4 years to be demonstrable in the faeces. In eight cases the discharge of the germs ceased as a direct sequel to the operation, in the last case not until more than 1½ years after it. This patient was a woman, aged 35, who in December 1943 had suffered from typhoid fever. At the operation in January 1945, six large and thirty smaller facetted calculi were found in her gall-bladder which, on histological examination, showed chronic cholecystitis. *S. typhi* was obtained in pure culture from the gall-bladder. She continued to discharge *S. typhi* in the faeces after the operation, being kept under regular supervision while she was in hospital and at more rare intervals after discharge. The last positive faeces test was in August 1946, more than 1½ years after the operation. In April 1947, she developed acute jaundice with pain in the right hypochondrium so violent that she compared it with labour pains. She was very jaundiced and her urine was very dark for a fortnight. The next faeces test, carried out in June 1947, was negative. As the subsequent tests also proved negative, she was readmitted to hospital for observation. Here two bile tests and numerous faeces tests proved negative. It is reasonable to presume in this case that she had, in addition to the numerous calculi in her gall-bladder, one or more calculi in the bile ducts from which they had passed into the duodenum during her biliary colic. Hence the cessation of the carrier state. It is also likely that her discharge of the specific germ had continued till this attack in April 1947, i.e. more than 2 years after the operation.

In the last four of these thirty-two chronic carrier cases, the circumstances were such that they were operated on within a year of the cessation of the illness, i.e. 4, 5, 6, and 7 months respectively after they had become afebrile. All four ceased to be carriers as a direct response to the operation. Two of them, however, differed from the rest with regard to the operation findings, for in neither case were calculi found in the gall-bladder.

One of them, a woman aged 58, continued to discharge *S. typhi* in the faeces after the cessation of her illness. Though she was advised to go home and return to hospital after a year for renewed observation and, if need be, an operation, she insisted on having it at once because of her home conditions. As the X-ray evidence was suggestive of gall-stones, her plea for cholecystectomy was complied with 4 months after she had become afebrile. The operation revealed a gall-bladder of normal appearance, with small adhesions to the omentum, but no stones and only slight pathological changes under the microscope. The bile yielded *S. typhi* in pure culture.

The other case was that of the only child among our chronic carriers, and the only child faecal excreter among all the known carriers in western Norway. This boy, aged 9, had suffered from typhoid in April and May 1940, and had continued to discharge *S. typhi* in the faeces. Because of wartime conditions, and because his quarters at home were very overcrowded, he could hardly be discharged from hospital without having been rendered non-infectious. As there was X-ray evidence of functional disturbances of the gall-bladder, consent was given to an operation only 6 months after the cessation of the illness. The operation revealed quite firm adhesions to the bed of the liver and fibrous thickening of the neck of the gall-bladder and of the common bile duct, but no stones. The microscope showed chronic cholecystitis. *S. typhi* was obtained in pure culture from the bile.

The inclusion of these two cases among our chronic carriers may be challenged. They were the only cases, among those operated on, in which no stones could be found in the gall-bladder to suggest that they were responsible for the maintenance of the carrier state. But in both cases the operation showed adhesions between the gall-bladder and the surrounding structures, in the case of the boy adhesions to the omentum and considerable chronic cholecystitis. In addition, the gall-bladder bile yielded in both cases *S. typhi* in pure culture. These findings suggest that the carrier state would have continued without an operation. This is why we have included these two patients among our chronic carriers.

DISCUSSION

Our material covers a period of 28 years, during which both typhoid and paratyphoid B occurred in Bergen and neighbouring districts partly as isolated cases, partly as house or small local epidemics, and occasionally as considerable epidemics. Among the latter were milk-borne epidemics, but no certain water-borne epidemics. Nearly all the *S. typhi*

strains were xylose-positive, but there were a few xylose-negative strains. Among the *S. paratyphi* B strains were some which rapidly fermented inosit, and others which did so slowly, and a couple which had not fermented this hexamethylene during 14 days' incubation. There were also both rapidly and slowly dulcit- and rhamnose-fermenting strains. Our material was thus from both the epidemiological and the cultural aspects so all-round representative that it should present the occurrence of the two diseases in a clear perspective. Our material should, therefore, be well suited to throw light on the temporary and chronic carrier state in these diseases.

All who have suffered from typhoid or paratyphoid B and who continue to discharge the specific germ should be regarded as carriers. In some cases this condition is only temporary, in others it lasts for life. Opinions are still divided over the question: How long must the carrier state have lasted before the chances of its spontaneous cessation have vanished? According to some the time limit between a temporary and a chronic carrier is 3 months, according to others, 6 months, while many put it at 1 year.

Most of the chronic carriers in our material were not regarded as such till after they had discharged the specific germ for a year. Since 1940, however, we have in four cases shortened this interval considerably.

As our material shows, a not inconsiderable number of our typhoid and paratyphoid B patients have continued to discharge the specific germ during convalescence. Most of them, however, ceased to be infectious within a month of the cessation of the illness. Among the excreters who continued to be such for more than 3 months, there were in our material only two who ceased to be so spontaneously later on. One of them is listed as a temporary carrier who recovered spontaneously after 7 months, the other as a chronic carrier whose carrier state cleared up within 4 years after the cessation of the illness. Reference has been made in earlier studies of typhoid carriers in western Norway to spontaneous recovery after 9 months (Vogelsang, 1930) and after 14 months (Vogelsang & Haaland, 1933). In this connexion interest attaches to the above-mentioned chronic typhoid carrier whose carrier state certainly lasted for over $1\frac{1}{2}$ years, and who apparently did not cease to be so till she had suffered from violent biliary colic more than 2 years after an operation on the gall-bladder for the carrier state. The well-known saying: 'Once a typhoid carrier, always a typhoid carrier' may, therefore, not always be true. The exceptions are, however, so rare that when the carrier state has persisted for 3 months after the cessation of the illness, the chances of a spontaneous recovery are so small that they may, as a rule, be ignored.

As already pointed out, the temporary discharge of the specific germ in the urine can in most cases be stopped by urinary disinfectants. Chronic urinary carriers are therefore rare, and it is nearly always in the faeces that the chronic carrier discharges the specific germs. All the available evidence points to the gall-bladder as the permanent seat of the specific germ in nearly every case, and to gall-stones as the cause of this state of affairs (Haaland & Haaland, 1927). By cholecystectomy it is possible to cure this carrier state, but the longer the interval between infection and operation, the greater the likelihood of the biliary radicals of the liver also becoming infected with the creation of chronic foci in the liver. Experience in western Norway has shown that the earlier the operation the better the chances of a cure. Hence our conviction that it is most important to diagnose the carrier state as soon as possible. When, therefore, we can demonstrate the specific germ in the bile by duodenal tubage, and when cholecystography indicates gall-stones or functional disturbances of the gall-bladder, and when the carrier state has lasted at least 3 months after the cessation of the illness, we consider ourselves justified in declaring a faecal excreter to be a chronic carrier.

Of 1387 convalescents from typhoid and paratyphoid B, 185 (13·3 %) discharged the specific germ in the faeces or urine. This condition was temporary in 153 (11 %) and in thirty-two (2·3 %) it was chronic. In 3·3 % of the typhoid patients, and in 1·9 % of the paratyphoid B patients the carrier state was chronic. A comparison of these figures with those of other observers is difficult because the observation period was often too short.

Garbat (1922) undertook laboratory tests of 164 out of 183 cases of typhoid during an epidemic in an internment camp for German civilian prisoners in the U.S.A. in the first World War. Among these 164 were thirty-nine (21 %) with *S. typhi* in the faeces during convalescence. Further, there were fourteen cases in which three consecutive examinations of the faeces proved negative, while duodenal cultures showed numerous *S. typhi*. Thus altogether fifty-three (32 %) remained faecal carriers after the temperature had become normal. Of these, 28 or 29 % were temporary carriers, 17·5 % for 1 month, 8 % for 2 months, and 3 % for 3 months. After 3 months of convalescence *S. typhi* had disappeared in all but seven carriers. Subsequent tests were not carried out on all of them, but Garbat assumed that four, if not all of them, would undoubtedly remain chronic faecal carriers. This means from 2·4 to 4·2 % of all typhoid cases. In 6·7 % of all typhoid cases, or in 13·6 % of all cases of bacilluria, the carrier state persisted for 1–2 months after the cessation of fever. In only 1·2 % of all the typhoid cases, or in 2·5 % of all the bacteriologically positive cases, did the bacilluria continue for 2–3 months.

Bumke (1926) has dealt with a large material from the first World War consisting of 27,330 cases of typhoid, paratyphoid A and paratyphoid B. Examined for the discharge of the specific germ in faeces and urine, 1609 (6 %) of them were found to be excreters. Of 485 typhoid patients, 40–50 % became non-infectious in the first quarter and 10–20 % in the second quarter after the onset of the illness. The corresponding figures for the first and second quarters were 60–70 % and 10–20 % respectively for 323 paratyphoid B patients. Bumke calculated that 30–40 % of typhoid excreters become chronic carriers as do 20–30 % of paratyphoid B excreters. In our own material, 21·6 % of the convalescent excreters became chronic typhoid carriers, and 15·4 % of the convalescent paratyphoid B excreters.

Gill (1927) found that approximately 10 % of 348 typhoid patients became permanent carriers, but he does not say for how long they were kept under control.

Cumming (1932) maintained that from 90 to 95 % of typhoid patients are free from infection at the end of 4 weeks, the remaining 5–10 % becoming carriers for a longer or shorter period. The average age of his typhoid patients being 22 years, and their expectation of life at that age being 62, he argued that the permanent carrier is a source of infection for about 40 years. But he seems to have overlooked the fact that it is in the higher age groups that the chances are greatest of both *S. typhi* and *S. paratyphi* B patients becoming chronic carriers.

According to Browning, Coulthard, Cruickshank, Guthrie & Smith (1933) it is generally regarded as probable that 2–5 % of all typhoid patients become permanent carriers unless the disease is mild and infrequent, when the rate is probably lower. Of our 360 typhoid patients, 3·3 % became chronic carriers. In countries where typhoid fever is still comparatively common, Browning *et al.* (1933) have calculated that such carriers constitute 0·1 % or more of the total population.

With regard to paratyphoid B, Glass & Wright (1937) found that four out of ninety-eight patients continued to discharge it with the faeces 15 weeks after the beginning of the illness. In an outbreak of paratyphoid B in Bristol, Davies, Wiseman, Cooper and Davies (1940) found *S. paratyphi* B still being discharged by two out of thirty patients more than 44 days after the beginning of the illness. Holt, Vaughan & Wright (1942), in a considerable material of 339 cases, found that one man and fifteen women (5 %) continued to discharge *S. paratyphi* B with the faeces for more than 16 weeks after the beginning of the illness. The rate of clearing of faecal infections was found to be particularly slow in women over the age of 20. Of twenty-six women over 40, nine continued to discharge *S. paratyphi* B with the faeces for more than 16 weeks. In our material, out of a total of fifty paratyphoid B patients over the age of 50, six patients, all women, became chronic carriers. Holt *et al.* (1942) have not recorded their observations on the urine largely because they felt that many of them were invalidated by contamination from receptacles.

Savage (1942) considered it obvious that a material proportion of paratyphoid patients continue for some time as temporary carriers, but that we do not yet know the percentage which become chronic carriers, i.e. persistence over a year after convalescence, and whether this percentage is higher or lower than for typhoid fever.

In our material, two of our twenty chronic paratyphoid B carriers eluded further control. All the seven subsequently operated on at least a year or more after cessation of the illness were cured. Seven continued to be carriers till death, and four, still under control, have hitherto discharged *S. paratyphi* B with the faeces for 1¾, 4, 23 and 25 years respectively. None of our chronic paratyphoid B carriers has ceased spontaneously to discharge the organisms. Further, as already pointed out, two women were found to be chronic paratyphoid B carriers after discharge from hospital. Both had been ill in 1921, and one of them was cured after an operation in 1930, while the other, still under control, continues to discharge *S. paratyphi* B with the faeces. Adding these two to the twenty other chronic carriers from among the 1027 paratyphoid B patients, we get a chronic carrier rate of 2·1 %. Our material has been so carefully examined that we may be justified in drawing the conclusion that fully 2 % of the persons contracting paratyphoid B fever will become chronic carriers as compared with about 3·5 % after typhoid fever.

As early as 1912, Prigge associated the high chronic carrier rate in elderly persons with the incidence of gall-stones, which also rises with age. The post-mortem material of the Bergen City Hospital for the period 1912–28 (Vogelsang, 1929) showed a gall-stone rate in 2690 persons over the age of 20 of 6·5 % (3·9 % for men and 9·8 % for women). There was a considerable rise in this rate among women about the age of 50. Such a rise came at a higher age in men. It is, therefore, possible that the greater liability of elderly women to suffer from gall-stones contributes to the frequency with which they become chronic carriers.

SUMMARY

1. In a material consisting of 417 cases of typhoid fever and 1055 cases of paratyphoid B investigated over a period of 28 years, infection with *S. typhi* was found to be considerably more serious than infection with *S. paratyphi* B. In childhood and among young

folk the *S. paratyphi* B mortality was low, but in the age group over 30 it reached 5 %. But even in childhood infection with *S. typhi* gave a mortality of 8·5 %, rising at a higher age to 16 %.

2. Of the 1387 patients surviving the infections 13·3 % were found to be excreters during convalescence, 11 % being temporary and 2·3 % being chronic carriers.

3. Of the temporary carriers, 7·9 % were faecal and 3·7 % were urinary carriers. The percentage of temporary excreters was approximately the same for the typhoid and paratyphoid B patients—40 % were men and 60 % were women. The number of temporary carriers rose with the patients' age, and in the age group over 30 years, about 15 % were temporary carriers in the case of both infections.

4. Of the temporary carriers, only one-tenth discharged the specific germ for more than 4 weeks after the cessation of the illness. After an interval of 3 months, it is most exceptional for the carrier state to cease spontaneously. We may, therefore, feel justified in fixing this interval as the dividing line between the temporary and the chronic carrier state.

5. Of the typhoid patients 3·3 %, and of the paratyphoid B patients 1·9 %, became chronic carriers. Thirty-one of them were faecal and only one was a urinary excreter. There was only one child found to be a chronic typhoid carrier. Chronic carriers were also rare among young folk, and the incidence of this state rose much with age, as many as twelve of the total of thirty-two chronic carriers being over the age of 50. Eleven of these twelve were women, five being typhoid and six being paratyphoid B carriers.

6. Most of the chronic carriers have been kept under control for a long time. The only chronic typhoid carrier to recover spontaneously was a woman, aged 52. Cholecystectomy was performed on fourteen chronic carriers. In all the cases in which the carrier state had lasted for at least a year, gall-stones and chronic cholecystitis were found, and the specific germ was obtained in pure culture from the gall-bladder. A woman who had continued to discharge *S. typhi* for more than 1½ years after the operation, ceased to do so after this interval. The object of the operation was not achieved in one case.

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