Epidem. Inf. (1987), 99, 295–306
Printed in Great Britain

Salmonella serotypes and incidence of multiply-resistant salmonellae isolated from diarrhoeal patients in Hong Kong from 1973–82

By JULIA LING*, P. Y. CHAU† and B. ROWE‡

** Department of Microbiology, The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, New Territories, Hong Kong † Department of Microbiology, University of Hong Kong, Queen Mary Hospital, Hong Kong, ‡ Division of Enteric Pathogens, Central Public Health Laboratory, London NW9 5HT, UK*

(*Accepted 19 March 1987*)

SUMMARY

Salmonella was the most frequent bacterial pathogen isolated from patients with acute diarrhoea in Hong Kong. In Queen Mary Hospital, the major hospital on Hong Kong Island, 94·7% of salmonellae isolated from faecal specimens from patients during the period 1973–82 belonged to the gastroenteric group, while 5·3% belonged to the enteric fever group. Amongst the gastroenteric group, 68 salmonella serotypes were identified, with *Salmonella derby*, *S. typhimurium* and *S. anatum* being the predominant ones. Three outbreaks caused by *S. johannesburg*, *S. worthington* and *S. wandsworth* were detected.

Of *S. typhimurium*, 61·6% were resistant to multiple antibiotics and belonged to four major phage types: 193, 22, 138 and U288. The majority (96·8%) of *S. johannesburg* strains which caused a widespread epidemic were multiply-resistant. Multiple antibiotic resistance was rarely observed in most other gastroenteric salmonellae.

S. typhi was the commonest of the enteric fever group isolated from the blood of patients. Nineteen phage types were identified; E1 being the commonest (18·5%) while 21% were nontypable. Many of these isolated were resistant to streptomycin or sulphadiazine, but none were resistant to ampicillin, chloramphenicol or trimethoprim.

INTRODUCTION

Salmonellosis is an important public health problem in many parts of the world. In Hong Kong gastroenteric salmonella infections are continuously on the increase while the enteric fevers have declined in incidence (Huang & Chan-Teoh, 1964; Chau & Huang, 1977). The salmonella serotypes responsible for food-poisoning vary widely in their distribution in different countries. A large variety of salmonella serotypes may be isolated from one locality, but usually there are only a few common ones, and these may differ from region to region. However, *Salmonella typhimurium* is the most common salmonella serotype causing human

salmonellosis in many parts of the world (Vernon, 1977; Turnbull, 1979; Hepner, 1980; Barker, Old & Sharp, 1980; Beaton & Taplin, 1981; Anonymous, 1982; PHLS Communicable Disease Surveillance Center, 1984; Jegathesan, 1984).

Until about 1960, these salmonellae were usually sensitive to a wide range of antimicrobial agents. Since then, resistance to multiple antimicrobial agents has been observed in gastroenteric strains isolated throughout the world (see for example, Anderson & Datta, 1965; Manten *et al.* 1971; Neu *et al.* 1975; Voogd *et al.* 1977; Threlfall, Ward & Rowe, 1978*a*, *b*). In the 1970s, a number of very extensive epidemics of human infections caused by multiply-resistant salmonellae were reported (Cherubin, 1981; Frost *et al.* 1982). In Hong Kong, antibiotic resistance in salmonellae was rare until 1972 when multiply-resistant *S. johannesburg* caused a widespread outbreak extending over a period of 5 years (Chau *et al.* 1982).

The incidence of antibiotic resistance differs markedly in different parts of the world. This may be affected by the foods of animal origin, the addition of antibiotics to animal feeds, the types of patients involved, local policies for the treatment and isolation of infected patients and the use of antibiotics. In addition, the spread of a drug resistant bacterial population is greatly facilitated by international trade and travel, and in this respect Hong Kong is especially vulnerable. Apart from the work by Huang & Chan-Teoh (1964) and Chau & Huang (1977), there has been no updated report on the incidence of salmonella and their antibiotic susceptibility in Hong Kong. This paper aims to provide information on the distribution of salmonellae and their incidence of antibiotic resistance in Hong Kong during the period 1973–82.

MATERIALS AND METHODS

Salmonellae of the gastroenteric group were isolated from stools or rectal swabs of diarrhoeal patients of Queen Mary Hospital using a selective migration method of Chau & Huang (1974). Standard biochemical tests and serological typing by slide agglutination tests using salmonella antisera (Wellcome Reagents Limited, Beckenham, England) were used to identify *Salmonella* sp. (Kauffmann, 1966; Manual of Clinical Microbiology).

Salmonella strains from blood and other specimens such as bile and pus were isolated according to standard bacteriological methods (Manual of Clinical Microbiology).

S. typhi strains were phage typed by the method of Craigie & Felix (1947) as reviewed by Anderson & Williams (1956) and *S. typhimurium* by the methods of Felix & Callow (1943) and Callow (1959) as reviewed by Anderson (1964).

All salmonella isolates from clinical specimens were routinely tested for their susceptibility to antibiotics using the disk susceptibility testing method of Kirby & Bauer (Bauer *et al.* 1966) on Mueller–Hinton agar. These strains were stored on nutrient agar slants until they were randomly selected for susceptibility testing using the agar dilution method. Bacterial strains were grown to late exponential phase in 3 ml nutrient broth from which dilutions were made to obtain a cell density of 10^3 colony forming units (c.f.u.) per inoculation spot on Mueller–Hinton agar plates containing ampicillin (A, 20 mg/l), chloramphenicol (C, 20 mg/l),

kanamycin (K, 10 mg/l), streptomycin (S, 20 mg/l), tetracycline (T, 10 mg/l), nalidixic acid (Nx, 25 mg/l) or rifampicin (Rif, 25 mg/l) and SAF (Sulfonamide Antagonist Free) medium (MAST Laboratories, Liverpool, England) incorporated with sulphadiazine (Su, 100 mg/l), trimethoprim (Tm, 2 mg/l) or co-trimoxazole (Sxt, 1/20 mg/l). The inoculation was performed by a multipoint inoculator (AM80 automatic inoculator, Dynatech Laboratories Inc., Alexandria, Va.). Two *Escherichia coli* K12 strains, Jp995 and UB1139 were included in each plate controls. The plates were incubated overnight at 37 °C. Visible growth on the inoculation spot of the antibiotic plate indicated that the bacterial strain was resistant to the antibiotic.

RESULTS

Prevalence of salmonellae in Hong Kong

The number of salmonella islations from faecal specimens of diarrhoeal patients from Queen Mary Hospital in Hong Kong during a 10-year period from 1973–82 constituted 62% of the total faecal bacterial pathogens with a general increase of 55% (Table 1). The majority (94·7%) of these were the gastroenteric salmonellae, of which 68 serotypes were identified (Table 2). The typhoid and paratyphoid group of salmonellae constituted the remaining 5·3% of the salmonella isolations from stools.

The six commonest serogroups of the gastroenteric salmonellae identified were groups B (38·1%), R (23·3%), E (21·9%), C (12·2%) and D (2·1%) (Table 3). Amongst the group B salmonellae, *S. derby* was the most frequently isolated serotype, closely followed by *S. typhimurium*, constituting respectively 13·3% and 12·9% of the total gastroenteric salmonellae isolated. *S. anatum* (8·3%) was the predominant serotype amongst the group E salmonellae identified.

Three epidemics caused by three rare serotypes were identified: *S. johannesburg* (Group R), *S. wandsworth* (Group Q) and *S. worthington* (Group G). *S. johannesburg* caused a widespread epidemic from 1973–77 (Teoh-Chan *et al.* 1977), comprising 43% of the total number of salmonella isolates from faecal specimens during this period. The incidence of *S. johannesburg* declined dramatically after 1977 and no *S. johannesburg* strain was detected in 1982 from any clinical specimen. *S. worthington* was responsible for a protracted hospital outbreak which occurred in 1974 (Ip *et al.* 1976). *S. wandworth* was responsible for another hospital outbreak in 1980 (Im, Chow & Chau, 1981).

The gastroenteric group of salmonellae constituted a small proportion (25·4%) of the total salmonella isolations from blood cultures (Table 3). Nine serotypes of

Table 1. *Distribution of salmonellae isolated from faecal specimens of diarrhoeal patients in Queen Mary Hospital in Hong Kong from 1973–82*

Group of salmonellae	Year										Total	%
	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82		
Gastroenteric	145	367	326	251	159	197	192	221	257	342	2457	(94·7)
Enteric fever	18	6	10	18	14	13	10	18	14	17	138	(5·3)
Total	163	373	336	269	173	210	202	239	271	359	2595	

Table 2. *Salmonella serotypes of the gastroenteric group isolated from stools in Queen Mary Hospital in Hong Kong from 1973–82*

Group A
S. nitra

Group B
S. abony
S. agona
S. ayinde
S. chester
S. derby
S. duisburg
S. essen
S. gloucester
S. java
S. reading
S. stanley
S. stanleyville
S. typhimurium
S. saint-paul
S. san-diego
S. togo

Group C_1
S. aba
S. amersfoort
S. braenderup
S. choleraesuis
S. isangi
S. kaduna
S. kivu
S. potsdam
S. montevideo
S. oranienburg
S. oslo
S. tennessee

Group C_2
S. chincol
S. manhattan
S. newport
S. sterrenbos
S. tshiongwe
S. muenchen
S. lindenburg
S. litchfield

Group C_3
S. emek
S. virginia

Group C_4
S. ardwick

Group D_1
S. berta
S. enteritidis
S. goettingen
S. mendoza
S. panama

Group D_2
S. india

Group E_1
S. anatum
S. amsterdam
S. give
S. kalina
S. london

Group E_1 (cont'd)
S. madjorio
S. meleagridis
S. nchanga
S. newlands
S. onireke
S. oxford
S. regent
S. vejle
S. suberu

Group G
S. ajiobo
S. worthington

Group I
S. hvittingfoss

Group M
S. oskarshamn

Group N
S. odozi

Group P
S. yoff

Group Q
S. wandsworth

Group R
S. johannesburg

Group S
S. vietnam

the gastroenteric group were identified. *S. choleraesuis* was exclusively isolated from blood (9·0%) and other organs, and is recognized as an important invasive pathogen of man (Parker, 1984). Amongst other gastroenteric serotypes isolated from blood, *S. typhimurium* was the most common, constituting 5·9% of the total salmonella isolates from blood cultures. The other serotypes were only isolated sporadically.

A total of 82 salmonella isolates were obtained from other clinical specimens such as bile, pus, urine, abscesses, aspirates or cerebrospinal fluid (Table 3). Forty (48·8%) of the salmonella isolates belonged to the gastroenteric group while the rest belonged to the enteric fever group. Ten gastroenteric salmonella serotypes were identified. Of these, *S. johannesburg* was predominant from 1973–76, constituting 11% of isolates probably because it was epidemic during this period. *S. typhimurium* and *S. derby* were two frequently isolated serotypes throughout the period of study, each constituting 6·1% of the total salmonella isolations from these specimens.

https://doi.org/10.1017/S0950268800067777 Published online by Cambridge University Press

Table 3. *Prevalence of salmonellae from clinical specimens*

	Faecal specimens	Blood cultures	Other specimens
S. derby	327 (13·3)*	4 (4·9)	5 (12·5)
S. typhimurium	318 (12·9)	19 (23·2)	5 (12·5)
Other group B	292 (11·9)	1 (1·2)	5 (12·5)
S. newport	44 (1·8)	1 (1·2)	2 (5·0)
Other group C	255 (10·4)	34 (41·5)	8 (20·0)
S. enteritidis	24 (1·0)	9 (11·0)	2 (5·0)
Other group D	27 (1·1)	0 (0·0)	0 (0·0)
S. anatum	204 (8·3)	0 (0·0)	0 (0·0)
Other group E	333 (13·6)	0 (0·0)	4 (0·0)
S. johannesburg	573 (23·3)	10 (12·2)	9 (22·5)
Other	60 (2·4)	4 (4·9)	0 (0·0)
Total gastroenteric salmonellae	2457	82	40
S. typhi	97 [70·3]†	222 [92·1]	30 [71·4]
S. paratyphi A	3 [2·2]	9 [3·7]	9 [21·4]
S. paratyphi B	31 [22·5]	0[0·0]	1 [2·4]
S. paratyphi C	4 [2·9]	8 [3·3]	1 [2·4]
S. sendai	3 [2·2]	2 [0·8]	1 [2·4]
Total enteric fever group of salmonellae	138	241	42
Total salmonellae	2595	323	82

* Percentage of total gastroenteric salmonellae from different specimens in parenthesis.
† Percentage of total enteric fever group of salmonellae from different specimens in brackets.

Salmonellae of the enteric fever group were mainly isolated from blood, some from other specimens such as urine, pus, bile and abscesses, and a small proportion from faecal specimens. *S. typhi* was responsible for 68·7% of the total salmonella isolations from blood during the period of study (Table 3). *S. paratyphi A* and *C* and *S. sendai* together constituted only 5·9%. *S. paratyphi B* was not detected in the blood but was recovered from faecal specimens instead. The enteric fever group of salmonellae constituted 5·3% of the salmonella isolations from faecal specimens, of which 3·7% were *S. typhi* (Table 3). *S. typhi* was also the most frequent *Salmonella* sp. of the enteric fever group to be isolated (36·6%) from other specimens (Table 3).

Of the 158 *S. typhi* strains randomly selected for phage-typing, 39 were Vi-negative. A total of 19 phage types were identified amongst the 119 Vi-positive strains (Table 4). E1 was the commonest phage type, to which 18·5% of the strains belonged. Of the strains, 6–11% belonged to types M1, D2, DVS, 53 or UVS–1 while 4·2% or less belonged to each of the remaining 13 types. A high proportion of strains (21·8%) were untypable.

Antibiotic resistance in salmonellae

Resistance to streptomycin and sulphonamide was common in salmonella isolates. The incidence of strains resistant to the other antibiotics tested (ampicillin, tetracycline, chloramphenicol, kanamycin and trimethoprim) varied greatly but

Table 4. *Phage types of Vi-positive* S. typhi *strains*

Phage type	No.	%
Untypable	26	21·8
E1	22	18·5
M1	13	10·9
D2	10	8·4
DVS	10	8·4
53	7	5·9
UVS–1	7	5·9
J1	5	4·2
E2	4	3·4
A	3	2·5
E0	2	1·7
O	2	1·7
46	2	1·7
B1	1	0·8
C4	1	0·8
E1 variant	1	0·8
J3	1	0·8
L1	1	0·8
M3	1	0·8
Total	119	100·0

was much less common. Table 5 shows the distribution of resistance to individual antibiotics and multiple antibiotic resistance of some of the common salmonellae.

About 50% of the *S. typhimurium* strains tested were resistant to two or more antibiotics (Table 5). However, only strains isolated from 1979 onwards were resistant to six or seven antibiotics (ASTCKSu and ASTCKSuTm respectively). High-level trimethoprim-resistance was first detected in 1979 and that of chloramphenicol-resistance in 1975. Ampicillin-resistance was probably present before the commencement of this study. A total of 25 different antibiotic resistance patterns in *S. typhimurium* were seen over the 10-year period. No particular resistance pattern was predominant although some, such as ASTCSu, ASTSu and STSu were found more often than others.

A total of 58 *S. typhimurium* strains which were resistant to two or more antibiotics including ampicillin, chloramphenicol or trimethoprim were selected for phage-typing. The most frequently encountered phage type was 193 to which 27 (46·6%) strains belonged (Table 6). Ten of these had the resistance pattern ASTSu. All the six strains of phage type 104a were resistant to ASTCSu. Strains isolated from 1980 onwards belonged to five phage types different from those seen previously. Nine were of phage type 22, 6 were U288, 4 each were 138 and untypable, and only 1 was 100. These strains showed a variety of resistance patterns with no obvious relationship.

Of the 315 *S. johannesburg* isolates selected for study, 95·2% were resistant to two or more antibiotics (Table 5). Of these, 110 (46·8%) isolated from 1973–75 were ASTCKSu-resistant and 87·7% isolated in 1976 and 1977 were ASCKSu-resistant. Only four strains were isolated in 1980 and 1981 and were sensitive to all the antibiotics tested. Thus, in contrast to the situation seen in *S. typhimurium*, in *S. johannesburg* there were two predominant resistance patterns occurring

https://doi.org/10.1017/S0950268800067777 Published online by Cambridge University Press

Table 5. *Resistance to antimicrobial drugs amongst salmonellae of the gastroenteric group*

Salmonella serotype	Total no. of strains tested	% of strains resistant to									% of strains sensitive
		Ampicillin	Tetra-cycline	Chloram-phenicol	Kana-mycin	Trime-thoprim	Strepto-mycin	Sulpha-diazine	One anti-biotic	Two or more anti-biotics	
Group B.											
S. derby	193	2·6	9·8	1·0	2·6	0·5	14·5	14·5	5·2	13·8	81·0
S. typhimurium	177	31·6	37·9	19·2	20·9	7·3	41·2	49·7	11·3	50·3	38·4
Others	86	3·5	5·8	5·8	3·5	0·0	17·4	20·9	12·8	15·1	72·1
Group C salmonellae	136	7·4	6·6	3·7	5·9	1·5	10·3	22·0	20·2	5·5	74·3
Group D salmonellae	26	7·7	15·4	7·7	11·5	3·8	23·0	26·9	11·5	27·0	61·5
Group E											
S. anatum	131	0·8	12·2	0·0	0·0	0·0	20·6	20·6	11·4	16·1	72·5
Others	126	4·0	9·5	3·2	5·6	18·3	15·1	0·8	8·0	14·2	77·8
Group R											
S. johannesburg	315	82·9	87·9	62·9	77·8	1·3	81·9	75·2	1·6	95·2	3·2

Table 6. *Phage types of ampicillin-, chloramphenicol- or trimethoprim-resistant* S. typhimurium *strains*

Phage type	No.	%
193	27	46·6
22	9	15·5
104a	6	10·3
U288	6	10·3
138	4	6·9
UT*	4	6·9
RDNC†	1	1·7
100	1	1·7
Total	58	100·0

* UT, untypable.

† RDNC, reaction pattern of the typing phages on the strain does not conform to those of the existing scheme.

Table 7. *Resistance to antimicrobial drugs amongst salmonellae of the enteric fever group*

	Salmonella serotype				
	S. typhi	*S. paratyphi A*	*S. paratyphi B*	*S. paratyphi C*	*S. sendai*
Total no. of strains tested	81	10	6	5	8
No of strains resistant to					
Ampicillin	—	—	1	—	—
Streptomycin	41 (50·6)*	—	2	2	—
Tetracycline	—	1	1	—	—
Chloramphenicol	—	—	1	—	—
Kanamycin	—	—	1	—	—
Sulphadiazine	12 (14·8)	1	2	—	1
Trimethoprim	—	—	1	—	—
One antibiotic	37 (45·7)	—	3	2	1
Two or more antibiotics	8 (9·9)	1	1	—	—
No. of strains sensitive	36 (44·4)	9	2	3	7

* Percentage in parenthesis.

consecutively during the outbreak with the pattern ASTCKSu changing to ASCKSu. Ten *S. wandsworth* strains isolated during the hospital outbreak were resistant to ASK.

In contrast to the above three salmonella serotypes, most of the other serotypes were sensitive to the antibiotics tested except for streptomycin, sulphonamide and tetracycline (Table 5). Of these organisms, 23% or less were resistant to streptomycin and 27% or less to sulphonamide. Resistance to tetracycline could be found in 9·8%, 12·2% and 15·4% of *S. derby*, *S. anatum* and group D salmonellae respectively (Table 5). Multiple resistance was uncommon in these salmonellae, except for simultaneous resistance to streptomycin and sulphonamide.

Despite the large number of isolates of *S. derby*, most strains (81%) were sensitive to all the antibiotics tested. High-level resistance to trimethoprim was detected only in 1979 in one strain. Chloramphenicol-resistance was first detected

in 1980 in one strain and in another in 1982. Five- or six-antibiotic resistances were found in only 5 out of the 193 strains tested.

Table 7 shows the distribution of resistance to individual antibiotics and multiple antibiotic resistances in *S. typhi*, *S. paratyphi A*, *B*, *C* and *S. sendai*. Only resistance to streptomycin or sulphadiazine was common, being found in 41% and 15% of these salmonellae respectively, while resistance to other antibiotics was very rare. Of these strains, 9% were resistant to two or more antibiotics of which 8% were simultaneously resistant to streptomycin and sulphonamide. Only one *S. paratyphi B* strain isolated in 1982 was resistant concomitantly to ampicillin, chloramphenicol and trimethoprim.

DISCUSSION

Salmonella is an important cause of bacterial diarrhoea in Hong Kong. In this study, which covered bacterial isolates from the microbiology laboratory of Queen Mary Hospital, the only large general hospital on Hong Kong Island during the period 1973–82, a large variety of *Salmonella* sp. were identified, with *S. johannesburg* being the most common during 1973–76, followed by *S. derby* and *S. typhimurium* which were isolated in large numbers throughout the period of study. Many other serotypes of salmonellae were seen but each type was only rarely or sporadically isolated. The results correspond well with data from the Medical and Health Department on culture results from other diarrhoeal patients in Hong Kong. These data also showed that the prevalent salmonellae were *S. johannesburg*, *S. typhimurium* and *S. derby*, each comprising 28·8%, 16·9% and 15·7% respectively of the total salmonella isolations from faecal specimens. The most common salmonella serogroups were B (40·5%), R (30·3%), E (16·1%) and C (10·2%) (Institute of Pathology, personal communication). The results from Queen Mary Hospital are thus similar to that of the general situation in Hong Kong. This situation of one or two predominant salmonellae of variable occurrence is in general similar to that in the United Kingdom and the United States (WHO Scientific Working Group, 1980; CDC, 1984).

As the gastroenteric salmonellae are mainly animal pathogens, the large variety of salmonella serotypes including rare ones can be related to locally-consumed food animals or food products. Data of Chau and his colleagues (1977) showed that salmonellae commonly isolated from pigs for human consumption in Hong Kong were similar to those found in humans except for different frequencies of isolation. This might be due to the variation in pathogenicity of these organisms in different hosts. Wong & Chau (unpublished data) also showed that a variety of salmonellae from chickens were similar to those from man. Both pig and chicken food products are very popular amongst the local people, so that these animals are probably common sources of human salmonellosis in Hong Kong.

The high incidence of *S. johannesburg* in this locality during a specific period indicated that it was responsible for an outbreak widespread throughout Hong Kong. Indeed, the organism was isolated from both in- and out-patients of hospitals and clinics. *S. johannesburg* had not been isolated in Hong Kong before the epidemic and must therefore have been introduced from outside sources by contaminated food or food products either continuously being imported or as one

batch into this locality. However, the former is unlikely since both the government laboratory and the microbiology laboratory of Queen Mary Hospital failed to isolate *S. johannesburg* from imported food, animal feeds and milk powders available to the paediatric wards during the epidemic years (Teoh-Chan *et al.* 1977; Chau, personal communication). In addition, there was no clustering of cases related to a particular food or locality. On the other hand, the outbreak could have arisen in the community due to ingestion of one batch of contaminated imported food and then extended by hospital cross-infection when infected patients were admitted. These patients, usually discharged after the acute symptoms subsided because of the shortage of beds, would infect other subjects at home or nurseries. The chronicity of *S. johannesburg* infection resulting in its prolonged presence in the faeces to up to 1 year (Teoh-Chan *et al.* 1977) contributed significantly to the rapid spread of this organism. *S. johannesburg* may also have had a special ability to spread from person to person, since only this organism caused hospital cross-infection although a variety of salmonellae were present in the paediatric wards (Teoh-Chan *et al.* 1977). From 1977 onwards, this organism appeared to lose the ability to spread or to infect since it decreased dramatically in incidence. The other outbreaks caused by *S. worthington* and *S. wandsworth* were mainly hospital infections (Ip *et al.* 1976; Im, Chow & Chau, 1981), both of which ended within 4 months after the source of infection was identified and measures taken to eliminate the source.

It is interesting to note the distribution of multiple resistance amongst the gastroenteric salmonellae in Hong Kong. Multiple drug resistances were rarely found in *S. derby*, *S. anatum* and other gastroenteric salmonella serotypes even though some types, such as *S. derby*, were frequently isolated in this locality. Occurrence of multiple resistances in these salmonellae was sporadic. In *S. typhimurium*, multiple drug resistances were encountered frequently. Various resistance patterns were seen without any one type being dominant. This organism also showed an increase in trimethoprim-resistance from 1979 onwards. However, in *S. johannesburg* which caused the widespread epidemic, the majority of strains were multiply-resistant. Although various resistance patterns were observed from 1973–75, one pattern (ASTCKSu) predominated. From 1976–77, almost all the isolates showed a single resistance pattern (ASCKSu) which differed from the previous one by the loss of resistance to tetracycline (Chau, Wong & Fok, 1978). The multiplicity of antibiotics to which these organisms were resistant suggests that the resistances were most probably mediated by plasmids. Another study will investigate the epidemiology of these salmonella infections using plasmids as an epidemiological marker.

Despite the prevalence of resistance to ampicillin and chloramphenicol amongst the major gastroenteric salmonella isolates, and the endemicity of *S. typhi* in this locality, our *S. typhi* has remained sensitive to these two antibiotics. This would be discussed further in our next paper (Ling & Chau, 1987).

Although gastroenteritis caused by salmonellae usually does not require antibiotic therapy, these organisms occasionally become invasive leading to systemic infections which require active treatment with ampicillin or chloramphenicol. The high incidence of multiply-resistant salmonellae has thus attracted considerable attention due to the therapeutic problems they cause.

REFERENCES

ANDERSON, E. S. (1964). The phage typing of salmonellae other than *S. typhi*. In *World Problem of Salmonellosis* (ed. E. Van Oye), pp. 89–110. The Hague: Dr W. Junk.

ANDERSON, E. S. & DATTA, N. (1965). Resistance to penicillins and its transfer to Enterobacteriaceae. *Lancet* ii, 407–409.

ANDERSON, E. S. & WILLIAMS, R. E. O. (1956). Bacteriophage typing of enteric pathogens and staphylococci and its use in epidemiology. *Journal of Clinical Pathology* **9**, 94–127.

ANONYMOUS (1982). Food poisoning and salmonellosis surveillance in England and Wales: 1981. *British Medical Journal* **185**, 1127–1128.

BARKER, R., OLD, D. C. & SHARP, J. C. M. (1980). Phage type/biotype groups of *Salmonella typhimurium* in Scotland 1974–1976: variation during spread of epidemic clones. *Journal of Hygiene* **84**, 115–125.

BAUER, A. W., KIRBY, W. M. M., SHERRIS, J. C. & TURCK, M. (1966). Antibiotic susceptibility testing by a standardized single disk method. *American Journal of Clinical Pathology* **45**, 493–496.

BEATON, C. & TAPLIN, J. (1981). National Salmonella/Shigella surveillance – 1980. *Communicable Diseases Intelligence (Australia)* **81**, 2.

CALLOW, B. R. (1959). A new phage typing scheme for *Salmonella typhimurium*. *Journal of Hygiene* **57**, 346–359.

CENTERS FOR DISEASE CONTROL (1984). Human *Salmonella* isolates – United States, 1983. *Morbidity and Mortality Weekly Report* **33**, 693–695.

CHAU, P. Y. & HUANG, C. T. (1974). A one day selective migration procedure for detecting salmonellae in faeces. *Journal of Clinical Pathology* **27**, 405–407.

CHAU, P. Y. & HUANG, C. T. (1977). Salmonellosis in Hong Kong. *Public Health (London)* **91**, 83–89.

CHAU, P. Y., SHORTRIDGE, K. F. & HUANG, C. T. (1977). *Salmonella* in pig carcasses for human consumption in Hong Kong: a study on the mode of contamination. *Journal of Hygiene* **78**, 253–260.

CHAU, P. Y., WONG, W. T. & FOK, Y. P. (1978). Resistance to chloramphenicol and ampicillin in *Salmonella johannesburg* in Hong Kong: observations over a five-year period 1973–1977. *Journal of Hygiene* **81**, 343–351.

CHAU, P. Y., LING, J., THREFALL, E. J. & IM, S. W. K. (1982). Genetic instability of R plasmids in relation to the shift of drug resistance patterns in *Salmonella johannesburg*. *Journal of General Microbiology* **128**, 239–245.

CHERUBIN, C. E. (1981). Antibiotic resistance of *Salmonella* in Europe and the United States. *Review of Infectious Diseases* **3**, 1105–1126.

CRAIGIE, J. & FELIX, A. (1947). Typing of typhoid bacilli with Vi bacteriophage. *Lancet* i, 823–827.

FELIX, A. & CALLOW, B. R. (1943). Typing of paratyphoid B bacilli by means of Vi bacteriophage. *British Medical Journal* ii, 127–130.

FROST, J. A., ROWE, B., WARD, L. R. & THREFALL, E. J. (1982). Characterization of resistance plasmids and carried phages in an epidemic clone of multi-resistant *Salmonella typhimurium* in India. *Journal of Hygiene* **88**, 193–204.

HEPNER, E. (1980). Food poisoning and Salmonella infections in England and Wales 1976–1978. An analysis of reports to the Communicable Disease Surveillance Center of the Public Health Laboratory Service. *Public Health (London)* **94**, 337–349.

HUANG, C. T. & CHAN-TEOH, C. H. (1964). *Salmonella* serotypes isolated in Hong Kong. *Journal of Tropical Medicine and Hygiene* **67**, 95–99.

IM, S. W. K., CHOW, K. & CHAU, P. Y. (1981). Rectal thermometer mediated cross-infection with *Salmonella wandsworth* in a paediatric ward. *Journal of Hospital Infection* **2**, 171–174.

IP, H. M. H., SIN, W. K., CHAU, P. Y., TSE, D. & TEOH-CHAN, C. H. (1976). Neonatal infection due to *Salmonella worthington* transmitted by a delivery-room suction apparatus. *Journal of Hygiene* **77**, 307–314.

JEGATHESAN, M. (1984). Salmonella serotypes isolated from man in Malaysia over the 10-year period 1973–1982. *Journal of Hygiene* **92**, 395–399.

KAUFFMANN, F. (1966). *The Bacteriology of Enterobacteriaceae*. 2nd. edition. Copenhagen: Munksgaard.

LING. J. & CHAU, P. Y. (1987). Incidence of plasmids in multiply-resistant salmonella isolates from diarrhoeal patients in Hong Kong from 1973–82. *Epidemiology & Infection* **99**, 307–321.

MANTEN, A., GUINEE, P. A. M., KAMPELMACHER, E. H. & VOOGD, C. E. (1971). An eleven-year study of drug resistance in *Salmonella* in the Netherlands. *Bulletin of the World Health Organization* **45**, 85–93.

Manual of Clinical Microbiology. American Society of Microbiology.

NEU, H. C., CHERUBIN, C. E., LANGO, E. D., FLOUTON, B. & WINTER, J. (1975). Antimicrobial resistance and R factor transfer among isolates of *Salmonella* in the Northeastern United States: a comparison of human and animal isolates. *Journal of Infectious Diseases* **132**, 617–622.

PARKER, M. T. (1984). Enteric infections: typhoid and paratyphoid fever. In *Topley and Wilson's Principles of Bacteriology, Virology and Immunity*. Vol. 3 *Bacterial diseases* (ed. G. R. Smith), 7th. edition, pp. 407–433. London: Arnold.

PUBLIC HEALTH LABORATORY SERVICE COMMUNICABLE DISEASE SURVEILLANCE CENTER (1984). Food poisoning and salmonella surveillance in England and Wales: 1982. *British Medical Journal* **288**, 306–308.

TEOH-CHAN, C. H., CHAU, P. Y., TSE, D., SIN, W. K., IP, H. M. H. & LAN, R. (1977). Hospital *Salmonella johannesburg* infection and its possible role in the community spread of the infection in Hong Kong. *Journal of Hygiene* **78**, 113–119.

THRELFALL, E. J., WARD, L. R. & ROWE, B. (1978*a*). Epidemic spread of a chloramphenicol-resistant strain of *Salmonella typhimurium* phage type 204 in bovine animals in Britain. *Veterinary Record* **103**, 438–440.

THRELFALL, E. J., WARD. L. R. & ROWE, B. (1978*b*). Spread of multiresistant strains of *Salmonella typhimurium* phage types 204 and 193 in Britain. *British Medical Journal* ii, 997.

TURNBULL, P. C. B. (1979). Food poisoning with special reference to salmonella: its epidemiology, pathogenesis and control. *Clinical Gastroenterology* **8**, 663–714.

VERNON, E. (1977). Food poisoning and salmonella infections in England and Wales, 1973–1975. *Public Health* **91**, 225–235.

VOOGD, C. E., VAN LEEUWEN, W. J., GUINEE, P. A. M., MANTEN, A. & VALKENBURG, J. J. (1977). Incidence of resistance to ampicillin, chloramphenicol, kanamycin and tetracycline among *Salmonella* species isolated in the Netherlands in 1972, 1973 and 1974. *Antonie van Leeuwenhoek* **43**, 269–281.

WHO SCIENTIFIC WORKING GROUP (1980) Enteric infections due to *Campylobacter, Yersinia, Salmonella* and *Shigella*. *Bulletin of the World Health Organization* **58**, 519–537.