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Multidrug resistance among different serotypes of clinical *Salmonella* isolates in Taiwan

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Abstract

Of the 798 clinical *Salmonella* isolates collected from multiple hospitals in Taiwan, resistance to ampicillin (48.5%), chloramphenicol (55.3%), streptomycin (59.0%), sulfamethoxazole (68.0%), and tetracycline (67.8%) was high, whereas resistance to all 5 antimicrobials (ACSSuT R-type) comprised 327 (41%) and was highly prevalent in *Salmonella enterica* serotype Typhimurium (72.7%, 176/242), the most common serotype. Additional resistance to trimethoprim was present in 155 (19.4% overall) of the ACSSuT R-type isolates from several serotypes. Reduced susceptibility to fluoroquinolone (FQ) (ciprofloxacin MIC >0.125–1 μg/mL and nalidixic acid-resistant) was detected in 223 (27.9%) isolates including 117 (14.7% overall) that were also ACSSuT-resistant. Full resistance to FQ was detected in *Salmonella* Choleraesuis (35.5%, 6/17) and *Salmonella* Schwarzengrund (16.7%, 10/60); both serotypes were also multiresistant to other antimicrobials. Studies are needed to determine the sources of different multidrug-resistant serotypes. Continued national surveillance is underway to monitor changes in resistance trends and to detect further emergence of resistant *Salmonella* serotypes in Taiwan.
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Keywords: *Salmonella*; Penta-resistance; Multidrug resistance; Serotypes; Fluoroquinolones

1. Introduction

Salmonella infections occur worldwide in both developed and developing countries. Most *Salmonella* infections are caused by a single species, *Salmonella enterica*, which consists of over 2500 serotypes (or serovars) (Bopp et al., 2003). Salmonellosis caused by nontyphoidal serotypes is usually self-limited with mild to moderate gastroenteritis. However, invasive *Salmonella* infections may result in bacteremia and focal infections with higher mortality rates, especially in immunocompromised hosts and older people (Hohmann, 2001; Vugia et al., 2004). When antimicrobial treatment is necessary, ampicillin and trimethoprim–sulfamethoxazole (SXT) were 2 of the drugs of choice for many years. However, because of increasing resistance to these antimicrobials, use of fluoroquinolones (FQs) (in adults) and extended-spectrum cephalosporins (in children) has become common (Hohmann, 2001; Threlfall, 2002; Parry, 2003).

The emergence of *Salmonella enterica* serotype Typhimurium definitive phage type 104 (DT104) having resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole, and tetracycline (ACSSuT R-type) was a major concern worldwide (Threlfall, 2002). This penta-resistance was found to be mediated by the antibiotic resistance gene cluster in *Salmonella* genomic island 1 (SGI1), and SGI1 has been identified in other *Salmonella* Typhimurium phage types and several other serotypes (Boyd et al., 2001; Doublet et al., 2005). In recent years, there has been increasing reports of *Salmonella* having resistance and decreased susceptibility to FQs, the latter of which is manifested by being resistant to the old quinolone nalidixic acid and having higher FQ ciprofloxacin MICs (Piddock, 2002). In addition, resistance to extended-spectrum cephalosporins due to extended-spectrum β-lactamase production is increasingly being found in different serotypes

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Table 1
Serotype distribution of clinical *Salmonella* isolates in Taiwan in different years and specimen types

Serotype	All (1998–2002 combined)		Year						Specimen source[a]			
			1998		2000		2002		Stool		Blood	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Typhimurium	242	30.3	88	30.4	58	41.1	96	26.1	190	30.4	35	27.6
Enteritidis	91	11.4	26	9.0	18	12.8	47	12.8	54	8.6	26	20.5
Stanley	66	8.3	20	6.9	10	7.1	36	9.8	62	9.9	2	1.6
Schwarzengrund	60	7.5	33	11.4	12	8.5	15	4.1	43	6.9	15	11.8
Newport	46	5.8	13	4.5	5	3.5	28	7.6	37	5.9	8	6.3
Albany	36	4.5	14	4.8	4	2.8	18	4.9	34	5.4	–	–
Virchow	29	3.6	7	2.4	1	0.7	21	5.7	26	4.2	3	2.4
Weltevreden	27	3.4	7	2.4	7	5.0	13	3.5	27	4.3	–	–
Agona	25	3.1	11	3.8	1	0.7	13	3.5	24	3.8	1	0.8
Paratyphi B	23	2.9	7	2.4	1	0.7	15	4.1	21	3.4	2	1.6
Derby	22	2.8	8	2.8	8	5.7	6	1.6	22	3.5	–	–
Braenderup	20	2.5	11	3.8	1	0.7	8	2.2	20	3.2	–	–
Cholerasuis	17	2.1	5	1.7	4	2.8	8	2.2	1	0.2	11	8.7
Other serotypes[b]	94	11.8	39	13.5	11	7.8	44	12.0	64	10.2	24	18.9
Total	798		289		141		368		625		127	

[a] There were 46 isolates from specimens other than stool and blood.
[b] Including 8 *Salmonella* Typhi from blood and 8 isolates whose serotypes could not be determined.

from several countries including Taiwan (Parry, 2003; Yan et al., 2005).

The objective of the present study was to study serotype distribution and prevalence of antimicrobial resistance among different serotypes commonly causing human salmonellosis in Taiwan. *Salmonella* isolates were collected from multiple hospitals in different regions of Taiwan as part of a national antimicrobial surveillance program (Lauderdale et al., 2004). The prevalence of resistance among clinical *Salmonella* isolates from Taiwan was also compared with data reported from the United States and Europe.

2. Materials and methods

2.1. Isolates

Salmonella isolates were collected as part of the Taiwan Surveillance of Antimicrobial Resistance (TSAR) (Lauderdale et al., 2004). The isolates were collected between October and December 1998 from 44 hospitals, March and May 2000 from 21 hospitals, and July and September 2002 from 26 hospitals from the 4 geographic regions of Taiwan. The collection processes of TSAR have been described previously (Lauderdale et al., 2004). Briefly, a fixed number of inpatient and outpatient isolates were collected from each hospital. In addition, each hospital was asked to submit an additional 10 *Salmonella* isolates regardless of patient type during the collection period. The identification of each isolate was confirmed using a combination of standard conventional biochemical methods (Bopp et al., 2003). Serotyping was performed by the Danish Institute for Food and Veterinary Research in Denmark following the Kauffmann–White Scheme for designation of *Salmonella* serotypes.

2.2. Antimicrobial susceptibility testing

MICs were determined using the broth microdilution method following the guidelines of the Clinical and Laboratory Standards Institute (formerly National Committee for Clinical Laboratory Standards) (CLSI/NCCLS, 2003) using custom-designed 96-well panels (Sensititre, Trek Diagnostics, East Essex, UK). CLSI/NCCLS (2004) interpretive criteria were used when available. Resistance to streptomycin was defined as $\geq$32 μg/mL (Threlfall et al., 2003). Isolates tested resistant to ciprofloxacin by broth microdilution method were confirmed by E-test according to manufacturer's instructions (AB BIODISK, Solna, Sweden).

2.3. Data analysis

Susceptibility interpretation analysis was made using the WHONET software (Stelling and O'Brien 1997). Univariate analysis was performed using Epi Info 6.04 (CDC, Atlanta, GA), a database and statistical program for public health. Significance of differences in frequencies and proportions was tested by the χ^2 test with Yates' correction.

3. Results

3.1. Isolate source

A total of 798 nonduplicate *Salmonella* isolates were collected between 1998 and 2002, with 289, 141, and 368 collected in 1998, 2000, and 2002, respectively. The majority (78.3%, 625) of the isolates were from stool samples, and 15.9% (127) of the isolates were from blood samples, with the rest from other body sites. Of the 564 patients whose age group was known, 79.1% (446) were from pediatric patients and 20.9% (118) were from adults. Of the 278 pediatric group patients whose exact age

Table 2
Prevalence of resistance (%) to 11 antimicrobial agents in different *Salmonella* serotypes from Taiwan

Antimicrobial agent	All (N = 798)	Typhimurium (n = 242)	Enteritidis (n = 91)	Stanley (n = 66)	Schwarzengrund (n = 60)	Newport (n = 46)	Albany (n = 36)	Virchow (n = 29)	Weltevreden (n = 27)	Agona (n = 25)	Paratyphi B (n = 23)	Derby (n = 22)	Braenderup (n = 20)	Cholerasuis (n = 17)
Ampicillin	48.5	76	3.3	60.6	85	2.2	100	3.4	3.7	40.0	0	77.3	60	82.4
Cefotaxime	0.1	0	0	0	1.7	0	0	0	0	0	0	0	0	0
Ceftazidime	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chloramphenicol	55.3	80.2	4.4	92.4	86.7	2.2	100	89.7	3.7	40.0	0	77.3	15.0	88.2
Ciprofloxacin	2.0	0	0	0	16.7	0	0	0	0	0	0	0	0	35.3
Gentamicin	12.7	13.2	4.4	0	68.3	2.2	0	3.4	0	0	0	0	0	82.4
Nalidixic acid	30.6	21.5	22	3	98.3	4.3	80.6	96.6	0	4.0	0	68.2	0	94.1
Streptomycin	59.0	81.8	18.7	77.3	98.3	15.2	50	65.5	3.7	64.0	8.7	95.5	30.0	94.1
Sulfisoxazole	68.0	88.4	31.9	92.4	98.3	10.9	100	93.1	22.2	80.0	8.7	95.5	60.0	94.1
Tetracycline	67.8	87.6	27.5	92.4	91.7	34.8	100	89.7	3.7	76.0	4.3	95.5	60.0	100
SXT	35.6	17.4	13.2	92.4	88.3	6.5	100	89.7	3.7	4.0	0	13.6	60.0	70.6

Table 3
Prevalence of multidrug and FQ resistance among common *Salmonella* serotypes in Taiwan

Serotype	Number (%) of isolates with resistance phenotype of					
	CIP^{RS}	AMP/SXT^{R}	ACSSuT	ACSSuTTm	ACSSuT and CIP^{RS}	ACSSuTTm and CIP^{RS}
Typhimurium	49 (20.2)	36 (14.9)	176 (72.7)	34 (14.0)	37 (15.3)	34 (14.0)
Enteritidis	20 (22.0)	3 (3.3)	1 (1.1)	1 (1.1)	0	0
Stanley	2 (3.0)	40 (60.6)	31 (47.0)	31 (47.0)	1 (1.5)	1 (1.5)
Schwarzengrund	49 (81.7)	48 (80.0)	42 (70.0)	40 (66.7)	34 (56.7)	34 (56.7)
Newport	2 (4.3)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)	1 (2.2)
Albany	29 (80.6)	36 (100.0)	18 (50.0)	18 (50.0)	15 (41.7)	15 (41.7)
Virchow	27 (93.1)	1 (3.4)	1 (3.4)	1 (3.4)	0	0
Weltevreden	0	1 (3.7)	1 (3.7)	1 (3.7)	0	1 (3.7)
Agona	1 (4.0)	0	10 (40.0)	0	1 (4.0)	0
Paratyphi B	0	0	0	0	0	0
Derby	15 (68.2)	2 (9.1)	16 (72.7)	2 (9.1)	13 (59.1)	1 (4.5)
Braenderup	0	12 (60.0)	3 (15.0)	3 (15.0)	0	0
Choleraesuis	10 (58.8)	12 (70.6)	14 (82.4)	12 (70.6)	7 (41.2)	6 (35.3)
Other serotypes	19 (20.2)	13 (13.8)	13 (13.8)	11 (13.9)	8 (8.5)	6 (6.4)
Total (798)	223 (27.9)	205 (25.7)	327 (41.0)	155 (19.4)	117 (14.7)	87 (10.9)

CIP^{RS} = ciprofloxacin reduced susceptible (resistant to nalidixic acid and having an CIP MIC of ≥0.125–1 μg/mL); AMP/SXT^{R} = ampicillin and SXT-resistant; ACSSuT = resistant to ampicillin, chloramphenicol, streptomycin, sulfisoxazole, and tetracycline; Tm = trimethoprim (isolates with ACSSuTTm resistance were resistant to SXT as expected).

was known, the age mean ± SD was 2.6 ± 1.8 years including 64% (178) from those ≤1 year old. In the 95 adults whose exact age was known, the age mean ± SD was 58.4 ± 19.8 and 38.9% of them were ≥65 year old. Thus, the majority of the patients were from the extreme age groups.

3.2. Serotype distribution

The top-ranked 13 serotypes of the 798 isolates are listed in Table 1, which also lists the serotype distribution from different years and specimen types (stool and blood). *Salmonella* Typhimurium was the most common serotype in all 3 years surveyed (242, 30.3%) comprising 30.4%, 41.1%, and 26.1% of the isolates in 1998, 2000, and 2002, respectively. *Salmonella* Enteritidis was the second most common serotype in 2000 and 2002 (12.8%) and the third most common serotype in 1998 (9.0%). Overall, *Salmonella* Stanley, *Salmonella* Schwarzengrund, and *Salmonella* Newport were the 3rd, 4th, and 5th serotypes in the years surveyed, but their rankings varied in different years. The rank order and the proportions of the serotypes varied among the specimen source. *Salmonella* Typhimurium comprised similar proportions in stool (30.7%) and blood (27.6%). Although *Salmonella* Enteritidis was the second most common serotype in stool (8.7%) and blood (20.5%) specimens, there was a marked difference in proportions. Other serotypes comprising >5% of the blood isolates included Schwarzengrund (11.8%), Choleraesuis (8.7%), Newport (6.3%), and Typhi (6.3%).

3.3. Antimicrobial susceptibility

Resistance to individual antimicrobial agent overall and by each serotype is presented in Table 2. Among all 798 *Salmonella* isolates the overall rates of resistance were high for ampicillin (48.5%), chloramphenicol (55.3%), streptomycin (59.0%), sulfisoxazole (68.0%), tetracycline

Table 4
Comparison of the prevalence (%) of resistance among clinical *Salmonella* isolates from Taiwan, Europe, and United States[a]

Antimicrobial agent	All serotypes combined			*Salmonella* Typhimurium			*Salmonella* Enteritidis		
	Taiwan (n = 798)	Europe (n = 27059)	USA (n = 2009)	Taiwan (n = 242)	Europe (n = 6777)	USA (n = 393)	Taiwan (n = 91)	Europe (n = 14636)	USA (n = 338)
Ampicillin	48.5	22.0	13.0	76	59.0	34.0	3.3	6.0	7.0
Cefotaxime	0.1	0.4	NT	0	0.5	NT	0	0.3	NT
Chloramphenicol	55.3	14.0	9.0	80.2	47.0	23.0	4.4	0.5	1.0
Ciprofloxacin	2.0	0.5	0.05	0	0.6	0.0	0	0.4	0.0
Gentamicin	12.7	2.0	1.0	13.2	6.0	2.0	4.4	0.5	0.3
Nalidixic acid	30.6	14.0	2.0	21.5	8.0	1.0	22.0	13.0	4.0
Sulfisoxazole	68.0	30.0	13.0	88.4	60.0	32.0	31.9	6.0	2.0
Tetracycline	67.8	26.0	15.0	87.6	64.0	32.0	27.5	3.0	4.0
SXT	35.6	NT	1.0	17.4	NT	2.0	13.2	NT	1.0

NT = not tested.

[a] Data source: Taiwan—present study; Europe—data of 10 countries in Europe from the Entero-net Surveillance system (Threlfall et al., 2003); USA—US CDC National Antimicrobial Resistance Monitoring System (http://www.cdc.gov/narms/annual/2002/2002ANNUALREPORTFINAL.pdf).

(67.8%), and SXT (35.6%). A total of 25.7% of the isolates were resistant to both ampicillin and SXT. There was marked variation the resistance profiles of difference serotypes. For example, resistance to ampicillin was 3.3% (3/91) in *Salmonella* Enteritidis compared to 76% (184/242) in *Salmonella* Typhimurium. Co-resistance to both ampicillin and SXT ranged from 0% in *Salmonella* Paratyphi B (0/23) to 100% in *Salmonella* Albany (all 36 isolates).

Isolates with reduced susceptibility to FQs, as indicated by being resistant to nalidixic acid and having ciprofloxacin MIC of ≥0.125 to 1 μg/mL, was found in 223 (27.9%) isolates (Table 3). Five serotypes had >50% reduced susceptibility to FQ including Virchow, Schwarzengrund, Albany, Derby, and Choleraesuis. Even in *Salmonella* Typhimurium and *Salmonella* Enteritidis, the 2 most common *Salmonella* serotypes, isolates with FQ reduced susceptibility comprised over 20%.

Full resistance to FQ ciprofloxacin (MIC, 12 to >32 μg/mL; MIC_{50}, 32 μg/mL) was found in 16 (2.0%) isolates from 2 serotypes, Choleraesuis (35.3%, 6/17) and Schwarzengrund (16.7%, 10/60). Of noteworthy is that in *Salmonella* Choleraesuis, none of the 5 isolates in 1998 was FQ resistant but 2 (50%) of the 4 isolates in 2000 and 4 (50%) of the 8 isolates in 2002 were FQ resistant ($P = 0.14$), indicating the emergence of this resistance in this serotype. FQ-resistant *Salmonella* Schwarzengrund was present as early as 1998 (15.2%, 5/33) and stayed so in 2000 (8.3%, 1/12) and 2002 (20%, 3/15) ($P = 0.70$). Combining the reduced susceptibility and resistance to ciprofloxacin, only 1 isolate each in *Salmonella* Choleraesuis (6.3%, 1/17) and *Salmonella* Schwarzengrund (1.7%, 1/60) remained fully susceptible to FQ.

Multidrug resistance was common among many of the serotypes (Table 3). A total of 327 (41.0%) of isolates were resistant to ampicillin, chloramphenicol, streptomycin, sulfonamide (sulfisoxazole), and tetracycline (ACSSuT R-type), the penta-resistance phenotype initially associated with definitive phage type DT104 in *Salmonella* Typhimurium but has been found in other serotypes in recent years. We also compared changes in resistance over the years in *Salmonella* Typhimurium, the most common serotype, and found that ACSSuT penta-resistance increased from less than 70% in 1998–2000 to 79.2% in 2002 in Taiwan ($P = 0.45$) (data not shown). The ACSSuT R-type was also present at ≥70% in serotypes Choleraesuis, Derby, and Schwarzengrund. Additional resistance to trimethoprim (ACSSuTTm R-type) was present in 155 (47.4%) of the 327 ACSSuT penta-resistant isolates. ACSSuTTm R-type was highly prevalent in serotypes Choleraesuis and Schwarzengrund. The majority (117, 75.5%) of the 155 ACSSuTTm-resistant strains also had reduced susceptibility to FQs (Table 3). Two ACSSuT penta-resistant and ciprofloxacin-resistant *Salmonella* Schwarzengrund isolates also had intermediate susceptibility and resistance to ceftazidime and cefotaxime.

3.4. Comparison of resistance with other countries

Comparison of the frequency of resistance in all serotypes combined and in *Salmonella* Typhimurium and *Salmonella* Enteritidis to 9 antimicrobials is shown in Table 4. Higher resistance to ciprofloxacin was only seen when all serotypes were combined but not in *Salmonella* Typhimurium and *Salmonella* Enteritidis because the ciprofloxacin resistance in Taiwan isolates was attributed to *Salmonella* Choleraesuis and *Salmonella* Schwarzengrund, 2 serotypes not commonly found in Western countries. However, isolates from Taiwan were overall more resistant to several antimicrobials including ampicillin, chloramphenicol, gentamicin, nalidixic acid, sulfisoxazole, tetracycline, and SXT. This higher resistance was also seen in both *Salmonella* Typhimurium and *Salmonella* Enteritidis from Taiwan.

4. Discussion

Because the majority of human cases of nontyphoidal salmonellosis are acquired through the consumption of contaminated food and water, data on the proportions of serotypes and their resistance patterns in different countries are important for the global public health management as food consumption practices vary in different countries and increasing global travel and food trade increase the likelihood of acquiring infections from nondomestic sources. One example is that an estimated 30% of human salmonellosis in Denmark was acquired through travel (DANMAP, 2004). The data are also important for detecting emerging resistance and serotypes. Isolation of a multiresistant *Salmonella* Albany in France in food fish imported from Thailand is one such example (Doublet et al., 2003).

Salmonella Typhimurium and *Salmonella* Enteritidis have been the 2 leading serotypes found in human salmonellosis in most countries including Taiwan, as data from our study indicated. However, trends in serotype distribution can vary considerably in different countries in different years. In the United States, *Salmonella* Typhimurium, *Salmonella* Enteritidis, *Salmonella* Newport were the top 3 *Salmonella* serotypes, accounting for about 50% of *Salmonella* isolates from human sources between 1992 and 2002 (CDC, 2004). A recent study found *Salmonella* Enteritidis to be the leading serotype (79%) between 1999 and 2002 in Spain (Rodriguez-Avial et al., 2005). In contrast, in Thailand, *Salmonella* Weltevreden was the most common *Salmonella* serotype isolated from humans between 1993 and 2002 (12.5% overall), with *Salmonella* Enteritidis in a close second place (11%) (Bangtrakulnonth et al., 2004). Our data indicated that several serotypes commonly found in Taiwan are distinct from other countries, especially *Salmonella* Schwarzengrund and *Salmonella* Choleraesuis, together with *Salmonella* Typhimurium and *Salmonella* Enteritidis, accounted for approximately 70% of invasive salmonellosis in Taiwan.

Although there was marked variation in the prevalence of antimicrobial resistance in serotypes causing human salmonellosis in Taiwan, resistance to some antimicrobials was similarly high among several serotypes. Penta-resistance (resistant to ampicillin, chloramphenicol, streptomycin, sulfonamide, and tetracycline; ACSSuT R-type) ranged from 1% in *Salmonella* Enteritidis to over 70% in *Salmonella* Typhimurium, but reduced susceptibility to FQ was found at similar rates (>20%) for these 2 serotypes. Both serotypes also had higher rates of resistance to several antimicrobials compared to rates reported in Western countries. Over one-fourth of Taiwan's *Salmonella* isolates were resistant to both ampicillin and SXT. This leaves FQs and extended-spectrum cephalosporins as the drugs of choice for *Salmonella* infections in Taiwan in situations when treatment is necessary.

Thus, the emerging resistance and reduced susceptibilities to FQ in our *Salmonella* isolates is of great concern for Taiwan. Reduced susceptibility to FQ was found in all but 2 of the 13 common *Salmonella* serotypes and was present in over 50% in 5 serotypes. Treatment failure and poor clinical response have been associated with isolates having reduced susceptibility to FQ in patients treated with FQ for extraintestinal salmonellosis (Aarestrup et al., 2003; Crump et al., 2003). Recently, the CLSI/NCCLS (2004) added a guideline recommending clinical laboratories to routinely test for nalidixic acid resistance in extraintestinal *Salmonella* isolates to alert physicians of this emerging resistance.

In our study, nearly all *Salmonella* Schwarzengrund and *Salmonella* Choleraesuis had either reduced susceptibility or full resistance to FQ. Although we found only a few *Salmonella* Choleraesuis in our collection, our data confirm the emergence of FQ-resistant *Salmonella* Choleraesuis in Taiwan (Chiu et al., 2002; Yan et al., 2005). Data on *Salmonella* Schwarzengrund prevalence are still limited, but a FQ-resistant strain of *Salmonella* Schwarzengrund was recently the cause of a nosocomial outbreak in Oregon, USA. The index patient had been hospitalized in the Philippines and had probably acquired the infection there (Olsen et al., 2001). The incidence and epidemiology of this serotype in Taiwan and other countries warrant further investigation.

The high prevalence of resistance in *Salmonella* isolates in Taiwan may be due to several factors. In addition to *Salmonella*, many other Gram-negative pathogens in Taiwan also have high rates of antimicrobial resistance (Lauderdale et al., 2004), which is attributable in part to the widespread use of antimicrobials in outpatient settings, where aminopenicillins (most common), tetracyclines, trimethoprim/sulfamethoxazole, and quinolones are commonly used (Ho et al., 2004). These antimicrobials are also commonly used in Taiwan food animals (McDonald et al., 2001). The high prevalence of ACSSuT R-type in different serotypes in Taiwan may also be due to the spread the SGI1 found in *Salmonella* Typhimurium DT104. The SG1, which contains the antibiotic gene cluster conferring the penta-resistance ACSSuT, has recently been found to be an intergrative mobile element (Doublet et al., 2005).

Worldwide, the emergence of FQ resistance and increasing reduced susceptibility in *Salmonella* have been linked to the use of FQs in food animals (Threlfall, 2002). FQ enrofloxacin was used in about one third of feed mills surveyed in Taiwan (McDonald et al., 2001). Resistance to FQ is usually associated with stepwise mutations in the drug target DNA gyrase and/or alterations in efflux pump (Piddock, 2002). Reduced susceptibility to FQ is associated with single mutation in the drug target, whereas additional mutation under selective pressure renders the isolate fully resistant to FQ. Because nearly half of the ACSSuT R-type strains in Taiwan had additional resistance to trimethoprim (ACSSuTTm R-Type), and over half of these ACSSuTTm R-type isolates also had reduced susceptibility to FQ ciprofloxacin; treatment options are limited. Although we found only a few isolates (5, <1%) with intermediate susceptibility and resistance to extended-spectrum cephalosporins, strains of *Salmonella* possessing various extended-spectrum β-lactamases are emerging in different serotypes in many countries (Parry, 2003). Recently, several isolates resistant to both ciprofloxacin and ceftriaxone were found in *Salmonella* Choleraesuis and other uncommon serotypes in Taiwan adding to the challenge in therapy (Yan et al., 2005).

In conclusion, high prevalence of multidrug resistance is present in many serotypes causing human salmonellosis in Taiwan. These resistance profiles likely reflect the pattern of antimicrobial use in both human medicine and food animal industry in Taiwan. The government in Taiwan has implemented more stringent control measures to restrict antimicrobial use in outpatients and food animals. Studies are needed to determine the sources of different resistant serotypes. Continued national surveillance is underway to monitor changes in resistance trends and to detect further emergence of resistant *Salmonella* serotypes in Taiwan.

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