SEROTYPES AND ANTIMICROBIAL RESISTANCE OF *SALMONELLA ENTERICA* SSP IN CENTRAL THAILAND, 2001-2006

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Abstract. This study was carried out to elucidate the epidemiological trends and antimicrobial susceptibilities against *Salmonella* serovars among Thai patients and asymptomatic carriers during 2001-2006 in central Thailand. A total of 1,401 human and 260 non-human isolates from various sources were included. The isolates were characterized using serotyping and antimicrobial susceptibility testing. The most common serovars in patients submitting stool samples were *S.* Weltevreden, *S.* Stanley, *S.* Anatum, and *S.* Rissen. Significantly higher odds ratios were observed in blood samples versus stool sample for *S.* Choleraesuis, *S.* Enteritidis, *S.* Typhimurium, and *S.* Typhi. Children under five years old suffered the most frequently from gastroenteritis. The patients most commonly infected with an invasive serovar were children and people from 26 to 55 years of age. Antimicrobial susceptibility data revealed that *S.* Schwarzengrund, *S.* Choleraesuis, *S.* Anatum, *S.* Stanley, *S.* Rissen, and *S.* Typhimurium were the most resistant serovars observed. The invasive serovar, *S.* Choleraesuis was resistant to cefotaxime and norfloxacin. Antimicrobial resistance to cefotaxime, was observed in *S.* Agona, *S.* Rissen, *S.* Typhimurium, *S.* Anatum, and *S.* Weltevreden. An alarmingly high frequency of resistance to third generation cephalosporins was observed. We recommend Thai authorities take action in order to prevent spread of resistant *S.* Choleraesuis and other serovars among animals and humans by enforcing a more strict policy on the use of antimicrobials in food animals.

Key words: *Salmonella enterica*, serotype, antimicrobial resistance, Thailand

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INTRODUCTION

Salmonella enterica is a common cause of human gastroenteritis and bacteremia worldwide (Schlundt *et al*, 2004; Voetsch *et al*, 2004; Hendriksen *et al*, 2009; Morpeth *et al*, 2009). A wide variety of animals, par-

ticularly food animals, have been identified as reservoirs for non-Typhi *Salmonella* (Guard-Petter, 2001; Bangtrakulnonth *et al*, 2004; Vindigni *et al*, 2007). Although approximately 2,600 serovars of *Salmonella enterica* have been identified, most human infections are caused by a limited number of serovars and in general these infections are self limited. Some *Salmonella* serovars, such as *Salmonella enterica* serovar Choleraesuis, *S.* Dublin, *S.* Panama, *S.* Heidelberg, and *S.* Enteritidis, have a propensity to cause extra-intestinal infections in humans. When compared to other serovars of non-Typhi *Salmonella*, infections with these serovars are associated with higher rates of bacteremia, meningitis, and mortality (Helms *et al*, 2003; Chiu *et al*, 2004; Helms *et al*, 2006; Jones *et al*, 2008; Hendriksen *et al*, 2009).

For patients with severe salmonellosis, antimicrobial chemotherapy may be lifesaving. Due to the increasing prevalence of fluorquinolone resistance and the increasingly use of third generation cephalosporins to treat *Salmonella* infections in humans (Hohmann, 2001; Grohskopf *et al*, 2005; Kulwichit *et al*, 2007; Lee *et al*, 2009), these drugs have been designated as critically important for human health by the World Health Organization (Collignon *et al*, 2009).

In developed countries, *S.* Typhimurium and *S.* Enteritidis are the most common causes of human salmonellosis, but other serovars have been reported to be more prevalent in specific regions and even within countries (Herikstad *et al*, 1997; Bangtrakulnonth *et al*, 2004; Galanis *et al*, 2006; Hendriksen *et al*, 2009; Lee *et al*, 2009). Laboratory surveillance of *Salmonella* serovars in humans, animals and food products is crucial for understanding the epidemiology of the different serovars and spread from these reservoirs to people. Numerous publications have addressed the emergence of different *Salmonella* serovars in Thailand, providing additional knowledge of the epidemiology and reservoirs accounting for infections in humans (Aarestrup *et al*, 2003; Bangtrakulnonth *et al*, 2004; Archambault *et al*, 2006; Aarestrup *et al*, 2007; Hendriksen *et al*, 2008, 2009). A retrospective observational study was conducted to elucidate the epidemiological trends and antimicrobial susceptibilities of the most common *Salmonella* serovars among Thai patients during 2001-2006 in central Thailand.

This study also assessed which infected age groups were associated with gastrointestinal salmonellosis and bacteremia using descriptive data.

The data gained in this study may assist policy makers to develop serovar specific interventions to minimize the burden of the most common *Salmonella* serovars in Thailand, and to enforce a more restrictive policy regarding the use of antimicrobials for primary production.

MATERIALS AND METHODS

Bacterial isolates

From August 2001 to March 2006, a total of 1,401 *Salmonella* isolates obtained from humans and 260 isolates from 209 various non-human sources were serotyped and the antimicrobial susceptibilities were determined at the Regional Medical Sciences Center, Samut Songkhram, Thailand. The human isolates (patient stool=922 specimens, patient blood=136 specimens, and stool from asymptomatic carriers=343 specimens) originated from 8 sentinel hospitals in central Thailand. The asymptomatic carriers were mainly food handlers working in food producing factories; stool

samples were collected during routinely screening for gastrointestinal diseases. Several *Salmonella* serovars (*N*) were isolated from non-human samples (*n*). The isolates originating from non-human sources were obtained from fresh retail meat [pork (*N*=83/*n*=65), seafood (*N*=20/*n*=16), chicken (*N*=44/*n*=30), beef (*N*=14/*n*=12), freshwater fish and prawn (*N*=2/*n*=2)], ready to eat food (*N*=6/*n*=6), vegetables (*N*=3/*n*=3), beverages (*N*=1/*n*=1), fresh water (*N*=8/*n*=7), waste water from raw animal products (*N*=3/*n*=3), ice (*N*=2/*n*=2) and swabs from unidentified sources (*N*=74/*n*=62). The isolates were identified using approved internationally recognised standard procedures as previously described (Bangtrakulnonth *et al*, 2004).

Statistical analysis

SAS version 9.1.3 (SAS Institute, Cary, NC) was used to assess the association of specific serovars present in patients submitting blood samples, patients submitting stool samples and asymptomatic carriers submitting stool samples. The significance level was set at $p < 0.05$.

Serotyping

O and H antigens were characterized by agglutination with hyperimmune sera (S & A reagents lab, Bangkok, Thailand) and serotypes were assigned according to the Kauffmann-White scheme (Grimont *et al*, 2007).

Antimicrobial susceptibility testing

Susceptibilities to antimicrobial agents were determined on a limited number of isolates from human stool samples, human blood samples and non-human samples using disk diffusion according to the Bauer-Kirby technique (CLSI, 2002, 2006). The antimicrobials differed by isolate source. The following ten antimicrobials were used: ampicillin, 10 µg; chloramphenicol, 30 µg; tetracycline, 30 µg; trimethoprim + sulfamethoxazole, 25 µg; ciprofloxacin, 5 µg; cefotaxime, 30 µg; nalidixic acid, 30 µg; streptomycin, 10 µg, and gentamicin, 10 µg. Clinical and Laboratory Standards Institute guidelines (CLSI, 2002, 2006) and clinical breakpoints were used for interpretation of the antimicrobial susceptibility test results. Quality control using *E. coli* ATCC 25922 was conducted on a weekly basis according to CLSI (2002, 2006).

RESULTS

Distribution of serovars

A total of 1,661 *Salmonella* isolates were collected during 2001- 2006. Of these, 922 isolates were obtained from patient stool samples, comprised of 60 different serovars. One hundred thirty-six isolates were obtained from patients blood samples, comprised of 14 different serovars; 343 isolates were obtained from stool samples originating from asymptomatic carriers, comprised of 45 different serovars; 260 isolates were obtained from 209 samples of non-human origin, comprised of 35 different serovars. Of the 209 samples, 170 were comprised of one serovar, 30 samples were comprised of 60 serovars, 7 samples were comprised of 21 serovars, 1 sample was comprised of 5 serovars and another sample was comprised of 4 serovars.

The 10 most common serovars in patients submitting stool samples were *S.* Weltevreden (14.8%), *S.* Stanley (12.9%), *S.* Anatum (9.7%), *S.* Rissen (8.4%), *S.* Enteritidis (5.0%), *S.* Typhimurium (4.2%), *S.* Corvallis (4.1%), *S.* Virchow (3.5%) *S.* Panama (3.3%), and *S.* Derby (2.9%) (Table 1). The 10 most common serovars causing bacteremia in patients were *S.* Choleraesuis (41.9%), *S.* Enteritidis (22.1%),

Table 1
Origin and frequency of specific serotypes from central Thailand, 2001-2006.

Serotype	Numbers and percentages of isolates from various sources			
	Human sources			Non-human sources
	Patient stool samples	Patient blood samples	Asymptomatic carrier stool samples	
S. Stanley[a]	119 (12.9)	3 (2.2)	44 (12.8)	27 (10.4)
S. Weltevreden[b,c]	136 (14.8)	4 (2.9)	15 (4.4)	17 (6.5)
S. Anatum[a,c]	89 (9.7)	1 (0.7)	55 (16.0)	47 (18.1)
S. Rissen	77 (8.4)		25 (7.3)	25 (9.6)
S. Enteritidis[b,d]	46 (5.0)	30 (22.1)	7 (2.0)	3 (1.2)
S. Choleraesuis[d]	7 (0.8)	57 (41.9)	1 (0.3)	
S. Typhimurium[d]	39 (4.2)	18 (13.2)	8 (2.3)	6 (2.3)
S. Derby[a]	27 (2.9)		20 (5.8)	10 (3.8)
S. Corvallis[b]	38 (4.1)	2 (1.5)	6 (1.7)	23 (8.8)
S. Panama	30 (3.3)	3 (2.2)	11 (3.2)	5 (1.9)
S. Virchow	32 (3.5)	1 (0.7)	7 (2.0)	10 (3.8)
S. Schwarzengrund[a]	20 (2.2)		18 (5.2)	14 (5.4)
S. Agona	20 (2.2)	1 (0.7)	12 (3.5)	6 (2.3)
S. Albany	21 (2.3)		11 (3.2)	7 (2.7)
S. Hadar[a]	13 (1.4)		12 (3.5)	2 (0.8)
S. Orion[a]	2 (0.2)		17 (5.0)	1 (0.4)
S. I (1),4,(5),(12) :i,-	14 (1.5)	5 (3.7)		1 (0.4)
S. Braenderup[a]	6 (0.7)		12 (3.5)	
S. Senftenberg	10 (1.1)		7 (2.0)	8 (3.1)
S. Mbandaka	11 (1.2)	2 (1.5)	3 (0.9)	
S. Kentucky	10 (1.1)		5 (1.5)	2 (0.8)
S. Lexington[a]	4 (0.4)		11 (3.2)	5 (1.9)
S. Worthington	10 (1.1)		5 (1.5)	3 (1.2)
S. Hvittingfoss	8 (0.9)		5 (1.5)	
S. Amsterdam	6 (0.7)		5 (1.5)	7 (2.7)
S. Kedougou	9 (1.0)		2 (0.6)	1 (0.4)
S. Thompson[a]	4 (0.4)		7 (2.0)	
S. Bovismorbificans	8 (0.9)		1 (0.3)	3 (1.2)
S. Typhi[d]	1 (0.1)	8 (5.9)		
S. Blockley	4 (0.4)		4 (1.2)	
S. Ohio	7 (0.8)			4 (1.5)
S. Paratyphi B var. Java	4 (0.4)		3 (0.9)	
Other[e]	90 (9.8)	1 (0.7)	4 (1.2)	23 (8.8)
Total	922 (100.4)	136 (99.9)	343 (100.0)	260 (100.0)

[a]Significantly lower OR in patient stool compared to asymptomatic carriers; [b]significantly higher OR in patient stool compared to asymptomatic carriers; [c]significantly lower OR in patient blood compared to patient stool; [d]significantly higher OR in patient blood compared to patient stool; [e]*S.* Dublin, *S.* Livingstone, *S.* Montevideo, *S.* I 3,10:eh:-, *S.* Sandiego, *S.* Augustenborg, *S.* Bareilly, *S.* Brunei, *S.* Chester, *S.* Give, *S.* Krefeld, *S.* Newport, *S.* I 4,(5),12:b:-, *S.* Havana, *S.* Cerro, *S.* Aberdeen, *S.* Javiana, *S.* Saintpaul, *S.* Alachua, *S.* Manhattan, *S.* Oslo, *S.* Poona, *S.* Virginia, *S.* Adelaide, *S.* Altona, *S.* Farmsen, *S.* Liverpool, *S.* London, *S.* Muenchen, *S.* Pakistan, *S.* Potsdam, *S.* Rubislaw, *S.* I 6,8:-,1,5, *S.* I 6,8:Z4Z23:-, *S.* I 47:-:-, *S.* I 13,23:Z:-, *S.* Singapore, *S.* Yoruba, *S.* Zanzibar, *S.* II 1,7:g:t:-, *Salmonella houtenae*

S. Typhimurium (13.2%), *S.* Typhi (5.9%), S. I (1),4,(5),(12):i- (3.7%), *S.* Weltevreden (2.9%), *S.* Stanley (2.2%), *S.* Panama (2.2%), *S.* Corvallis (1.5%), and *S.* Mbandaka (1.5%). *S.* Typhi, *S.* Choleraesuis, and *S.* I (1),4,(5),(12):i-, were more frequent in blood samples than stool samples and were rarely observed among asymptomatic carriers.

The following serovars were more common in blood than stool: *S.* Choleraesuis (OR 94.3; 95% CI 41.6-213.7), *S.* Typhi (OR 57.6; 95% CI 7.1-464.0), *S.* Enteritidis (OR 5.4; 95% CI 3.3-8.9), and *S.* Typhimurium (OR 3.5; 95% CI 1.9-6.2). *S.* Stanley, *S.* Weltevreden, and *S.* Anatum were more common in stool than blood (OR 0.2; 95% CI 0.1-0.5).

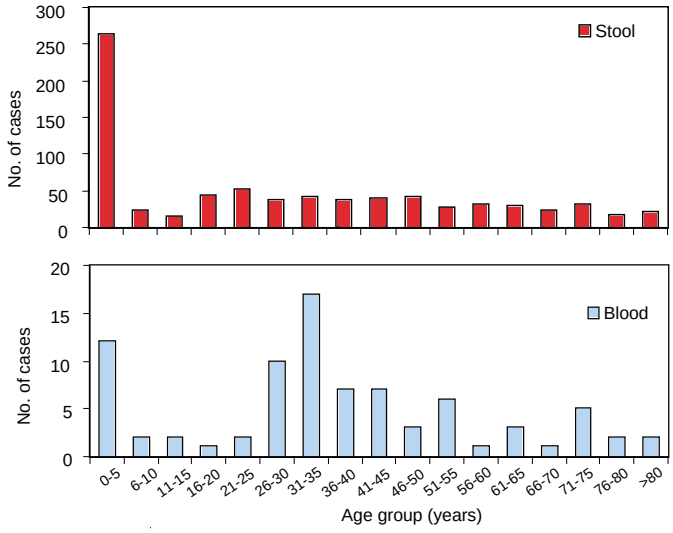

Fig 1–Distribution of age groups among patients submitting stool and blood samples during 2001-2006.

Only 5 of the 10 most common serovars were present in both patients and healthy carriers in stool: *S.* Stanley, *S.* Anatum, *S.* Rissen, *S.* Weltevreden, and *S.* Derby (Table 1). The odds of patients having the following serovars in stool (OR 0.1; 95% CI 0.1-0.4 to OR 0.6; 95% CI 0.4-0.8) were less common than asymptomatic carriers: *S.* Anatum, *S.* Derby, *S.* Schwarzengrund, *S.* Hadar, *S.* Orion, *S.* Braenderup, *S.* Lexington, and *S.* Thompson. *S.* Weltevreden (OR 3.8; 95% CI 2.2-6.6), *S.* Enteritidis (OR 2.5; 95% CI 1.1-5.6), and *S.* Corvallis (OR 2.4; 95% CI 1.0-5.8) had significantly higher odds ratios of being found in patients submitting stool samples.

The most common serovars isolated from non-human sources were *S.* Anatum (15.0%), *S.* Stanley (10.9%), and *S.* Rissen (10.1%). Interestingly, *S.* Choleraesuis was not found in non-human sources.

Age distribution

Out of 770 cases of *Salmonella* causing gastroenteritis during 2001-2006, 263 were in children <5 years old. None of the other age groups had >50 cases (Fig 1). The distribution of patients with invasive serovars differed from the distribution of patients suffering from gastrointestinal salmonellosis. Patients <5 years old and 26-55 years old were at greater risk of infection than the other age groups (Fig 1). The cases peaked in patients 31-35 years old.

Antimicrobial resistance

Antimicrobial susceptibility data of the fifteen most commonly isolated serovars from patients, asymptomatic carriers and non-human sources revealed *S.* Schwarzengrund, *S.* Choleraesuis, *S.* Anatum, *S.* Stanley, *S.* Rissen, and *S.* Typhimurium as the serovars with the most resistant profiles (Table 2), most with resistance to 9 or 10 out of the 12 antimicrobials tested. *S.* Weltevreden was resistant to 7 of the 12 antimicrobials tested, but the levels of resistance were milder than *S.* Enteritidis, which was resistant to 6 of the 12 antimicrobials tested.

More than 70% resistance to tetracy-

Table 2
Frequency of resistance among predominate non-typhoidal *Salmonella* serotypes in patients, including carriers and non-human sources.

Serovars	Percentage of resistant isolates (the number of isolates tested).											
	Ampicillin	Chloramphenicol	Tetracycline	Sulfamethoxazole + Trimethoprim	Norfloxacin	Cefotaxime	Ceftriaxone	Ciprofloxacin	Sulfamethoxazole	Streptomycin	Nalidixic acid	Gentamicin
S. Schwarzengrund	87 (47)	29 (28)	76 (22)	84 (44)	15 (46)	0 (39)	0 (28)	11 (18)	94 (16)	83 (12)	97 (38)	90 (20)
S. Choleraesuis	88 (60)	77 (30)	80 (30)	47 (57)	2 (60)	8 (59)	0 (8)	0 (7)	100 (4)	89 (9)	93 (42)	29 (7)
S. Anatum	61 (157)	16 (82)	76 (91)	46 (164)	2 (163)	2 (153)	0 (68)	0 (48)	73 (51)	43 (42)	40 (134)	4 (56)
S. Stanley	36 (169)	20 (79)	80 (82)	26 (170)	1 (160)	0 (150)	0 (59)	2 (49)	92 (38)	77 (35)	5 (145)	9 (45)
S. Typhimurium	75 (64)	61 (36)	86 (37)	66 (61)	0 (63)	4 (51)	0 (28)	0 (21)	89 (18)	71 (17)	45 (44)	71 (21)
S. Rissen	56 (109)	35 (46)	92 (48)	47 (115)	0 (108)	5 (101)	0 (29)	0 (18)	85 (26)	50 (16)	16 (94)	8 (25)
S. Albany	82 (33)	71 (17)	85 (20)	80 (35)	6 (32)	0 (35)	0 (15)	0 (4)	100 (3)	25 (8)	95 (21)	0 (6)
S. Panama	76 (42)	73 (30)	81 (31)	78 (41)	7 (43)	0 (44)	0 (21)	0 (8)	100 (4)	67 (9)	27 (22)	0 (8)
S. Agona	5 (38)	21 (24)	64 (25)	24 (37)	0 (35)	6 (32)	0 (22)	0 (12)	40 (10)	22 (9)	46 (24)	0 (10)
S. Derby	24 (46)	50 (32)	82 (34)	64 (50)	0 (52)	0 (49)	0 (22)	0 (10)	80 (10)	75 (8)	7 (28)	0 (10)
S. Hadar	4 (24)	6 (16)	87 (15)	46 (26)	0 (24)	0 (25)	0 (15)	0 (7)	57 (7)	33 (6)	94 (16)	0 (7)
S. Corvallis	8 (60)	0 (11)	82 (11)	12 (60)	0 (60)	0 (63)	0 (15)	0 (10)	94 (16)	79 (14)	29 (63)	6 (17)
S. Virchow	11 (45)	18 (17)	28 (18)	12 (43)	0 (43)	0 (43)	0 (11)	0 (5)	100 (3)	17 (6)	69 (36)	0 (7)
S. Weltevreden	7 (153)	3 (89)	23 (90)	16 (148)	0 (160)	1 (142)	0 (44)	0 (35)	27 (30)	3 (32)	0 (100)	0 (35)
S. Enteritidis	21 (81)	0 (34)	54 (39)	37 (78)	0 (80)	0 (71)	0 (26)	0 (22)	45 (20)	5 (21)	55 (66)	0 (35)

cline and sulfamethoxazole was observed in 11 of 15 serovars. A high level of resistance to third generation cephalosporins was observed among the 15 serovars. *S.* Choleraesuis was resistant to cefotaxime and norfloxacin. Antimicrobial resistance to cefotaxime was observed with *S.* Agona (6%), *S.* Rissen (5%), *S.* Typhimurium (4%), *S.* Anatum (2%), and *S.* Weltevreden (1%) (Table 2). *S.* Schwarzengrund, *S.* Albany, *S.* Panama, *S.* Anatum, and *S.* Stanley were resistant to ciprofloxacin and norfloxacin. The antimicrobial resistance ratio between human and non-human sources was not different (data not shown).

DISCUSSION

Our data suggest the serovars found in patients having gastrointestinal salmonellosis have changed over time. In 1990, the prevalence of *S.* Enteritidis dramatically increased until 1995 where it caused an annual morbidity rate of 1.47/100,000 people (Sakai and Chalermchaikit, 1996; Boriraj *et al*, 1997). This serovar predominated mostly in Bangkok and southern Thailand and was found in both stool (41.7%) and blood (35.8%) samples (Boriraj *et al*, 1997). Between 1993 and 2002, a survey showed a decrease in the prevalence of *S.* Enteritidis compared to other nontyphoidal serovars from 14.3% in 1993 to 12.6% in 2002 (Bangtrakulnonth *et al*, 2004). However, this trend changed and there was an increase again from 2002 to 2007 (Hendriksen *et al*, 2009). Regional differences are seen; *S.* Enteritidis was previously the third most common serovar in Bangkok region, exceeded by *S.* Stanley and *S.* Rissen, but was exceeded by *S.* Weltevreden in southern Thailand (Hendriksen *et al*, 2009). These data correlate well with the findings of our study, where *S.* Enteritidis was ranked fifth and second, in stool and blood samples, respectively, exceeded by the same serovars as seen in a study by Hendriksen *et al* (2009).

The differences observed in our study between the serovars originating from patients submitting stool and blood samples are similar to those found by Hendriksen *et al* (2009), who found blood samples were more likely to be infected by the serovars *S.* Enteritidis, *S.* Choleraesuis, *S.* Typhimurium, and *S.* I (1),4,(5),(12):i:-. It is worrisome that nearly 50% of all bacteremia cases in this study were caused by *S.* Choleraesuis. *S.* Choleraesuis is a host adapted serovar mainly affecting pigs, but in humans can result in severe infections. In this region, authorities may consider targeting this serovar by initiating intervention strategies in the production of swine aiming to diminish the burden of this serovar or eradicate it, as was accomplished in Europe.

In this study, the serovar distribution in stool samples from healthy carriers was similar to serovars from healthy humans in northern Thailand (Padungtod and Kaneene, 2006). They found *S.* Anatum and *S.* Rissen among the top 3 most common serovars. Interestingly, Padungtod and Kaneene (2006) identified *S.* Weltevreden as the most common serovar despite it being associated with seafood (Aarestrup *et al*, 2003; Ponce *et al*, 2008). Patient stools had significantly lower odds ratios of common serovars known to be present in food animals, such as pigs, chickens and cattle, compared to healthy carriers. This observation is propably biased since asymptomatic carriers, being food handlers or factory workers, may have close contact to food or food animal.

S. Anatum, *S.* Stanley, *S.* Rissen, *S.* Corvallis, and *S.* Weltevreden were found in non-human samples from chicken,

pork, and seafood. In Thailand, *S.* Stanley, *S.* Anatum, and *S.* Rissen have been associated with pigs (Archambault *et al*, 2006; Vindigni *et al*, 2007; Chuanchuen *et al*, 2008; Hendriksen *et al*, 2008), *S.* Corvallis has been associated with chicken and pigs (Archambault *et al*, 2006; Vindigni *et al*, 2007; Chuanchuen *et al*, 2008) and *S.* Weltevreden has been associated with seafood (Boonmar *et al*, 1998b; Aarestrup *et al*, 2003; Bangtrakulnonth *et al*, 2004; Ponce *et al*, 2008).

The age distribution of infections in our study and others probably results from children acquiring immunity to *Salmonella*, and deteriorating immune status in the elderly (Hohmann, 2001). Diarrhea in children caused by non-typhoidal *Salmonella* is believed to be endemic in Thailand (Moolasart *et al*, 1997; Bodhidatta *et al*, 2002). In a study by Hendriksen *et al* (2009), they found, from 2002 to 2007 in Thailand, 32.6% of all *Salmonella* cases were observed among children from 0 to 5 years of age and peaked again with 14% of all cases in people >60 years old. Hendriksen *et al* (2009) also suggested *S.* Anatum, *S.* Enteritidis, and *S.* Weltevreden caused age specific, infections which mainly affected people >6 years old, while *S.* Stanley, *S.* Panama, and *S.* I (1),4,(5),12:i:- caused infections mainly in children <6 years old (Hendriksen *et al*, 2009).

The peak in bacteremia cases occurred in children <5 years old and in people 26-55 years old, with the most infected group being the 26-35 year old group. Hendriksen *et al* (2009) found odds ratios of 1.63 (95% CI 1.1-2.5) and 1.51 (95% CI 1.1-2.0) in the 6-20 and 21-40 year old age groups for being infected with *S.* Choleraesuis compared to other salmonella infections. Odds ratios were 2.18 (95% CI 1.81-2.61) and 1.86 (95% CI 1.51-2.29) in the 21-40 and 41- 60 year old age groups for being infected with *S.* Enteritidis (Hendriksen *et al*, 2009). These two serovars represented 64% of the bacteremia cases in our study. *S.* I (1),4,(5),(12):i:-, was the forth most common serovar in blood samples in our study, and may be responsible for children infected with an invasive serovar. Hendriksen *et al* (2009) found an odds ratio <1 for people >5 years old and an odds ratio of 2.01 (95% CI 1.67-2.43) for being infected in the blood with *S.* I (1),4,(5),(12):i:-.

Since the late 1990s, an increased level of resistance, especially to fluoroquinolones, has been described in Thailand (Boonmar *et al*, 1998a).

Lee *et al* (2009) found a level of resistance to ciprofloxacin and ceftriaxone among non-typhoidal *Salmonella* in seven Southeast Asian countries. They found the highest frequencies of resistance to ciprofloxacin and ceftriaxone in Taiwan and Thailand. Our data show a similar trend of resistance in *S.* Choleraesuis to cefotaxime central Thailand. To date, only a few reports from Taiwan and Thailand have described resistance to third generation cephalosporins and fluoroquinolones in *S.* Choleraesuis (Chiu *et al*, 2002; Li *et al*, 2005; Su *et al*, 2005; Kulwichit *et al*, 2007). It is noteworthy to mention a third generation cephalosporin, ceftiofur, is used extensively in swine production in Thailand (Kulwichit *et al*, 2007).

We observed a high level of resistance to multiple antimicrobials in *S.* Schwarzengrund, especially to fluoroquinolones. This phenomenon has previously been described present in chickens (Aarestrup *et al*, 2007). *S.* Rissen is highly resistant to many antimicrobials and third generation cephalosporins. One study found *tetB* in *S.* Rissen responsible for all tetracycline resistance in

investigated samples from Thailand compared to *tetA* commonly found in Danish, German, and Spanish samples (Hendriksen *et al,* 2008). *S.* Corvallis resistance to third generation cephalosporins was not seen in this study, but it has the potential of acquiring resistance to this class of drugs as was seen in Bulgaria (Archambault *et al,* 2006). *S.* Weltevreden exhibited less resistance. This observation correlates well with a previous study in Thailand (Aarestrup *et al,* 2003).

We recommend Thai authorities take action to prevent the spread of invasive *S.* Choleraesuis among animals and the humans to reduce the high cost of hospitalizations associated with the treatment of invasive multi-drug resistant *S. C*holeraesuis infections. We also recommend enforcing a strict policy on the use of antimicrobials in food animals and a ban on the use of third generation cephalosporins as a growth promoter.

We suggest public health authorities obtain epidemiological data on a routine basis investigating invasive serovars to determine possible links to reservoirs for future intervention and prevention programs. The data obtained should be useful for microbiologists and pharmacologists in hospitals for empiric treatment of gastro- and extra-intestinal salmonellosis.

This study evaluated the presence of *Salmonella* serovars from human and non-human sources in central Thailand. Children <5 years old were most likely to be infected with non-typhoidal *Salmonella. M*id age people were also frequently infected, especially by invasive serovars. Highly resistant serovars were found to confer resistance to both fluoroquinolones and third generation cephalosporins. An alarmingly high frequency of resistance to third generation cephalosporins was observed in the invasive serovar *S*. Choleraesuis. We recommend Thai authorities to take action to prevent the spread of invasive *S. C*holeraesuis among animals and humans by enforcing a more restrictive policy on the usage of antimicrobials in food animals and a ban on the use of third generation cephalosporins as a growth promoter.

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