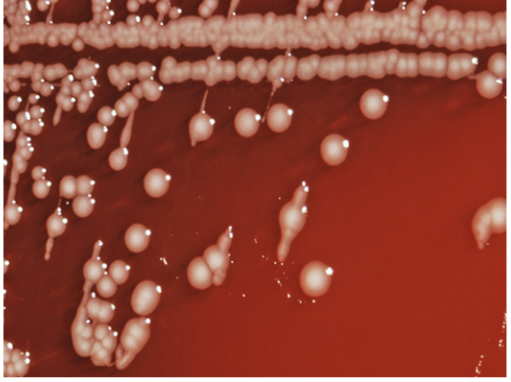

NARMS

National Antimicrobial Resistance Monitoring System: Enteric Bacteria

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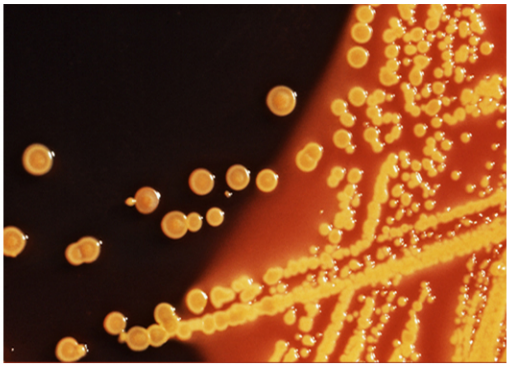
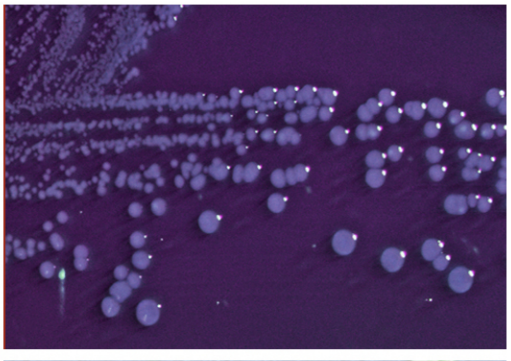
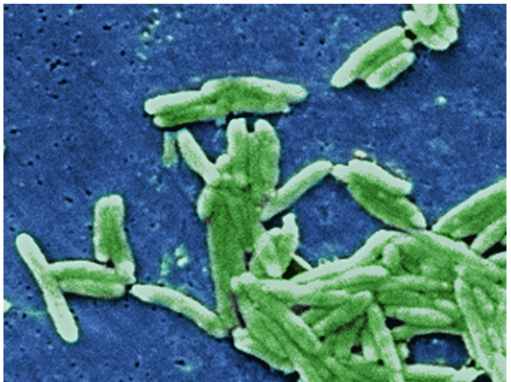
2006

Human Isolates Final Report







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CDC
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List of Abbreviations and Acronyms

ACSSuT	Resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, and tetracycline
ACSSuTAuCf	Resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline, amoxicillin-clavulanic acid, and ceftiofur
ACSuTm	Resistance to at least ampicillin, chloramphenicol, and trimethoprim-sulfamethoxazole
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
CLSI	Clinical and Laboratory Standards Institute
EIP	Emerging Infections Program
ELC	Epidemiology and Laboratory Capacity
EMB	Eosin methylene blue
ENTFM	*Enterococcus faecium*
ENTFS	*Enterococcus faecalis*
ERS	Enterococci Resistance Surveillance
EUCAST	European Committee on Antimicrobial Susceptibility Testing
FDA-CVM	Food and Drug Administration -Center for Veterinary Medicine
FoodNet	Foodborne Diseases Active Surveillance Network
MDR-AmpC	Resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, and tetracycline, amoxicillin-clavulanic acid, and ceftiofur, and decreased susceptibility to ceftriaxone (MIC ≥ 2 µg/mL)
MIC	Minimum inhibitory concentration
NARMS	National Antimicrobial Resistance Monitoring System for Enteric Bacteria
OR	Odds ratio
PCR	Polymerase chain reaction
PHLIS	Public Health Laboratory Information System
USDA	United States Department of Agriculture
VRE	Vancomycin–resistant enterococci
WHO	World Health Organization

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Information Available Online: Previous reports and additional information about NARMS are posted on the CDC NARMS website: http://www.cdc.gov/narms General information on antimicrobial resistance, NARMS partners, related programs and selected resources are available at CDC NARMS resources website: http://www.cdc.gov/narms/resources.htm

Introduction

The National Antimicrobial Resistance Monitoring System (NARMS) for Enteric Bacteria is a collaboration among the Centers for Disease Control and Prevention (CDC), Food and Drug Administration (FDA-CVM), and U.S. Department of Agriculture (USDA). The primary purpose of NARMS at CDC is to monitor antimicrobial resistance among foodborne enteric bacteria isolated from humans. Other components of the interagency NARMS program include surveillance for resistance in enteric bacterial pathogens isolated from foods, conducted by the FDA Center for Veterinary Medicine (http://www.fda.gov/AnimalVeterinary/SafetyHealth/AntimicrobialResistance/NationalAntimicrobialResistanceMonitoringSystem/default.htm), and resistance in enteric pathogens isolated from animals, conducted by the USDA Agricultural Research Services (http://www.ars.usda.gov/main/site_main.htm?modecode=66-12-05-08).

Many NARMS activities are conducted within the framework of CDC's Emerging Infections Program (EIP), Epidemiology and Laboratory Capacity (ELC) Program, and the Foodborne Diseases Active Surveillance Network (FoodNet). In addition to surveillance of resistance in enteric pathogens, the NARMS program at CDC also includes public health research into the mechanisms of resistance, education efforts to promote prudent use of antimicrobial agents, and studies of resistance in commensal organisms.

Before NARMS was established, CDC monitored antimicrobial resistance in *Salmonella, Shigella*, and *Campylobacter* through periodic surveys of isolates from a panel of sentinel counties. NARMS at CDC began in 1996 with prospective monitoring of antimicrobial resistance among clinical non-Typhi *Salmonella* and *Escherichia coli* O157 isolates in 14 sites. In 1997, testing of clinical *Campylobacter* isolates was initiated in the five sites participating in FoodNet. Testing of clinical *Salmonella enterica* serotype Typhi and *Shigella* isolates was added in 1999. Since 2003, all 50 states have been forwarding a representative sample of non-Typhi *Salmonella, Salmonella* ser. Typhi, *Shigella*, and *E. coli* O157 isolates to NARMS for antimicrobial susceptibility testing, and 10 FoodNet states have been participating in *Campylobacter* surveillance.

This annual report includes CDC's surveillance data for 2006 for clinical non-Typhi *Salmonella, Salmonella* ser. Typhi, *Shigella*, *Campylobacter* and *E. coli* O157 isolates. Resistance trends and comparisons with previous years are included when appropriate. Antimicrobial subclasses defined by Clinical and Laboratory Standards Institute (CLSI) are used in data presentation and analysis. CLSI subclasses constitute major classifications of antimicrobial agents, e.g., aminoglycosides and cephalosporins.

This report also includes World Health Organization's categorization of antimicrobials of critical importance to human medicine (Table I) and data from the *Escherichia coli* Resistance Study, which is part of NARMS surveillance of commensal bacteria. Appendix A summarizes the *Escherichia coli* Resistance Surveillance Pilot Study conducted in 2006.

Additional NARMS data and more information about NARMS activities are available at http://www.cdc.gov/narms

Summary of NARMS 2006 Surveillance Data

Population

In 2006, all 50 states participated in NARMS, representing approximately 298 million persons (Table II). Surveillance for antimicrobial resistance included non-Typhi *Salmonella, Salmonella* ser. Typhi, *Shigella*, and *Escherichia coli* O157. *Campylobacter* resistance to antimicrobial agents was monitored in 10 states that comprise the Foodborne Diseases Active Surveillance Network (FoodNet), representing approximately 44.5 million persons (14.9% of the U.S. population).

Clinically Important Antimicrobial Resistance Patterns

In the United States, certain fluoroquinolones (e.g., ciprofloxacin) and third-generation cephalosporins (e.g., ceftriaxone) are antimicrobial agents commonly used to treat severe *Salmonella* infections, including *Salmonella* ser. Typhi, the organism that causes typhoid fever. Fluoroquinolones are also used to treat *Campylobacter* infections. Nalidixic acid is an elementary quinolone; resistance to nalidixic acid correlates with decreased susceptibility or resistance to ciprofloxacin and possible treatment failure. Ceftiofur is a third-generation cephalosporin used in food animals in the United States; resistance to ceftiofur among *Enterobacteriaceae* correlates with decreased susceptibility to ceftriaxone. A substantial proportion of isolates tested by NARMS in 2006 demonstrated resistance to these clinically important antimicrobial agents, as follows:

- 19.6% (160/816) of *Campylobacter* isolates were resistant to the fluoroquinolone ciprofloxacin, compared with 12.9% (28/217) in 1997 (OR=2.0, 95% CI [1.3, 3.1]).
    - 21.6% (21/97) of *Campylobacter coli* isolates were resistant to ciprofloxacin.
    - 19.5% (138/709) of *Campylobacter jejuni* isolates were resistant to ciprofloxacin.
- 2.7% (60/2,184) of non-Typhi *Salmonella* isolates were resistant to the quinolone nalidixic acid, compared with 0.4% (5/1,324) in 1996 (OR=9.5, 95% CI [3.8, 23.8]).
    - *Salmonella* ser. Enteritidis was the most common serotype among nalidixic acid–resistant non-Typhi *Salmonella* isolates: 48.3% (29/60) of quinolone–resistant isolates were serotype Enteritidis.
    - Nalidixic acid resistance in serotype Enteritidis was 7.0% (29/412) in 2006, compared with 0.9% (3/351) in 1996 (OR 95% CI [2.7–45.4]).
- 3.6% (79/2,184) of non-Typhi *Salmonella* isolates were resistant to the third-generation cephalosporin ceftiofur, compared with 0.2% (2/1324) in 1996 (OR=29.8, 95% CI [7.3, 121.7]).
    - *Salmonella* ser. Newport was the most common serotype among ceftiofur–resistant non-Typhi *Salmonella* isolates: 34.1% (27/79) of ceftiofur–resistant isolates were serotype Newport.
    - Ceftiofur resistance among serotype Newport was 12.4% (27/217) in 2006, compared with 0% in 1996.
- 54.0% (175/324) of *Salmonella* ser. Typhi isolates were resistant to the quinolone nalidixic acid, compared with 19.2% (32/167) in 1999 (OR=5.2, 95% CI [3.3, 8.1]).

Multidrug Resistance

Multidrug resistance is described in NARMS by the number of antimicrobial subclasses and also by specific coresistant phenotypes. Antimicrobial subclasses are used as defined by CLSI (Table IV). Multidrug resistance by the number of antimicrobial subclasses is defined as resistance to two or more CLSI subclasses. For non-Typhi *Salmonella*, a common multidrug-resistant phenotype in 2006 includes resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, and tetracycline (ACSSuT). Another common phenotype includes resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline, amoxicillin-clavulanic acid, and ceftiofur, and decreased susceptibility to ceftriaxone (minimum inhibitory concentration ≥2 μg/mL) (MDR-AmpC).

- 14.6% (319/2,184) of non-Typhi *Salmonella* isolates were resistant to two or more CLSI subclasses, and 6.7% (146/2,184) were resistant to five or more CLSI subclasses.
    - Of the 319 non-Typhi *Salmonella* resistant to two or more CLSI subclasses, most were *Salmonella* ser. Typhimurium (34.2%, n=139), followed by serotype Newport (16.1%, n=35). Of the 146 NTS resistant to five or more CLSI subclasses, most were serotype Typhimurium (21.9%, n=89), followed by serotype Newport (12.9%, n=28). Serotypes Typhimurium and Newport were also the second and third most prevalent serotypes, respectively, among NTS submitted to NARMS in 2006.
    - 16.1% (35/217) of *Salmonella* ser. Newport isolates were resistant to two or more CLSI subclasses, and 12.9% (28/217) were resistant to five or more CLSI subclasses.
    - 34.2% (139/407) of *Salmonella* ser. Typhimurium isolates were resistant to two or more CLSI subclasses, and 21.9% (89/407) were resistant to five or more CLSI subclasses.
    - 2.9% (12/412) of *Salmonella* ser. Enteritidis isolates were resistant to two or more CLSI subclasses, and 0.2% (1/412) were resistant to five or more CLSI subclasses.

- 5.5% (121/2,184) of non-Typhi *Salmonella* isolates had the ACSSuT resistance pattern, compared with 8.8% (116/1,324) in 1996 (Table 1.20).
    - 19.7% (80/407) of *Salmonella* ser. Typhimurium isolates were ACSSuT, compared with 33.7% (103/306) in 1996 (OR=0.5, 95% CI [0.3, 0.7]).
    - 12.0% (26/217) of *Salmonella* ser. Newport isolates were ACSSuT, compared with 5.9% (3/51) in 1996.
- 2.0% (43/2,184) of non-Typhi Salmonella isolates had the MDR-AmpC resistance pattern (Table 1.20). These isolates consisted of five different serotypes. In 1996, MDR-AmpC phenotype was not detected in any serotype.
    - 10.6% (23/217) of *Salmonella* ser. Newport isolates were resistant to the MDR-AmpC phenotype, compared with none (0/51) in 1996 (95% CI [1.4, infinity]). Although the prevalence of the MDR-AmpC phenotype was higher than in 1996, prevalence of this phenotype among serotype Newport appears to be decreasing from the apparent peak of 25.0% in 2001.
    - 2.9% (12/407) of *Salmonella* ser. Typhimurium isolates had the MDR-AmpC resistance pattern.

World Health Organization's Categorization of Antimicrobials of Critical Importance to Human Medicine

The World Health Organization (WHO) convened a panel of experts to develop a list of essential antimicrobial agents according to their importance to human medicine. The participants categorized antimicrobial agents as either *Critically Important*, *Highly Important*, or *Important* based upon two criteria: (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non–human sources or diseases caused by organisms that may acquire resistance genes from non–human sources.

- Antimicrobial agents are considered critically important if both criteria (1) and (2) are true.
- Antimicrobial agents are highly important if either criteria (1) or (2) are true.
- Antimicrobial agents are important if neither criterion are true.

Table I: World Health Organization's categorization of antimicrobials of critical importance to human medicine

Critical Importance	Categorization of Antimicrobials	CLSI Subclass	Antimicrobial Agent
I	Critically important	Aminoglycosides	Amikacin
			Gentamicin
			Streptomycin
		Aminopenicillins	Ampicillin
		β-Lactamase inhibitor combinations	Amoxicillin-clavulanic acid
		Cephalosporins (3rd generation)	Ceftriaxone*
		Ketolides	Telithromycin
		Macrolides	Azithromycin
			Erythromycin
		Quinolones	Ciprofloxacin
			Nalidixic acid
II	Highly important	Aminoglycosides	Kanamycin
		Cephalosporin (1st generation)	Cephalothin
		Cephamycins	Cefoxitin
		Folate pathway inhibitors	Trimethoprim-sulfamethoxazole
		Phenicols	Chloramphenicol†
		Sulfonamides	Sulfamethoxazole
			Sulfisoxazole
		Tetracyclines	Tetracycline
III	Important	Lincosamides	Clindamycin

* Ceftiofur, a 3rd generation cephalosporin used in veterinary medicine, was included in NARMS testing since 1996.
† Florfenicol, a phenicol used in veterinary medicine, replaced chloramphenicol in the NARMS *Campylobacter* testing panel in 2005.

Table II: Population size and number of isolates received and tested, NARMS, 2006

State/Site	Population Size*	Non-Typhi *Salmonella*		*Salmonella* Typhi		*Shigella*		*E. coli* O157		*Campylobacter*†	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Alabama	4,587,564	49	(2.2%)	2	(0.6%)	12	(3.0%)	2	(0.9%)		
Alaska	676,301	4	(0.2%)	0	(0.0%)	1	(0.2%)	1	(0.4%)		
Arizona	6,178,251	46	(2.1%)	4	(1.2%)	26	(6.5%)	1	(0.4%)		
Arkansas	2,804,199	21	(1.0%)	1	(0.3%)	4	(1.0%)	6	(2.6%)		
California‡	26,240,388	214	(9.8%)	45	(13.9%)	2	(0.5%)	10	(4.3%)	34	(4.2%)
Colorado	4,751,474	34	(1.6%)	7	(2.2%)	8	(2.0%)	5	(2.1%)	90	(11.0%)
Connecticut	3,487,896	53	(2.4%)	4	(1.2%)	4	(1.0%)	2	(0.9%)	37	(4.5%)
Delaware	850,366	12	(0.5%)	0	(0.0%)	1	(0.2%)	1	(0.4%)		
District of Columbia	585,419	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)		
Florida	18,019,093	47	(2.2%)	15	(4.6%)	0	(0.0%)	0	(0.0%)		
Georgia	9,318,715	102	(4.7%)	5	(1.5%)	55	(13.7%)	29	(12.4%)	144	(17.6%)
Hawaii	1,275,264	15	(0.7%)	5	(1.5%)	3	(0.7%)	1	(0.4%)		
Houston, Texas§	2,169,248	34	(1.6%)	9	(2.8%)	16	(4.0%)	1	(0.4%)		
Idaho	1,461,183	9	(0.4%)	1	(0.3%)	0	(0.0%)	2	(0.9%)		
Illinois	12,759,673	79	(3.6%)	12	(3.7%)	15	(3.7%)	8	(3.4%)		
Indiana	6,294,124	45	(2.1%)	2	(0.6%)	2	(0.5%)	2	(0.9%)		
Iowa	2,967,270	18	(0.8%)	0	(0.0%)	4	(1.0%)	3	(1.3%)		
Kansas	2,756,267	13	(0.6%)	0	(0.0%)	5	(1.2%)	1	(0.4%)		
Kentucky	4,199,440	30	(1.4%)	2	(0.6%)	9	(2.2%)	4	(1.7%)		
Los Angeles¶	9,880,908	63	(2.9%)	17	(5.2%)	6	(1.5%)	1	(0.4%)		
Louisiana	4,243,634	43	(2.0%)	0	(0.0%)	5	(1.2%)	4	(1.7%)		
Maine	1,313,355	9	(0.4%)	1	(0.3%)	1	(0.2%)	2	(0.9%)		
Maryland	5,602,258	59	(2.7%)	12	(3.7%)	9	(2.2%)	2	(0.9%)	51	(6.3%)
Massachusetts	6,443,424	64	(2.9%)	3	(0.9%)	10	(2.5%)	3	(1.3%)		
Michigan	10,083,878	47	(2.2%)	5	(1.5%)	4	(1.0%)	2	(0.9%)		
Minnesota	5,143,134	40	(1.8%)	5	(1.5%)	11	(2.7%)	8	(3.4%)	156	(19.1%)
Mississippi	2,896,713	36	(1.6%)	2	(0.6%)	1	(0.2%)	1	(0.4%)		
Missouri	5,832,977	55	(2.5%)	2	(0.6%)	24	(6.0%)	6	(2.6%)		
Montana	945,428	4	(0.2%)	0	(0.0%)	1	(0.2%)	1	(0.4%)		
Nebraska	1,759,779	14	(0.6%)	1	(0.3%)	7	(1.7%)	4	(1.7%)		
Nevada	2,484,196	18	(0.8%)	1	(0.3%)	7	(1.7%)	6	(2.6%)		
New Hampshire	1,308,824	10	(0.5%)	0	(0.0%)	1	(0.2%)	1	(0.4%)		
New Jersey	8,640,218	56	(2.6%)	27	(8.3%)	16	(4.0%)	12	(5.2%)		
New Mexico	1,937,916	13	(0.6%)	0	(0.0%)	9	(2.2%)	1	(0.4%)	41	(5.0%)
New York**	11,116,461	92	(4.2%)	13	(4.0%)	5	(1.2%)	34	(14.6%)	130	(15.9%)
New York City††	8,250,567	77	(3.5%)	52	(16.0%)	13	(3.2%)	6	(2.6%)		
North Carolina	8,845,343	82	(3.8%)	5	(1.5%)	3	(0.7%)	3	(1.3%)		
North Dakota	636,453	3	(0.1%)	0	(0.0%)	11	(2.7%)	6	(2.6%)		
Ohio	11,458,390	62	(2.8%)	9	(2.8%)	6	(1.5%)	7	(3.0%)		
Oklahoma	3,568,132	29	(1.3%)	0	(0.0%)	7	(1.7%)	2	(0.9%)		
Oregon	3,680,968	25	(1.1%)	3	(0.9%)	6	(1.5%)	3	(1.3%)	93	(11.4%)
Pennsylvania	12,388,055	92	(4.2%)	7	(2.2%)	2	(0.5%)	3	(1.3%)		
Rhode Island	1,058,991	8	(0.4%)	2	(0.6%)	1	(0.2%)	1	(0.4%)		
South Carolina	4,324,799	9	(0.4%)	1	(0.3%)	1	(0.2%)	0	(0.0%)		
South Dakota	787,380	8	(0.4%)	1	(0.3%)	10	(2.5%)	3	(1.3%)		
Tennessee	6,068,306	91	(4.2%)	1	(0.3%)	9	(2.2%)	1	(0.4%)	40	(4.9%)
Texas‡‡	21,198,286	66	(3.0%)	12	(3.7%)	10	(2.5%)	1	(0.4%)		
Utah	2,585,155	3	(0.1%)	2	(0.6%)	0	(0.0%)	0	(0.0%)		
Vermont	620,196	5	(0.2%)	0	(0.0%)	1	(0.2%)	1	(0.4%)		
Virginia	7,628,347	64	(2.9%)	20	(6.2%)	6	(1.5%)	6	(2.6%)		
Washington	6,360,529	37	(1.7%)	2	(0.6%)	8	(2.0%)	7	(3.0%)		
West Virginia	1,806,760	22	(1.0%)	0	(0.0%)	3	(0.7%)	5	(2.1%)		
Wisconsin	5,568,505	46	(2.1%)	4	(1.2%)	11	(2.7%)	8	(3.4%)		
Wyoming	512,573	7	(0.3%)	0	(0.0%)	10	(2.5%)	3	(1.3%)		
Total	**298,362,973**	**2184**	**(100.0%)**	**324**	**(100.0%)**	**402**	**(100.0%)**	**233**	**(100.0%)**	**816**	**(100.0%)**

* US Census Bureau, 2006

† *Campylobacter* isolates are submitted only from FoodNet sites; total population size of FoodNet sites was 44,531,182

‡ Excluding Los Angeles County

§ Houston City

¶ Los Angeles County

** Excluding New York City

†† Five burroughs of New York City (Bronx, Brooklyn, Manhattan, Queens, Staten Island)

‡‡

Table III: Summary of trend analysis of the proportion of specific resistance phenotypes among *Campylobacter*, non-Typhi *Salmonella*, and *Salmonella* ser. Typhi isolates, 2006

Resistance Phenotype	Reference Year	Odds Ratio	[95% CI]*
Ciprofloxacin resistance in *Campylobacter*	1997	2.0	[1.3–3.1]
Nalidixic acid resistance in non-Typhi *Salmonella*	1996	9.5	[3.8–23.8]
Nalidixic acid resistance in *Salmonella* ser. Enteritidis	1996	–†	[2.7–45.4]†
Ceftiofur resistance in non-Typhi *Salmonella*	1996	29.8	[7.3–121.7]
Nalidixic acid resistance in *Salmonella* ser.Typhi	1999	5.2	[3.3–8.1]
ACSSuT resistance in *Salmonella* ser. Typhimurium‡	1996	0.5	[0.3–0.7]
MDR-AmpC resistance in *Salmonella* ser. Newport§	1996	–†	[1.4–infinity]†

* For logistic regression models that adjusted for site, odds ratios (ORs) (2006 vs. reference year) and 95% confidence intervals (CIs) were calculated using unconditional maximum likelihood estimation.
† Model included only year. In the analysis, the maximum likelihood estimate of the OR did not exist; only the 95% CIs, calculated using exact unconditional methods, are reported.
‡ Resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, and tetracycline.
§ Resistance to at least ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline, amoxicillin-clavulanic acid, and ceftiofur, and decreased susceptibility to ceftriaxone (MIC ≥ 2 μg/mL).

Surveillance and Laboratory Testing Methods

Surveillance Sites and Isolate Submissions

In 2006, NARMS conducted nationwide surveillance among approximately 298 million persons (2006 U.S. Census Bureau estimates). Public health laboratories systematically selected every 20th non-Typhi *Salmonella* (i.e., all *Salmonella* serotypes except serotype Typhi), *Shigella*, and *Escherichia coli* O157 isolate as well as every *Salmonella* ser. Typhi isolate received at their laboratories and forwarded these isolates to CDC for antimicrobial susceptibility testing.

Starting in 2005, a new scheme for *Campylobacter* isolate submission was initiated. Public health laboratories of the 10 state health departments that participated in CDC's Foodborne Diseases Active Surveillance Network (FoodNet) forwarded a representative sample of *Campylobacter* isolates to CDC for susceptibility testing. The FoodNet sites, representing approximately 45 million persons (2006 U.S. Census Bureau estimates), included California, Colorado, Connecticut, Georgia, Maryland, Minnesota, New Mexico, New York, Oregon, and Tennessee. Depending on burden of *Campylobacter* in each FoodNet site, one of three methods was used to obtain a representative sample of *Campylobacter* isolates for submission to CDC: all isolates received by Georgia, Maryland, New Mexico, Oregon, and Tennessee; every other isolate from California, Colorado, Connecticut, and New York; and every fifth isolate from Minnesota. From 1997 to 2004, one *Campylobacter* isolate was submitted each week from participating FoodNet sites to NARMS. This submission scheme was described in the 2004 NARMS Annual Report.

Testing of *Salmonella*, *Shigella*, and *Escherichia coli* O157

Antimicrobial Susceptibility Testing

Salmonella, *Shigella*, and *E. coli* O157 isolates were tested using broth microdilution (Sensititre®, Trek Diagnostics, Westlake, OH) to determine the minimum inhibitory concentration (MIC) for each of 15 antimicrobial agents: amikacin, ampicillin, amoxicillin-clavulanic acid, cefoxitin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfisoxazole, tetracycline, and trimethoprim-sulfamethoxazole (Table IV). Before 2004, sulfamethoxazole was used instead of sulfisoxazole to represent the sulfonamides. Interpretive criteria defined by CLSI were used when available. The resistance breakpoint for amikacin, according to CLSI guidelines, is ≥64 µg/mL. In 2002 and 2003, a truncated broth microdilution series was used for amikacin testing (0.5-4 µg/mL). For isolates that grew in all amikacin dilutions on the Sensititre panel (MIC>4 µg/mL), ETest (AB BIODISK, Solna, Sweden) was performed to determine amikacin MIC. The amikacin ETest strip range of dilutions was 0.016-256 µg/mL. Since 2004, amikacin had a full range of dilutions (0.5-64 µg/mL) on the Sensititre panel (CMV1AGNF).

Table IV: Antimicrobial agents used for susceptibility testing for *Salmonella*, *Shigella*, and *Escherichia coli* O157 isolates, NARMS, 2006

CLSI Subclass	Antimicrobial Agent	Antimicrobial Agent Concentration Range (μg/mL)	Breakpoints		
			Susceptible	Intermediate	Resistant
Aminoglycosides	Amikacin	0.5–64	≤16	32	≥64
	Gentamicin	0.25–16	≤4	8	≥16
	Kanamycin	8–64	≤16	32	≥64
	Streptomycin*	32–64	≤32		≥64
Aminopenicillins	Ampicillin	1–32	≤8	16	≥32
β-Lactamase inhibitor combinations	Amoxicillin-clavulanic acid	1/0.5–32/16	≤8 / ≤4	16/8	≥32 / ≥16
Cephalosporin (1st generation)	Cephalothin†	2–32	≤8	16	≥32
Cephalosporins (3rd generation)	Ceftiofur	0.12–8	≤2	4	≥8
	Ceftriaxone	0.25–64	≤8	16–32	≥64
Cephamycins	Cefoxitin	0.5–32	≤8	16	≥32
Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	0.12/2.4–4/76	≤2 / ≤38		≥4 / ≥76
Phenicols	Chloramphenicol	2–32	≤8	16	≥32
Quinolones	Ciprofloxacin	0.015–4	≤1	2	≥4
	Nalidixic acid	0.5–32	≤16		≥32
Sulfonamides‡	Sulfamethoxazole	16–512	≤256		≥512
	Sulfisoxazole	16–256	≤256		≥512
Tetracyclines	Tetracycline	4–32	≤4	8	≥16

* No CLSI breakpoints; resistance breakpoint used in NARMS is ≥64 μg/mL.
† Cephalothin has not been tested since 2003, but was tested in earlier years for *Salmonella*, *Shigella*, and *E. coli* O157.
‡ Sulfamethoxazole, which was tested during 1996–2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Additional Testing of *Salmonella* Strains

Cephalosporin Retesting of Isolates from 1996-1998

Review of *Salmonella* isolates tested in NARMS during 1996 to 1998 gave conflicting cephalosporin susceptibility results. In particular, some isolates previously reported in NARMS as ceftiofur-resistant exhibited a low ceftriaxone MIC and, in some cases, did not exhibit an elevated MIC to other β-lactams. Because these findings suggested that some previously reported results were inaccurate, we retested, using the 2003 NARMS Sensititre® plate, isolates of *Salmonella* tested in NARMS during 1996 to 1998 that exhibited an MIC ≥2 µg/mL to ceftiofur or ceftriaxone. The retest results were first included in the 2003 and 2004 NARMS annual reports.

Serotype Confirmation/Categorization

Salmonella serotype reported by the submitting laboratory was accepted with few exceptions. Serotype was confirmed by CDC for isolates that underwent subsequent molecular analysis for publication. Because of challenges associated with interpretation of tartrate fermentation assays, ability to ferment tartrate was confirmed for isolates reported as *Salmonella* ser. Paratyphi B by the submitting laboratory (serotype Paratyphi B is by definition unable to ferment L(+) tartrate). To distinguish *Salmonella* serotypes Paratyphi B and Paratyphi B var L(+) tartrate+ (formerly serotype Java), CDC performed Jordan's tartrate test and/or Kauffmann's tartrate test on all *Salmonella* ser. Paratyphi B isolates from 1996 to 2006 for which the tartrate result was not reported or was reported to be negative. Isolates negative for tartrate fermentation by both assays were categorized as serotype Paratyphi B. Isolates that were positive for tartrate fermentation by either assay were categorized as serotype Paratyphi B var L(+) tartrate+. Confirmation of other biochemical reactions or somatic and flagellar antigens was not performed at CDC.

Because of increased submissions of *Salmonella* ser. I 4,[5],12:i:- in 2006,, and recognition of the possibility that this serotype may have been under reported in previous years, isolates reported as serogroup B and tested in NARMS during 1996 to 2006 were reviewed for additional information; isolates that could be clearly identified as serogroup B, first-phase flagellar antigen "i", second phase flagellar antigen absent were categorized in this report as *Salmonella* ser. I 4,[5],12:i:-.

Testing of *Campylobacter*

Changes in testing methods in 2005

Starting in 2005, there were two major changes in the methodology used for *Campylobacter*. First, a surveillance scheme for selecting a representative sample of *Campylobacter* isolates for submission by FoodNet sites was implemented in 2005, which changed from a previous scheme that selected one *Campylobacter* isolate each week for submission during 1997 to 2004. In 2005 and 2006, *Campylobacter* isolates were susceptibility tested using Sensititre (Trek Diagnostics, Westlake, OH); isolates had been tested by Etest (AB BIODISK, Solna, Sweden) from 1997 to 2004. Second, florfenicol replaced chloramphenicol as the phenicol subclass representative drug, and telithromycin was added to the NARMS panel of agents tested in 2005.

Identification/Speciation and Antimicrobial Susceptibility Testing

In 2005 and 2006, isolates were confirmed as *Campylobacter* by determination of typical morphology using dark-field microscopy, and reactivity to catalase and oxidase tests. Identification of *C. jejuni* was performed using the hippurate hydrolysis test. Hippurate-positive isolates were identified as *C. jejuni*. Hippurate-negative isolates were further characterized with polymerase chain reaction (PCR) assay with specific targets for C. *jejuni (mapA or hipO* gene*)* or C. *coli*-specific *ceuE* gene (Linton et al 1997, Gonzales et al. 1997, Pruckler et al. 2006). The same methodology was used during 1997–2002.

In 2003 and 2004, putative *Campylobacter* isolates were identified as *C. jejuni* or *C. coli* using BAX® System PCR Assay according to the manufacturer's instructions (DuPont Qualicon, Wilmington, DE). Isolates not identified as *C. jejuni* or *C. coli* were further characterized by other PCR assays (Linton et al. 1996) or sent to the CDC *Campylobacter* Reference Laboratory.

Beginning in 2005, the broth microdilution methodology (Sensititre®,Trek Diagnostics, Westlake, OH) was used to determine the MICs for nine antimicrobial agents: azithromycin, ciprofloxacin, clindamycin, erythromycin, florfenicol, gentamicin, nalidixic acid, telithromycin, and tetracycline (Table V). Florfenicol replaced chloramphenicol in the NARMS panel to represent the phenicol antimicrobial subclass. Similar to the 2004 report, CLSI interpretive criteria for erythromycin, ciprofloxacin, and tetracycline (published in 2006) and revised NARMS criteria for azithromycin were used for all years in this report. In annual reports published before 2004, these CLSI interpretive criteria were not available, and NARMS used resistance breakpoints for azithromycin and erythromycin that were lower than the new and revised breakpoints. In addition, revised NARMS interpretive criteria, adopted from the FDA-CVM arm of NARMS, have been used for clindamycin, gentamicin, and nalidixic acid since 2004. From 1997 to 2004, Etest® (AB Biomerieux, Solna, Sweden)was used for susceptibility testing of *Campylobacter* isolates.

Table V: Antimicrobial agents used for susceptibility testing of *Campylobacter* isolates, NARMS, 1997–2006

CLSI Subclass	Antimicrobial Agent	Antimicrobial Agent Concentration Range (µg/mL)	Breakpoints		
			Susceptible	Intermediate	Resistant
Aminoglycosides	Gentamicin	0.12–32 0.016–256*	≤2	4	≥8
Ketolides	Telithromycin†	0.015–8	≤4	8	≥16
Lincosamides	Clindamycin	0.03–16 0.016–256*	≤2	4	≥8
Macrolides	Azithromycin	0.015–64 0.016–256*	≤2	4	≥8
	Erythromycin	0.03–64 0.016–256*	≤8	16	≥32
Phenicols	Chloramphenicol‡	0.016–256*	≤8	16	≥32
	Florfenicol§	0.03–64	≤4	N/A	N/A
Quinolones	Ciprofloxacin	0.015–64 0.002–32*	≤1	2	≥4
	Nalidixic acid	4–64 0.016–256*	≤16	32	≥64
Tetracyclines	Tetracycline	0.06–64 0.016–256*	≤4	8	≥16

* Etest dilution range used from 1997–2004.
† Telithromycin added to NARMS panel in 2005.
‡ Chloramphenicol, tested from 1997–2004, was replaced by florfenicol in 2005.
§ Currently only a susceptible breakpoint has been established. In this report isolates with a MIC ≥8 µg/mL are categorized as resistant.

Retesting

Known mechanisms of quinolone resistance in *Campylobacter* are expected to confer equivalent susceptibilities to nalidixic acid and ciprofloxacin. Similarly, known mechanisms of macrolide resistance are expected to confer equivalent susceptibilities to erythromycin and azithromycin. Confirmatory testing of isolates with conflicting results was performed by broth microdilution methods (Sensititre®, Trek Diagnostics, Westlake, OH). Totals reported here reflect the retest results.

Data Analysis

For all pathogens, MICs were categorized as resistant, intermediate (if applicable), or susceptible. Analysis was restricted to one isolate (per genus under surveillance) per patient based on the first isolate collected for non-Typhi *Salmonella*, *E.coli* 0157*, Shigella,* and *Campylobacter.* If two or more isolates were received for the same patient for *Salmonella* Typhi, the first blood isolate collected would be included in analysis. If no blood isolates were submitted, the first isolate collected would be included in analysis. Where established, CLSI interpretive criteria were used; streptomycin resistance was defined as MIC ≥64 µg/mL (Table IV). The 95% confidence intervals (CIs) for the percentage of resistant isolates are included in the MIC distribution tables. The 95% CIs were calculated using the Clopper-Pearson exact method. Multidrug resistance by CLSI antimicrobial subclass was defined as resistance to two or more subclasses.

When describing results for several years, multidrug resistance for *Salmonella* and *E. coli* O157 isolates was limited to the nine CLSI subclasses tested in all years from 1996 through 2005 represented by 13 agents: amoxicillin-clavulanic acid, ampicillin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline, and trimethoprim-sulfamethoxazole. For *Salmonella* ser. Typhi and *Shigella,* results for several years included the nine CLSI subclasses tested in all years from 1999 through 2006 represented by 14 agents (13 antimicrobial agents mentioned above and amikacin). Similarly, when describing multidrug resistance for several years for *Campylobacter* isolates, multidrug resistance was limited to the five CLSI subclasses tested in all years from

1997 through 2006, represented by ciprofloxacin, chloramphenicol/florfenicol, clindamycin, erythromycin, nalidixic acid, and tetracycline.

Logistic regression was performed to assess the change in antimicrobial resistance among *Salmonella* and *Campylobacter* isolates tested in NARMS in 2006 compared with resistance in the reference years: 1996 for non-Typhi *Salmonella*, 1999 for *Salmonella* ser. Typhi, and 1997 for *Campylobacter*. The analysis included the following:

1. Non-Typhi *Salmonella*: resistance to nalidixic acid, resistance to ceftiofur, resistance to one or more CLSI subclasses
2. *Salmonella* ser. Typhimurium: resistance to at least ACSSuT
3. *Salmonella* ser. Enteritidis: resistance to nalidixic acid
4. *Salmonella* ser. Newport: resistance to at least MDR-AmpC
5. *Salmonella* ser. Typhi: resistance to nalidixic acid
6. *Campylobacter* species: resistance to ciprofloxacin
7. *C. jejuni*: resistance to ciprofloxacin

The final regression models for non-Typhi *Salmonella,* and final models for serotypes Typhimurium and Typhi, adjusted for site using the nine Public Health Service geographic regions described in the Public Health Laboratory Information System (PHLIS [http://www.cdc.gov/ncidod/dbmd/phlisdata/]) based on the patient's state of residence. The PHLIS regions are East North Central, East South Central, Mid-Atlantic, Mountain, New England, Pacific, South Atlantic, West North Central, and West South Central. For all regression models that adjusted for site, odds ratios (ORs), and 95% confidence intervals (CIs) were calculated using unconditional maximum likelihood estimation. In the final regression models for serotypes Enteritidis and Newport, which included only year and used exact unconditional methods, the maximum likelihood estimate of the OR did not exist; only the 95% CIs are reported. For *Campylobacter*, the final regression models adjusted for site using patient's state of residence. The adequacy of model fit was assessed in several ways. The significance of the main effect of year was assessed using the likelihood ratio test. The likelihood ratio test was also used to test for significance of interaction between site and year, although the power of the test to detect a single site-specific interaction was low. The Hosmer and Lemeshow goodness-of-fit test also was used. Finally, residual analysis was performed to examine the influence of individual observations. Having assessed that the main effect of year was significant, we reported odds ratios (for 2006 vs. the reference year) that did not include 1.0 in the 95% CI as significant.

Results

1. Non-Typhi *Salmonella*

In non-Typhi *Salmonella*, an increase in resistance to two clinically important subclasses, (quinolones, represented by nalidixic acid and third-generation cephalosporins, represented by ceftiofur), was observed from 1996 to 2006. Nalidixic acid resistance increased from 0.4% to 2.7% and ceftiofur resistance increased from 0.2% to 3.6%. Resistance to at least ACSSuT was one of the most common multidrug-resistance phenotypes in 2006. This phenotype was found among 5.5% of non-Typhi *Salmonella* isolates, lower in prevalence than in 2005 (6.9%), and 1996 (8.8%).

In 2006, CDC received 2,276 non-Typhi *Salmonella* isolates, of which 2,184 (96.0%) were viable non-duplicates and tested for antimicrobial susceptibility (Table II). The antimicrobial agent with the highest prevalence of resistance was tetracycline (13.4%), followed by sulfisoxazole (12.0%), ampicillin (10.9%), and streptomycin (10.7%).

Fluoroquinolones (e.g., ciprofloxacin) and third-generation cephalosporins (e.g., ceftriaxone) are commonly used to treat severe *Salmonella* infections. Nalidixic acid is an elementary quinolone; resistance to nalidixic acid correlates with decreased susceptibility to ciprofloxacin and possible treatment failure. Ceftiofur is a third-generation cephalosporin used in food animals in the United States; resistance to ceftiofur correlates with decreased susceptibility to ceftriaxone. In 2006, the prevalence of resistance among non-Typhi *Salmonella* isolates was 2.7% for quinolones (represented by nalidixic acid) and 3.6% for third-generation cephalosporins (represented by ceftiofur) (Table 1.02).

The prevalence of nalidixic acid resistance increased from 0.4% (5/1,324) in 1996 to 2.7% (60/2,184) in 2006 (Table 1.02), a statistically significant increase (OR=9.5, 95% CI [3.8, 23.8]). The prevalence of ceftiofur resistance increased from 0.2% (2/1,324) in 1996 to 3.6% (79/2,184) in 2006, a statistically significant increase (OR=29.8, 95% CI [7.3, 121.7]).

Of the 2,184 non-Typhi *Salmonella* isolated in 2006, 1,752 (80.2%) showed no resistance to the drugs tested, similar to 2005 (80.6%) (Table 1.03). In 2006, 432 (19.8%) were resistant to one or more CLSI subclasses, 319 (14.6%) to two or more subclasses, 258 (11.8%) to three or more subclasses, 183 (8.4%) to four or more subclasses, and 146 (6.7%) to five or more subclasses. There was a statistically significant decline in resistance to one or more subclass from 33.8% in 1996 to 19.8% in 2006 (OR=0.6, 95% CI [0.5, 0.7]).

In 2006, resistance to at least ACSSuT was one of the most common multidrug-resistance phenotypes. This phenotype was found among 5.5% of non-Typhi *Salmonella* isolates, lower in prevalence than in 2005 (6.9%), and 1996 (8.8%). Another common multidrug-resistant phenotype among non-Typhi *Salmonell*a was resistance to at least MDR-AmpC, and 2.0% of the isolates displayed this pattern. The prevalence of the MDR-AmpC phenotype increased from 0% (0/1,324) in 1996 to 2.0% (43/2,184) in 2006. Isolates that demonstrate the MDR-AmpC phenotype also exhibit decreased susceptibility (≥2 µg/mL) to ceftriaxone. Six (0.3%) isolates were resistant to both nalidixic acid and ceftiofur (Table 1.03); this pattern was first detected in 1997.

In 2006, serotypes were identified for a higher proportion of isolates in NARMS (97.3%) than in the Public Health Laboratory Information System (PHLIS) (86.1%) (Table 1.04). The 20 most common serotypes accounted for 81.8% of isolates in NARMS and 70.2% in PHLIS. The same three most common serotypes were reported in NARMS and PHLIS, which accounted for 47.4% of isolates in NARMS and 41.9% in PHLIS. In NARMS; 2.2% of isolates were not completely serotyped in 2006, which was an increase compared with 1.0% in 2005. In 2006 *Salmonella* ser. Enteritidis was the most commonly reported serotype, whereas Typhimurium was the most common serotype reported to NARMS in previous years. *Salmonella* subspecies I 4,[5],12:i:- was the fourth most prevalent serotype reported to NARMS in 2006, whereas it was the 12th most common in 2005. It is not yet clear whether isolation rates or changes in reporting are responsible for these serotype prevalence changes.

Figure 1.01: How to read a squashtogram

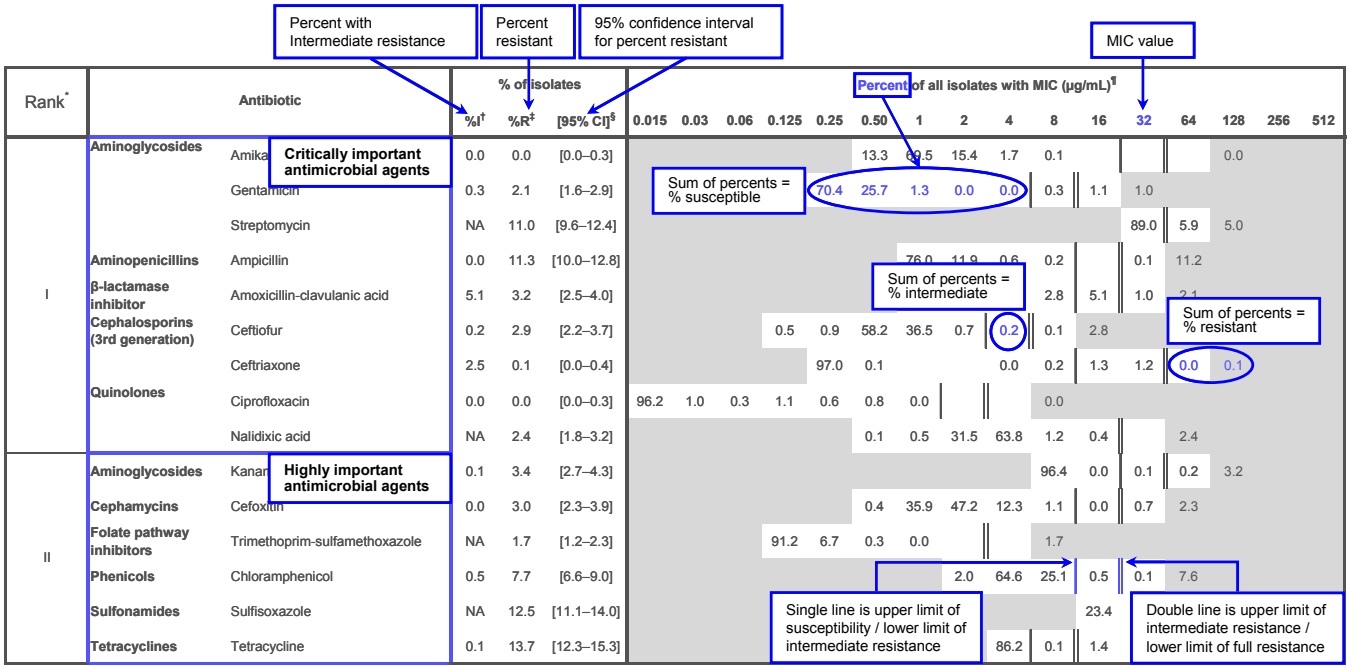


Figure 1.02: Proportional chart, a categorical graph of a squashtogram

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶													
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–0.9]						2.9	74.4	20.9	1.7							
		Gentamicin	0.2	2.7	[1.4–4.8]					60.0	34.6	2.5			0.2	1.0	1.7				
		Streptomycin	NA	29.5	[25.1–34.2]												70.5	17.2	12.3		
	Aminopenicillins	Ampicillin	0.0	28.3	[23.9–32.9]							61.4	10.1	0.2				28.3			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	14.5	4.4	[2.6–6.9]							69.8	2.0	0.7	8.6	14.5	0.2	4.2			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	4.2	[2.5–6.6]					0.5	48.9	45.7	0.7			4.2					
		Ceftriaxone	2.2	0.2	[0.0–1.4]					95.8					1.7	1.0	1.2	0.2			
	Quinolones	Ciprofloxacin	0.0	0.2	[0.0–1.4]	96.3	2.0		0.2	0.2	1.0				0.2						
		Nalidixic acid	NA	0.7	[0.2–2.1]							0.2	48.4	49.1	0.7	0.7		0.7			
II	**Aminoglycosides**	Kanamycin	0.0	5.2	[3.2–7.8]										94.6	0.2			5.2		
	Cephamycins	Cefoxitin	0.2	3.9	[2.3–6.3]							26.8	60.4	7.4	1.2	0.2	2.2	1.7			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	2.2	[1.0–4.2]				75.9	21.4	0.2	0.2			2.2						
	Phenicols	Chloramphenicol	0.7	22.1	[18.2–26.5]								2.5	49.9	24.8	0.7		22.1			
	Sulfonamides	Sulfisoxazole	NA	33.4	[28.8–38.2]											11.3	51.6	3.7			33.4
	Tetracyclines	Tetracycline	0.0	31.7	[27.2–36.5]									68.3		3.9	13.0	14.7			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

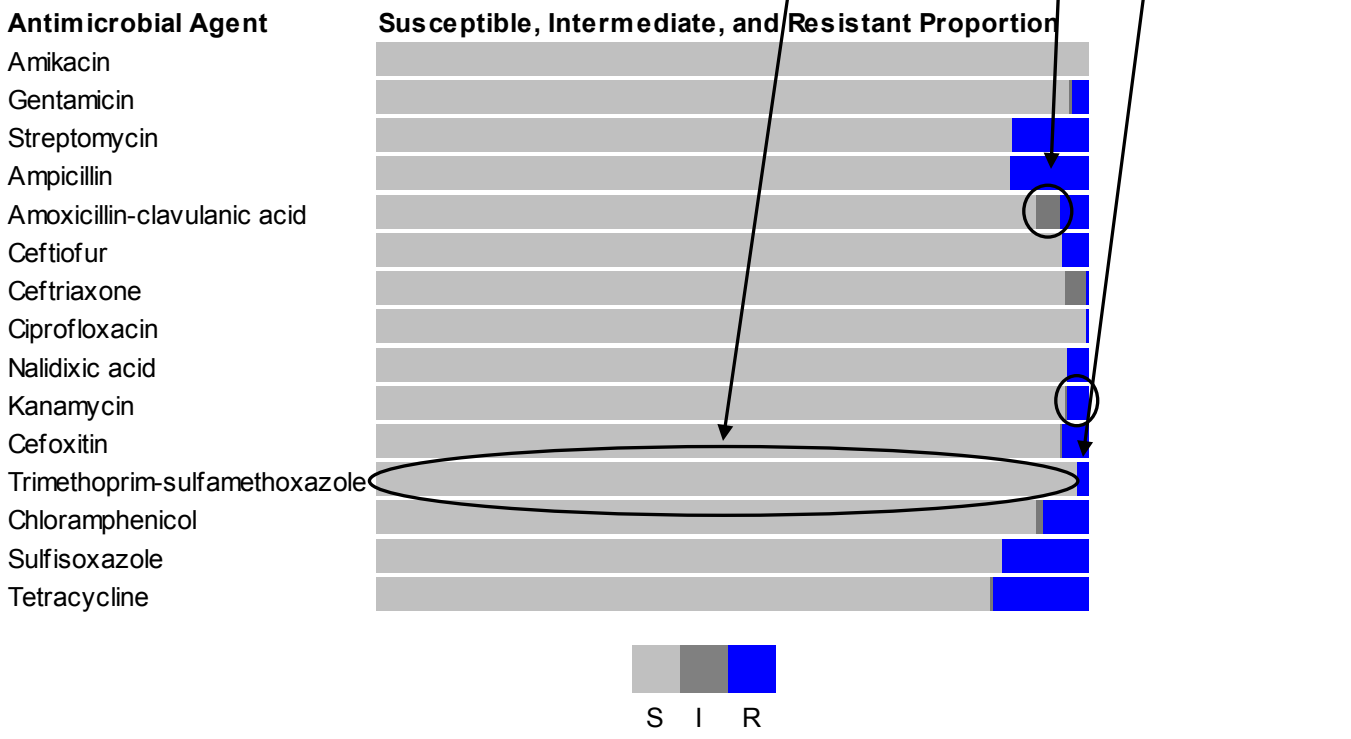


Table 1.01: Minimum inhibitory concentrations (MICs) and resistance of non-Typhi *Salmonella* isolates to antimicrobial agents, 2006 (N=2,184)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–0.2]						9.9	69.8	18.5	1.7	0.1	0.0					
		Gentamicin	0.5	2.0	[1.5–2.7]					64.6	31.7	1.1	0.2	0.0	0.5	0.7	1.3				
		Streptomycin	NA	10.7	[9.4–12.0]												89.3	5.3	5.4		
	Aminopenicillins	Ampicillin	0.0	10.9	[9.6–12.3]							79.6	8.9	0.5				10.9			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	3.5	3.7	[3.0–4.6]							86.5	2.5	0.6	3.2	3.5	1.4	2.3			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	3.6	[2.9–4.5]				0.2	0.7	49.7	45.0	0.8		0.0	3.6					
		Ceftriaxone	2.8	0.2	[0.0–0.5]					96.3	0.0			0.1	0.5	1.5	1.4	0.1	0.1		
	Quinolones	Ciprofloxacin	0.0	0.1	[0.0–0.3]	94.2	2.5	0.2	1.4	0.7	0.8	0.0			0.1						
		Nalidixic acid	NA	2.7	[2.1–3.5]							0.4	40.7	55.0	0.8	0.3	0.1	2.7			
II	**Aminoglycosides**	Kanamycin	0.2	2.9	[2.2–3.7]										96.7	0.2	0.2	0.0	2.8		
	Cephamycins	Cefoxitin	0.3	3.5	[2.8–4.4]						0.3	28.5	55.4	11.0	0.9	0.3	1.5	2.0			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	1.6	[1.2–2.3]				88.4	9.5	0.4	0.1			1.6						
	Phenicols	Chloramphenicol	0.7	6.4	[5.4–7.5]								1.9	61.0	29.9	0.7		6.4			
	Sulfonamides	Sulfisoxazole	NA	12.0	[10.7–13.5]											14.6	51.6	20.7	1.1	0.0	12.0
	Tetracyclines	Tetracycline	0.1	13.4	[12.0–14.9]									86.5	0.1	1.0	3.9	8.6			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 1.03: Antimicrobial resistance pattern for non-Typhi *Salmonella*, 2006

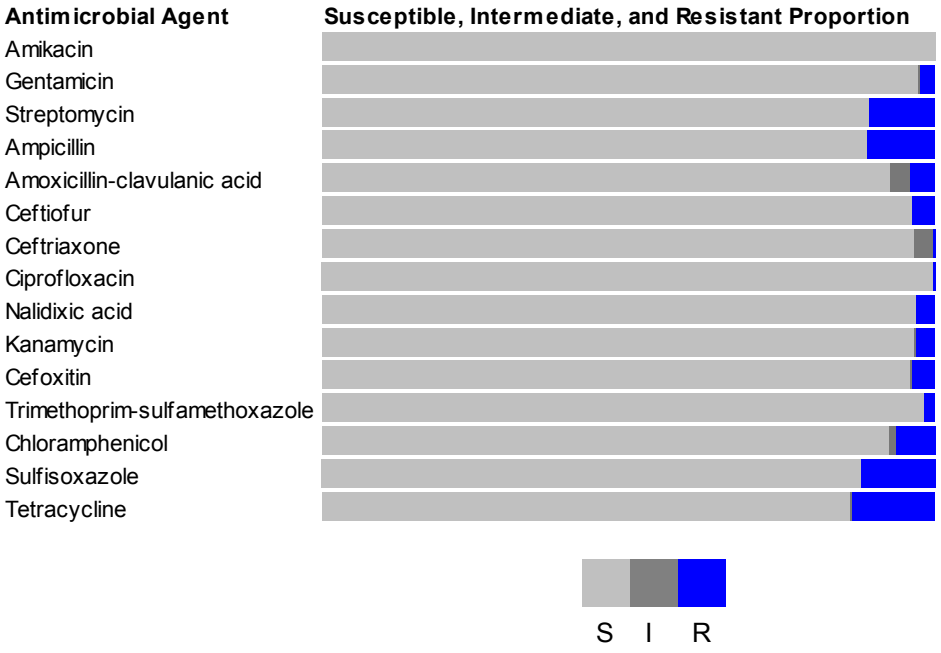


Table 1.02: Percentage and number of non-Typhi *Salmonella* isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			1324	1301	1460	1495	1377	1419	2008	1864	1794	2052	2184
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin	Not	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		(MIC ≥ 64)	Tested	0	0	1	0	0	0	0	0	1	0
		Gentamicin	4.8%	2.9%	2.8%	2.1%	2.7%	1.9%	1.3%	1.4%	1.3%	2.1%	2.0%
		(MIC ≥ 16)	63	38	41	32	37	27	27	26	24	44	44
		Streptomycin	20.6%	21.4%	18.6%	16.7%	16.3%	17.0%	13.2%	15.0%	11.8%	11.0%	10.7%
		(MIC ≥ 64)	273	278	272	250	224	241	265	279	212	225	233
	Aminopenicillins	Ampicillin	20.7%	18.3%	16.5%	15.5%	15.9%	17.4%	12.9%	13.6%	12.0%	11.3%	10.9%
		(MIC ≥ 32)	274	238	241	232	219	247	259	254	216	232	238
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid	1.1%	1.0%	1.7%	2.3%	3.9%	4.7%	5.3%	4.6%	3.7%	3.2%	3.7%
		(MIC ≥ 32)	15	13	25	34	54	66	106	86	67	65	81
	Cephalosporins (3rd generation)	Ceftiofur	0.2%	0.5%	0.8%	2.0%	3.2%	4.1%	4.3%	4.5%	3.4%	2.9%	3.6%
		(MIC ≥ 8)	2	6	12	30	44	58	87	83	61	60	79
		Ceftriaxone	0.0%	0.1%	0.0%	0.3%	0.0%	0.0%	0.2%	0.4%	0.6%	0.1%	0.2%
		(MIC ≥ 64)	0	1	0	5	0	0	4	8	10	3	4
	Quinolones	Ciprofloxacin	0.0%	0.0%	0.1%	0.1%	0.4%	0.2%	0.0%	0.2%	0.2%	0.0%	0.1%
		(MIC ≥ 4)	0	0	1	1	5	3	1	3	4	1	2
		Nalidixic acid	0.4%	0.9%	1.4%	0.9%	2.5%	2.6%	1.8%	2.3%	2.6%	2.4%	2.7%
		(MIC ≥ 32)	5	12	20	14	34	37	36	42	47	50	60
II	Aminoglycosides	Kanamycin	5.0%	5.1%	5.7%	4.3%	5.6%	4.8%	3.8%	3.4%	2.8%	3.4%	2.9%
		(MIC ≥ 64)	66	67	83	65	77	68	76	64	50	70	63
	Cephalosporin (1st generation)	Cephalothin	2.9%	2.2%	2.3%	3.5%	4.0%	4.0%	5.0%	5.4%	Not	Not	Not
		(MIC ≥ 32)	39	29	33	53	55	57	101	100	Tested	Tested	Tested
	Cephamycins	Cefoxitin	Not	Not	Not	Not	3.2%	3.4%	4.3%	4.2%	3.5%	3.0%	3.5%
		(MIC ≥ 32)	Tested	Tested	Tested	Tested	44	48	86	79	62	62	77
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	3.9%	1.8%	2.3%	2.0%	2.1%	2.0%	1.4%	1.9%	1.8%	1.7%	1.6%
		(MIC ≥ 4)	51	24	34	30	29	28	28	36	32	34	36
	Phenicols	Chloramphenicol	10.6%	10.1%	9.9%	9.2%	10.1%	11.6%	8.6%	10.0%	7.6%	7.7%	6.4%
		(MIC ≥ 32)	140	131	145	137	139	164	172	187	136	159	139
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole†	20.3%	22.8%	19.4%	18.0%	17.1%	17.7%	12.8%	15.0%	13.2%	12.5%	12.0%
		(MIC ≥ 512)	269	297	283	269	235	251	258	280	237	256	263
	Tetracyclines	Tetracycline	24.2%	21.7%	20.2%	19.3%	18.6%	19.7%	14.9%	16.3%	13.5%	13.7%	13.4%
		(MIC ≥ 16)	320	282	295	289	256	280	299	303	242	282	293

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 1.03: Resistance patterns of non-Typhi *Salmonella* isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	1324	1301	1460	1495	1377	1419	2008	1864	1794	2052	2184
	%	%	%	%	%	%	%	%	%	%	%
	n	n	n	n	n	n	n	n	n	n	n
No resistance detected	66.2%	68.4%	72.9%	74.2%	74.4%	72.3%	79.0%	77.7%	79.6%	80.6%	80.2%
	876	890	1064	1109	1024	1026	1586	1449	1428	1654	1752
Resistance ≥ 1 CLSI subclass*	33.8%	31.6%	27.1%	25.8%	25.6%	27.7%	21.0%	22.3%	20.4%	19.4%	19.8%
	448	411	396	386	353	393	422	415	366	398	432
Resistance ≥ 2 CLSI subclasses*	27.0%	24.1%	22.6%	20.4%	20.2%	22.1%	15.8%	17.7%	15.0%	14.8%	14.6%
	358	314	330	305	278	314	318	330	269	304	319
Resistance ≥ 3 CLSI subclasses*	18.1%	17.7%	16.7%	15.1%	15.6%	16.8%	12.2%	14.3%	11.7%	12.0%	11.8%
	240	230	244	225	215	239	244	266	210	247	258
Resistance ≥ 4 CLSI subclasses*	13.7%	13.7%	13.1%	12.2%	12.9%	14.2%	9.9%	11.6%	9.4%	9.1%	8.4%
	181	178	191	183	178	202	199	216	168	186	183
Resistance ≥ 5 CLSI subclasses*	10.0%	9.9%	10.1%	8.6%	9.9%	10.5%	8.3%	9.9%	8.1%	7.6%	6.7%
	132	129	147	129	137	149	167	185	146	156	146
At least ACSSuT†	8.8%	9.5%	8.9%	8.4%	8.9%	10.0%	7.8%	9.3%	7.1%	6.9%	5.5%
	116	124	130	125	122	142	156	173	128	141	121
At least ACSuTm‡	0.8%	0.4%	0.9%	0.9%	1.0%	0.5%	1.0%	1.2%	0.6%	0.9%	0.7%
	10	5	13	14	14	7	21	23	10	18	15
At least ACSSuTAuCf§	0.0%	0.3%	0.3%	1.5%	2.6%	2.5%	3.3%	3.2%	2.3%	2.0%	2.0%
	0	4	5	23	36	36	67	60	42	41	43
At least MDR-AmpC¶	0.0%	0.3%	0.3%	1.5%	2.6%	2.5%	3.3%	3.2%	2.3%	2.0%	2.0%
	0	4	5	23	36	36	67	60	42	41	43
Resistance to quinolone** and cephalosporin††	0.0%	0.2%	0.1%	0.1%	0.3%	0.3%	0.2%	0.2%	0.4%	0.3%	0.3%
	0	2	1	1	4	4	5	4	7	7	6

*CLSI: Clinical and Laboratory Standards Institute

†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline

‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole

§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur

¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)

**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)

††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

Table 1.04: Twenty most common non-Typhi *Salmonella* serotypes in NARMS and the Public Health Laboratory Information System, 2006

NARMS		Isolates	
Rank	Serotype	n	(%)
1	Enteritidis	412	(18.9%)
2	Typhimurium	407	(18.6%)
3	Newport	217	(9.9%)
4	I 4,[5],12:i:-	105	(4.8%)
5	Heidelberg	102	(4.7%)
6	Javiana	80	(3.7%)
7	Montevideo	62	(2.8%)
8	Paratyphi B var. L(+) tartrate+	49	(2.2%)
9	Oranienburg	48	(2.2%)
10	Muenchen	45	(2.1%)
11	Agona	42	(1.9%)
12	Saintpaul	30	(1.4%)
13	Braenderup	29	(1.3%)
14	Thompson	26	(1.2%)
15	Stanley	25	(1.1%)
16	Mississippi	24	(1.1%)
17	Infantis	22	(1.0%)
18	Hadar	22	(1.0%)
19	Tennessee	21	(1.0%)
20	Berta	19	(0.9%)
	Subtotal	**1787**	**(81.8%)**
	All other serotypes	339	(15.5%)
	Unknown serotype	6	(0.3%)
	Partially serotyped	49	(2.2%)
	Rough/Nonmotile isolates	3	(0.1%)
	Subtotal	**397**	**(18.2%)**
	Grand Total	**2184**	**(100.0%)**

PHLIS		Isolates	
Rank	Serotype	n	(%)
1	Typhimurium	6872	(17.0%)
2	Enteritidis	6740	(16.6%)
3	Newport	3373	(8.3%)
4	Heidelberg	1495	(3.7%)
5	Javiana	1433	(3.5%)
6	I 4,[5],12:i:-	1200	(3.0%)
7	Montevideo	1061	(2.6%)
8	Muenchen	753	(1.9%)
9	Oranienburg	719	(1.8%)
10	Mississippi	604	(1.5%)
11	Saintpaul	588	(1.5%)
12	Braenderup	561	(1.4%)
13	Agona	538	(1.3%)
14	Infantis	491	(1.2%)
15	Thompson	447	(1.1%)
16	Paratyphi B var. L(+) tartrate+	417	(1.0%)
17	Stanley	315	(0.8%)
18	Tennessee	312	(0.8%)
19	Hadar	275	(0.8%)
20	Bareilly	256	(0.7%)
	Subtotal	**28450**	**(70.2%)**
	All other serotypes	6459	(15.9%)
	Unknown serotype	4042	(10.0%)
	Partially serotyped	1448	(3.6%)
	Rough/Nonmotile isolates	110	(0.3%)
	Subtotal	**12059**	**(29.8%)**
	Grand Total	**40509**	**(100.0%)**

A. *Salmonella* ser. Enteritidis

In 2006, *Salmonella* ser. Enteritidis was the most common non-Typhi *Salmonella* serotype in NARMS. Most serotype Enteritidis isolates had no detected resistance. However, nalidixic acid resistance increased from 0.9% in 1996 to 7.0% in 2006 (95% CI [2.7, 45.4]) (Table 1.06).

In 2006, *Salmonella* ser. Enteritidis was the most common non-Typhi *Salmonella* serotype identified in NARMS, accounting for 18.9% (412/2,184) of non-Typhi *Salmonella* isolates (Table 1.04). Resistance was rare among serotype Enteritidis isolates tested in 2006. Most (88.6%) of the serotype Enteritidis isolates tested in 2006 had no detected resistance (Table 1.07). However, there was a statistically significant increase in nalidixic acid resistance from 0.9% in 1996 to 7.0% in 2006 (95% CI [2.7, 45.4]) (Table 1.06). Serotype Enteritidis was the most prevalent (48.3%) non-Typhi *Salmonella* serotype that had resistance to nalidixic acid (Table 1.20).

Table 1.05: Minimum inhibitory concentrations (MICs) and resistance of *Salmonella* ser. Enteritidis isolates to antimicrobial agents, 2006 (N=412)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–0.9]						25.5	63.8	9.5	1.2						
		Gentamicin	0.0	0.2	[0.0–1.3]					82.5	16.7	0.5					0.2			
		Streptomycin	NA	1.2	[0.4–2.8]												98.8	0.2	1.0	
	Aminopenicillins	Ampicillin	0.0	4.4	[2.6–6.8]							84.5	11.2					4.4		
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	0.5	0.5	[0.1–1.7]							93.4	2.2	1.2	2.2	0.5	0.2	0.2		
	Cephalosporins (3rd generation)	Ceftiofur	0.0	0.5	[0.1–1.7]				0.2	0.5	30.1	68.4	0.2			0.5				
		Ceftriaxone	0.0	0.0	[0.0–0.9]					99.5					0.5					
	Quinolones	Ciprofloxacin	0.0	0.0	[0.0–0.9]	86.7	6.1	0.2	5.6	1.2	0.2									
		Nalidixic acid	NA	7.0	[4.8–10.0]								18.9	73.1	0.7	0.2		7.0		
II	**Aminoglycosides**	Kanamycin	0.0	0.2	[0.0–1.3]										99.8				0.2	
	Cephamycins	Cefoxitin	0.0	0.5	[0.1–1.7]						0.5	25.5	69.9	3.4	0.2		0.5			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	0.5	[0.1–1.7]				90.3	8.7	0.5				0.5					
	Phenicols	Chloramphenicol	0.0	0.0	[0.0–0.9]								1.5	71.1	27.4					
	Sulfonamides	Sulfisoxazole	NA	1.5	[0.5–3.1]											11.4	63.3	23.3	0.5	1.5
	Tetracyclines	Tetracycline	0.2	1.7	[0.7–3.5]									98.1	0.2		0.2	1.5		

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 1.04: Antimicrobial resistance pattern for *Salmonella* ser. Enteritidis, 2006

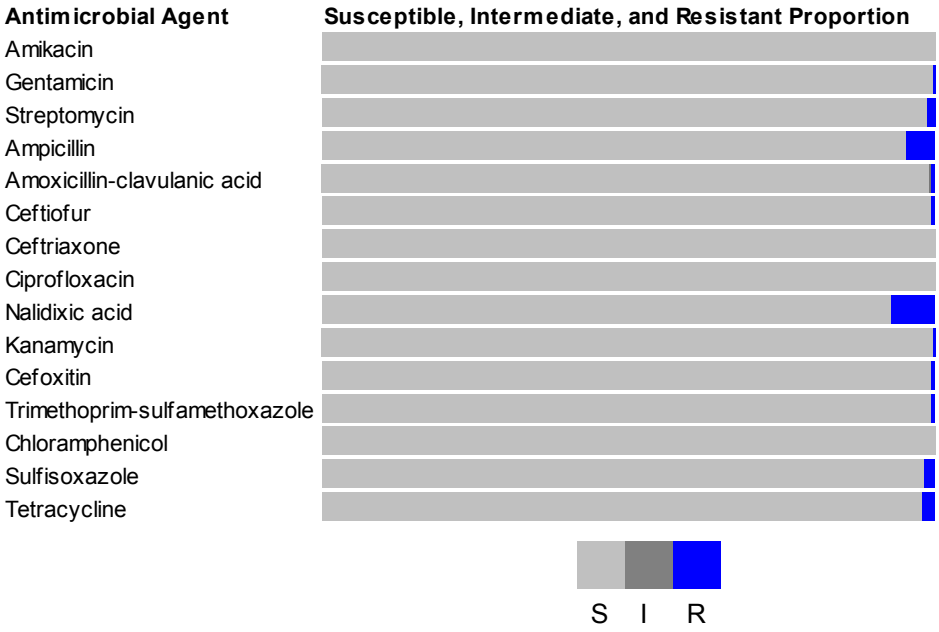


Table 1.06: Percentage and number of *Salmonella* ser. Enteritidis isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			351	301	244	269	319	277	337	257	271	384	412
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin (MIC ≥ 64)	Not Tested	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	4.8% 17	0.3% 1	0.4% 1	0.0% 0	0.3% 1	0.0% 0	0.3% 1	0.4% 1	0.4% 1	0.8% 3	0.2% 1
		Streptomycin (MIC ≥ 64)	2.0% 7	4.3% 13	1.6% 4	2.2% 6	0.0% 0	1.4% 4	1.8% 6	1.2% 3	2.2% 6	1.0% 4	1.2% 5
	Aminopenicillins	Ampicillin (MIC ≥ 32)	20.5% 72	11.3% 34	6.1% 15	10.8% 29	7.5% 24	8.7% 24	7.1% 24	2.3% 6	4.1% 11	2.9% 11	4.4% 18
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	0.6% 2	0.0% 0	0.0% 0	0.4% 1	0.0% 0	1.4% 4	0.6% 2	0.0% 0	0.0% 0	0.8% 3	0.5% 2
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.3% 1	0.0% 0	0.4% 1	0.0% 0	2.2% 6	0.0% 0	0.0% 0	0.0% 0	0.5% 2	0.5% 2
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Nalidixic acid (MIC ≥ 32)	0.9% 3	1.7% 5	2.0% 5	2.2% 6	2.2% 7	4.3% 12	3.9% 13	4.7% 12	6.6% 18	4.7% 18	7.0% 29
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.0% 0	0.7% 2	0.4% 1	0.4% 1	0.3% 1	0.7% 2	0.3% 1	0.0% 0	0.7% 2	0.3% 1	0.2% 1
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	4.0% 14	1.3% 4	0.0% 0	1.9% 5	0.9% 3	1.1% 3	0.6% 2	1.2% 3	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	Not Tested	Not Tested	Not Tested	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.0% 0	1.0% 4	0.5% 2
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	6.6% 23	1.3% 4	0.8% 2	0.7% 2	0.0% 0	0.7% 2	0.6% 2	0.8% 2	0.0% 0	0.5% 2	0.5% 2
	Phenicols	Chloramphenicol (MIC ≥ 32)	0.0% 0	0.7% 2	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.6% 2	0.4% 1	0.4% 1	0.5% 2	0.0% 0
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	8.5% 30	9.0% 27	2.0% 5	3.0% 8	0.9% 3	2.2% 6	1.8% 6	1.2% 3	1.8% 5	1.6% 6	1.5% 6
	Tetracyclines	Tetracycline (MIC ≥ 16)	16.8% 59	9.6% 29	6.6% 16	8.2% 22	1.9% 6	1.8% 5	4.5% 15	1.6% 4	3.3% 9	2.3% 9	1.7% 7

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 1.07: Resistance patterns of *Salmonella* ser. Enteritidis isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	351	301	244	269	319	277	337	257	271	384	412
	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	73.5% 258	77.4% 233	87.7% 214	83.6% 225	89.0% 284	86.6% 240	87.2% 294	91.8% 236	87.1% 236	91.9% 353	88.6% 365
Resistance ≥ 1 CLSI subclass*	26.5% 93	22.6% 68	12.3% 30	16.4% 44	11.0% 35	13.4% 37	12.8% 43	8.2% 21	12.9% 35	8.1% 31	11.4% 47
Resistance ≥ 2 CLSI subclasses*	19.1% 67	9.6% 29	6.6% 16	8.6% 23	1.9% 6	4.7% 13	4.2% 14	2.3% 6	3.0% 8	3.6% 14	2.9% 12
Resistance ≥ 3 CLSI subclasses*	8.0% 28	3.0% 9	0.8% 2	1.1% 3	0.3% 1	2.9% 8	2.4% 8	0.8% 2	1.1% 3	2.1% 8	2.2% 9
Resistance ≥ 4 CLSI subclasses*	4.6% 16	1.3% 4	0.0% 0	0.7% 2	0.0% 0	1.8% 5	1.5% 5	0.4% 1	0.7% 2	0.8% 3	0.7% 3
Resistance ≥ 5 CLSI subclasses*	1.7% 6	0.7% 2	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.3% 1	0.4% 1	0.7% 2	0.5% 2	0.2% 1
At least ACSSuT†	0.0% 0	0.3% 1	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.3% 1	0.4% 1	0.4% 1	0.5% 2	0.0% 0
At least ACSuTm‡	0.0% 0	0.3% 1	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.0% 0
At least ACSSuTAuCf§	0.0% 0	0.0% 0	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0
At least MDR-AmpC¶	0.0% 0	0.0% 0	0.0% 0	0.4% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0
Resistance to quinolone** and cephalosporin††	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.4% 1	0.0% 0	0.3% 1	0.0% 0

*CLSI: Clinical and Laboratory Standards Institute
†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline
‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole
§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur
¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)
**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)
††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

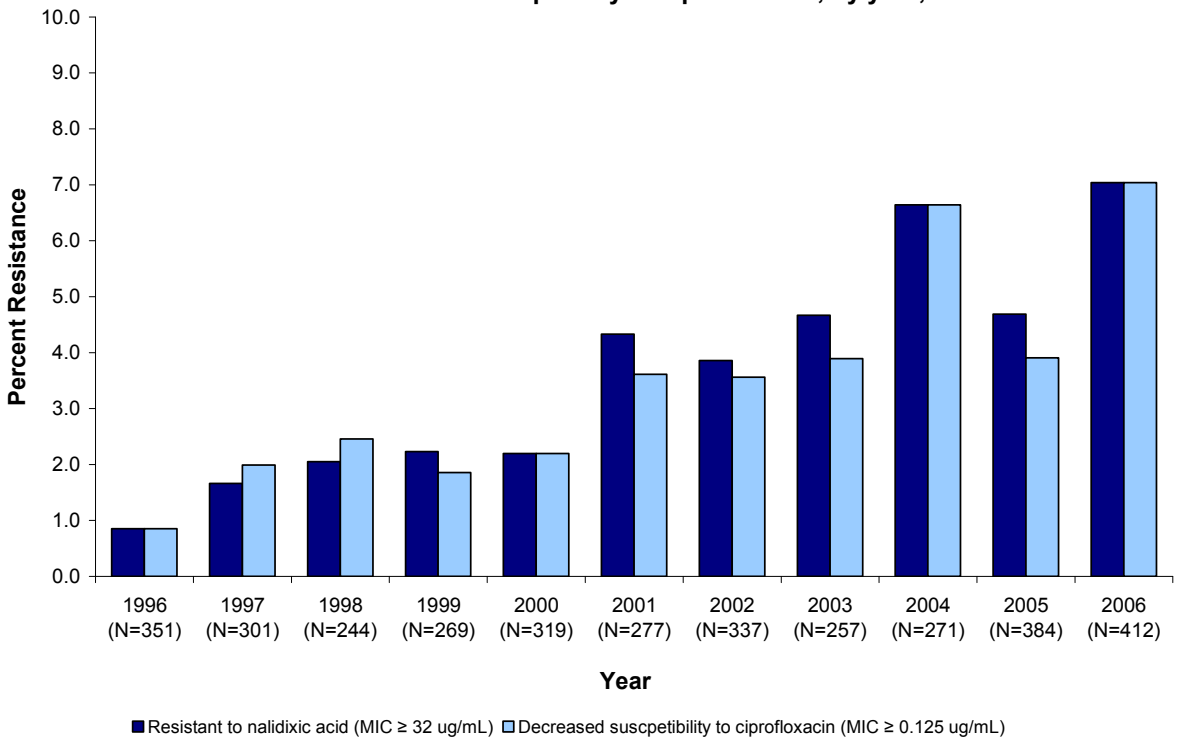
Resistance to nalidixic acid and decreased susceptibility to ciprofloxacin in *Salmonella* ser. Enteritidis, NARMS, 1996–2006

Salmonella ser. Enteritidis is a leading cause of salmonellosis in the United States. Serotype Enteritidis was the most common serotype reported to the National Antimicrobial Resistance Monitoring System (NARMS) and the second most common serotype among culture-confirmed infections reported to National *Salmonella* Surveillance System at CDC in 2006 (http://www.cdc.gov/ncidod/dbmd/phlisdata/default.htm). Consumption of egg-containing products and chicken prepared outside the home are risk factors of human *Salmonella* ser. Enteritidis infections (Altekruse et al. 2006; Voetsch et al. 2009).

While most non-Typhi *Salmonella* infections are self-limiting, antimicrobial agents, such as fluoroquinolones (e.g. ciprofloxacin) are essential to treat invasive infections (Mandell et al. 2000). Resistance to nalidixic acid (MIC ≥ 32 μg/mL), a quinolone, correlates with decreased susceptibility to ciprofloxacin (MIC ≥ 0.125 μg/mL). Enterobacteriaceae, including *Salmonella* spp., most commonly develop resistance to quinolones by acquiring chromosomal point mutations in the genes encoding DNA gyrase (*gyrA*, *gyrB*) and DNA topoisomerase IV (*parC*, *parE*). These mutations prevent quinolone drugs from binding to their targets, thereby enabling the bacteria to replicate (Crump et al. 2003). While a single point mutation is sufficient to confer nalidixic acid resistance, two or more point mutations are required to confer ciprofloxacin resistance according to current CLSI definitions. (Jacoby 2005). Additional plasmid-mediated mechanisms for decreased fluoroquinolone susceptibility include topoisomerase protection by Qnr proteins, acetylation by the Aac (6')-Ib-cr enzyme, and efflux by the QepA pump. Here we describe the trend in resistance to nalidixic acid and decreased susceptibility to ciprofloxacin among *Salmonella* ser. Enteritidis isolates in NARMS from 1996 to 2006. Isolate submission and testing are described in the methods section of this report.

Among *Salmonella* ser. Enteritidis submitted to NARMS, quinolone resistance was observed in 128 (3.7%) of 3,422 isolates from 1996 to 2006. This annual report highlights that the proportion of nalidixic acid resistance among *Salmonella* ser. Enteritidis significantly increased from 3/351 (0.9%) in 1996 to 29/412 (7.0%) in 2006 (95% CI [2.7, 45.4]). While none of the isolates showed resistance to both nalidixic acid and ciprofloxacin, decreased susceptibility to ciprofloxacin also increased from 1996–2006. As expected, nalidixic acid resistance was associated with decreased susceptibility to ciprofloxacin: 115 (90.0%) of 128 nalidixic acid–resistant isolates exhibited decreased susceptibility to ciprofloxacin, compared with 6 (0.2%) of 3,294 isolates that were not resistant to nalidixic acid (Chi-square, p <0.001) (*Figure A*). Six isolates that showed decreased susceptibility to ciprofloxacin remained susceptible to nalidixic acid. This phenotype could be due to the acquisition of plasmid-mediated fluoroquinolone resistance mechanisms such as *qnr, aac (6')-Ib-cr, or qepA*. Foodborne *Salmonella* ser. Enteritidis remains an important source for human salmonellosis infections in the United States. Continued public health surveillance for quinolone resistance and decreased susceptibility to fluoroquinolones, as well as identifying the mechanisms of resistance is critical and subsequent studies will be important in documenting these and other emerging mechanisms of resistance.

Figure A: Percentage of *Salmonella* ser. Enteritidis with nalidixic acid resistance and decreased susceptibility to ciprofloxacin, by year, 1996-2006



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B. *Salmonella* ser. Typhimurium

In 2006, *Salmonella* ser. Typhimurium was the second most common non-Typhi *Salmonella* serotype in NARMS. The ACSSuT resistant phenotype in serotype Typhimurium decreased from 33.7% in 1996 to 19.7% in 2006.

In 2006, *Salmonella* ser. Typhimurium was the second most common non-Typhi *Salmonella* serotype in NARMS, accounting for 18.6% (407/2,184) of non-Typhi *Salmonella* isolates (Table 1.04). Of the 407 serotype Typhimurium isolates tested, resistance was highest to sulfisoxazole (33.4%), tetracycline (31.7%), streptomycin (29.5%), ampicillin (28.3%), and chloramphenicol (22.1%) (Table 1.09). The prevalence of resistance among clinically important antimicrobial subclasses was 0.7% for quinolones (represented by nalidixic acid) and 4.2% for third-generation cephalosporins (represented by ceftiofur).

Resistance to other antimicrobial agents decreased since 1996 (Table 1.09). Resistance to tetracycline decreased from 49.3% in 1996 to 31.7% in 2006; ampicillin, from 50.0% to 28.3%; streptomycin, from 51.6% to 29.5%; chloramphenicol, from 39.9% to 22.1%; and gentamicin, from 4.2% to 2.7%.

Of the 407 *Salmonella* ser. Typhimurium isolates tested in 2006, 62.4% (254/407) had no detected resistance, a decrease from the 65.2% (285/437) of isolates in 2005 (Table 1.10). In 2006, 34.2% (139/407) were resistant to two or more CLSI subclasses, compared with 33.2% (145/437) in 2005. Similarly, in 2006, 21.9% (89/407) were resistant to at least five subclasses, compared with 23.6% (103/437) in 2005.

In 2006, the most common multidrug-resistant phenotype among *Salmonella* ser. Typhimurium was ACSSuT (19.7% of isolates). Since 1996, the prevalence of ACSSuT among *Salmonella* ser. Typhimurium decreased from 33.7% to 19.7%. In the logistic regression model, this decrease was statistically significant (OR=0.5, 95% CI [0.3, 0.7]).

One (0.2%) serotype *Salmonella* ser. Typhimurium isolate was resistant to both quinolones and third-generation cephalosporins in 2006. Since 1996, eight *Salmonella* ser. Typhimurium isolates have shown this multidrug resistance pattern.

Table 1.08: Minimum inhibitory concentrations (MICs) and resistance of *Salmonella* ser. Typhimurium isolates to antimicrobial agents, 2006 (N=407)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–0.9]						2.9	74.4	20.9	1.7							
		Gentamicin	0.2	2.7	[1.4–4.8]					60.0	34.6	2.5			0.2	1.0	1.7				
		Streptomycin	NA	29.5	[25.1–34.2]												70.5	17.2	12.3		
	Aminopenicillins	Ampicillin	0.0	28.3	[23.9–32.9]							61.4	10.1	0.2				28.3			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	14.5	4.4	[2.6–6.9]							69.8	2.0	0.7	8.6	14.5	0.2	4.2			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	4.2	[2.5–6.6]					0.5	48.9	45.7	0.7			4.2					
		Ceftriaxone	2.2	0.2	[0.0–1.4]					95.8					1.7	1.0	1.2	0.2			
	Quinolones	Ciprofloxacin	0.0	0.2	[0.0–1.4]	96.3	2.0		0.2	0.2	1.0				0.2						
		Nalidixic acid	NA	0.7	[0.2–2.1]							0.2	48.4	49.1	0.7	0.7		0.7			
II	**Aminoglycosides**	Kanamycin	0.0	5.2	[3.2–7.8]										94.6	0.2			5.2		
	Cephamycins	Cefoxitin	0.2	3.9	[2.3–6.3]							26.8	60.4	7.4	1.2	0.2	2.2	1.7			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	2.2	[1.0–4.2]				75.9	21.4	0.2	0.2			2.2						
	Phenicols	Chloramphenicol	0.7	22.1	[18.2–26.5]								2.5	49.9	24.8	0.7		22.1			
	Sulfonamides	Sulfisoxazole	NA	33.4	[28.8–38.2]											11.3	51.6	3.7			33.4
	Tetracyclines	Tetracycline	0.0	31.7	[27.2–36.5]									68.3		3.9	13.0	14.7			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 1.05: Antimicrobial resistance pattern for *Salmonella* ser. Typhimurium, 2006

Table 1.09: Percentage and number of *Salmonella* ser. Typhimurium isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			306	328	381	363	304	324	393	406	382	437	407
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin (MIC ≥ 64)	Not Tested	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	4.2% 13	4.6% 15	3.7% 14	2.2% 8	2.6% 8	1.5% 5	2.3% 9	2.0% 8	2.1% 8	1.8% 8	2.7% 11
		Streptomycin (MIC ≥ 64)	51.6% 158	55.2% 181	47.8% 182	43.3% 157	39.5% 120	40.1% 130	31.8% 125	35.2% 143	31.7% 121	27.9% 122	29.5% 120
	Aminopenicillins	Ampicillin (MIC ≥ 32)	50.0% 153	50.3% 165	45.7% 174	41.3% 150	42.1% 128	42.6% 138	33.6% 132	36.0% 146	31.9% 122	28.8% 126	28.3% 115
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	2.6% 8	3.4% 11	4.5% 17	2.8% 10	6.3% 19	6.2% 20	7.6% 30	5.4% 22	4.7% 18	3.2% 14	4.4% 18
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	1.5% 5	1.8% 7	1.9% 7	3.6% 11	3.1% 10	4.3% 17	4.9% 20	4.5% 17	2.5% 11	4.2% 17
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.3% 1	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.3% 1	0.2% 1	0.8% 3	0.0% 0	0.2% 1
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.2% 1
		Nalidixic acid (MIC ≥ 32)	0.3% 1	0.9% 3	0.5% 2	0.0% 0	1.3% 4	0.6% 2	1.3% 5	1.2% 5	0.5% 2	0.9% 4	0.7% 3
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	14.4% 44	15.5% 51	15.7% 60	12.9% 47	13.2% 40	8.3% 27	7.6% 30	7.1% 29	5.8% 22	5.7% 25	5.2% 21
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	2.0% 6	4.3% 14	3.9% 15	4.4% 16	4.3% 13	3.1% 10	5.6% 22	6.2% 25	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	Not Tested	Not Tested	Not Tested	3.6% 11	3.1% 10	4.3% 17	4.4% 18	4.7% 18	2.5% 11	3.9% 16
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	4.6% 14	3.0% 10	4.5% 17	2.8% 10	3.6% 11	2.5% 8	2.3% 9	3.4% 14	2.6% 10	2.7% 12	2.2% 9
	Phenicols	Chloramphenicol (MIC ≥ 32)	39.9% 122	36.0% 118	34.1% 130	28.9% 105	30.9% 94	31.8% 103	23.2% 91	27.8% 113	24.1% 92	24.3% 106	22.1% 90
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	53.3% 163	56.7% 186	50.1% 191	45.7% 166	45.4% 138	43.2% 140	32.1% 126	38.4% 156	35.9% 137	31.8% 139	33.4% 136
	Tetracyclines	Tetracycline (MIC ≥ 16)	49.3% 151	52.4% 172	46.5% 177	41.9% 152	43.4% 132	43.5% 141	31.8% 125	37.9% 154	30.1% 115	30.2% 132	31.7% 129

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 1.10: Resistance patterns of *Salmonella* ser. Typhimurium isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	306	328	381	363	304	324	393	406	382	437	407
	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	37.9% 116	39.0% 128	46.5% 177	50.4% 183	49.3% 150	49.1% 159	60.3% 237	54.9% 223	60.7% 232	65.2% 285	62.4% 254
Resistance ≥ 1 CLSI subclass*	62.1% 190	61.0% 200	53.5% 204	49.6% 180	50.7% 154	50.9% 165	39.7% 156	45.1% 183	39.3% 150	34.8% 152	37.6% 153
Resistance ≥ 2 CLSI subclasses*	56.2% 172	56.7% 186	51.4% 196	46.3% 168	47.0% 143	48.1% 156	36.1% 142	41.4% 168	37.2% 142	33.2% 145	34.2% 139
Resistance ≥ 3 CLSI subclasses*	51.0% 156	52.4% 172	47.8% 182	43.3% 157	43.4% 132	42.0% 136	32.3% 127	36.9% 150	31.4% 120	30.0% 131	30.5% 124
Resistance ≥ 4 CLSI subclasses*	45.4% 139	47.9% 157	43.3% 165	38.6% 140	39.8% 121	38.3% 124	28.5% 112	32.0% 130	28.0% 107	27.2% 119	27.3% 111
Resistance ≥ 5 CLSI subclasses*	35.6% 109	36.0% 118	34.6% 132	28.1% 102	30.6% 93	29.9% 97	23.4% 92	27.8% 113	24.3% 93	23.6% 103	21.9% 89
At least ACSSuT†	33.7% 103	35.1% 115	32.5% 124	27.8% 101	28.0% 85	29.6% 96	21.4% 84	26.1% 106	23.3% 89	22.2% 97	19.7% 80
At least ACSuTm‡	2.0% 6	0.6% 2	2.6% 10	2.2% 8	1.6% 5	0.9% 3	2.0% 8	3.2% 13	1.6% 6	2.1% 9	0.7% 3
At least ACSSuTAuCf§	0.0% 0	1.2% 4	1.0% 4	0.6% 2	2.0% 6	1.2% 4	1.8% 7	2.2% 9	2.6% 10	1.8% 8	2.9% 12
At least MDR-AmpC¶	0.0% 0	1.2% 4	1.0% 4	0.6% 2	2.0% 6	1.2% 4	1.8% 7	2.2% 9	2.6% 10	1.8% 8	2.9% 12
Resistance to quinolone** and cephalosporin††	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.3% 1	0.3% 1	0.5% 2	0.0% 0	0.3% 1	0.2% 1	0.2% 1

*CLSI: Clinical and Laboratory Standards Institute
†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline
‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole
§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur
¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)
**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)
††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

C. *Salmonella* ser. Newport

In 2006, Newport was the third most common non-Typhi *Salmonella* serotype in NARMS. The MDR-AmpC phenotype in *Salmonella* ser. Newport increased from 1996 to 2006. The MDR-AmpC phenotype was first noted in 1998, increased to 18.2% in 1999, peaked at 25.0% in 2001, and declined to 10.6% in 2006. A similar trend was observed for ceftiofur resistance.

In 2006, *Salmonella* ser. Newport was the third most commonly isolated non-Typhi *Salmonella* serotype in NARMS, accounting for 9.9% (217/2,184) of non-Typhi *Salmonella* isolates (Table 1.04). *Salmonella* ser. Newport isolates were most commonly resistant to ampicillin and sulfisoxazole (15.2%), tetracycline (14.3%), streptomycin (13.8%), cefoxitin (12.9%), and ceftiofur, chloramphenicol, and amoxicillin-clavulanic acid (12.4%) (Table 1.12). The prevalence of resistance among clinically important antimicrobial subclasses was 0.5% for quinolones (represented by nalidixic acid) and 12.4% for third-generation cephalosporins (represented by ceftiofur).

Ceftiofur resistance was first noted in one isolate (1.3%) in 1998; it increased to 18.2% in 1999, peaked at 27.4% in 2001, and declined to 12.4% in 2006 (Table 1.12). *Salmonella* ser. Newport was the most prevalent (34.2%) non-Typhi *Salmonella* serotype that showed resistance to ceftiofur (Table 1.20).

While the percentage of *Salmonella* ser. Newport isolates with no detected resistance declined from 86.3% in 1996 to 65.3% in 2001 (Table 1.13) resistance increased to 82.9% in 2006. Resistance to at least five subclasses of antimicrobial agents increased from 5.9% in 1996 to 12.9% in 2006 and peaked at 27.4% in 2001.

In 2006, the most common multidrug-resistant phenotype among *Salmonella* ser. Newport was at least ACSSuT (12.0% of isolates). Among these, most also showed resistance to amoxicillin-clavulanate and ceftiofur and decreased susceptibility (MIC ≥2 µg/mL) to ceftriaxone (the MDR-AmpC phenotype). Isolates that showed the MDR-AmpC phenotype comprised 10.6% of Newport submissions in 2006. MDR-AmpC resistance followed the same pattern as ceftiofur resistance (Table 1.13); it increased from 0% in 1996 to 18.2% in 1999, peaked at 25.0% in 2001, and declined to 10.6% in 2006. In the logistic regression model, the increase from 1996 to 2006 was statistically significant (95% CI [1.4, infinity]).

Table 1.11: Minimum inhibitory concentrations (MICs) and resistance of *Salmonella* ser. Newport isolates to antimicrobial agents, 2006 (N=217)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–1.7]						7.4	78.3	13.4	0.5		0.5					
		Gentamicin	0.5	0.9	[0.1–3.3]					67.7	30.4		0.5		0.5	0.5	0.5				
		Streptomycin	NA	13.8	[9.5–19.1]												86.2	0.9	12.9		
	Aminopenicillins	Ampicillin	0.0	15.2	[10.7–20.7]							77.0	6.9	0.9				15.2			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	0.9	12.4	[8.4–17.6]							82.0	2.3	0.5	1.8	0.9	6.5	6.0			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	12.4	[8.4–17.6]					0.5		45.2	40.1	1.8			12.4				
		Ceftriaxone	12.0	0.5	[0.0–2.5]						87.1				0.5		5.1	6.9		0.5	
	Quinolones	Ciprofloxacin	0.0	0.0	[0.0–1.7]	99.1	0.5				0.5										
		Nalidixic acid	NA	0.5	[0.0–2.5]							0.5	44.7	53.9	0.5		0.5				
II	**Aminoglycosides**	Kanamycin	0.5	2.3	[0.8–5.3]										96.8	0.5	0.5		2.3		
	Cephamycins	Cefoxitin	0.0	12.9	[8.7–18.1]						0.5	23.0	58.1	4.1	1.4		2.3	10.6			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	3.2	[1.3–6.5]				87.6	8.3	0.5	0.5			3.2						
	Phenicols	Chloramphenicol	0.5	12.4	[8.4–17.6]								1.8	76.0	9.2	0.5		12.4			
	Sulfonamides	Sulfisoxazole	NA	15.2	[10.7–20.7]											6.0	38.7	40.1			15.2
	Tetracyclines	Tetracycline	0.0	14.3	[9.9–19.7]									85.7			3.7	10.6			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 1.06: Antimicrobial resistance pattern for *Salmonella* ser. Newport, 2006

Table 1.12: Percentage and number of *Salmonella* ser. Newport isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			51	46	77	99	121	124	241	223	191	207	217
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin (MIC ≥ 64)	Not Tested	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	5.9% 3	4.3% 2	0.0% 0	0.0% 0	2.5% 3	3.2% 4	3.3% 8	3.1% 7	0.5% 1	1.0% 2	0.9% 2
		Streptomycin (MIC ≥ 64)	7.8% 4	4.3% 2	2.6% 2	19.2% 19	24.0% 29	31.5% 39	25.3% 61	24.2% 54	15.7% 30	14.0% 29	13.8% 30
	Aminopenicillins	Ampicillin (MIC ≥ 32)	5.9% 3	6.5% 3	2.6% 2	18.2% 18	23.1% 28	29.8% 37	24.9% 60	22.9% 51	15.7% 30	14.0% 29	15.2% 33
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	2.0% 1	0.0% 0	2.6% 2	18.2% 18	22.3% 27	26.6% 33	22.8% 55	21.5% 48	15.2% 29	12.6% 26	12.4% 27
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.0% 0	1.3% 1	18.2% 18	22.3% 27	27.4% 34	22.8% 55	22.0% 49	15.2% 29	12.6% 26	12.4% 27
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	3.0% 3	0.0% 0	0.0% 0	0.8% 2	1.8% 4	2.6% 5	1.4% 3	0.5% 1
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Nalidixic acid (MIC ≥ 32)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.8% 1	0.0% 0	0.8% 2	0.4% 1	0.5% 1	0.0% 0	0.5% 1
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	2.0% 1	0.0% 0	1.3% 1	1.0% 1	5.0% 6	7.3% 9	10.0% 24	4.5% 10	2.6% 5	1.9% 4	2.3% 5
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	3.9% 2	4.3% 2	2.6% 2	18.2% 18	22.3% 27	26.6% 33	22.8% 55	22.4% 50	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	Not Tested	Not Tested	Not Tested	22.3% 27	25.8% 32	22.4% 54	21.5% 48	15.2% 29	12.6% 26	12.9% 28
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	3.9% 2	4.3% 2	1.3% 1	2.0% 2	4.1% 5	1.6% 2	4.1% 10	0.9% 2	2.1% 4	1.9% 4	3.2% 7
	Phenicols	Chloramphenicol (MIC ≥ 32)	5.9% 3	4.3% 2	2.6% 2	18.2% 18	23.1% 28	28.2% 35	25.3% 61	22.4% 50	15.2% 29	13.5% 28	12.4% 27
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	11.8% 6	4.3% 2	3.9% 3	22.2% 22	23.1% 28	32.3% 40	25.7% 62	24.7% 55	16.8% 32	15.5% 32	15.2% 33
	Tetracyclines	Tetracycline (MIC ≥ 16)	7.8% 4	4.3% 2	2.6% 2	19.2% 19	23.1% 28	30.6% 38	25.7% 62	24.2% 54	16.8% 32	14.5% 30	14.3% 31

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 1.13: Resistance patterns of *Salmonella* ser. Newport isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	51	46	77	99	121	124	241	223	191	207	217
	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	86.3% 44	93.5% 43	94.8% 73	75.8% 75	75.2% 91	65.3% 81	72.2% 174	73.5% 164	82.2% 157	84.1% 174	82.9% 180
Resistance ≥ 1 CLSI subclass*	13.7% 7	6.5% 3	5.2% 4	24.2% 24	24.8% 30	34.7% 43	27.8% 67	26.5% 59	17.8% 34	15.9% 33	17.1% 37
Resistance ≥ 2 CLSI subclasses*	7.8% 4	4.3% 2	2.6% 2	18.2% 18	23.1% 28	32.3% 40	25.7% 62	25.1% 56	17.3% 33	15.0% 31	16.1% 35
Resistance ≥ 3 CLSI subclasses*	5.9% 3	4.3% 2	2.6% 2	18.2% 18	23.1% 28	31.5% 39	25.3% 61	23.3% 52	16.8% 32	14.5% 30	14.7% 32
Resistance ≥ 4 CLSI subclasses*	5.9% 3	4.3% 2	2.6% 2	18.2% 18	23.1% 28	31.5% 39	25.3% 61	22.9% 51	15.7% 30	14.0% 29	13.8% 30
Resistance ≥ 5 CLSI subclasses*	5.9% 3	4.3% 2	2.6% 2	18.2% 18	23.1% 28	27.4% 34	23.7% 57	22.4% 50	14.7% 28	12.6% 26	12.9% 28
At least ACSSuT†	5.9% 3	4.3% 2	1.3% 1	18.2% 18	23.1% 28	25.8% 32	23.7% 57	22.0% 49	14.7% 28	12.6% 26	12.0% 26
At least ACSuTm‡	3.9% 2	4.3% 2	1.3% 1	2.0% 2	4.1% 5	0.8% 1	3.7% 9	0.9% 2	1.0% 2	1.9% 4	2.3% 5
At least ACSSuTAuCf§	0.0% 0	0.0% 0	1.3% 1	18.2% 18	22.3% 27	25.0% 31	22.8% 55	21.1% 47	14.7% 28	12.6% 26	10.6% 23
At least MDR-AmpC¶	0.0% 0	0.0% 0	1.3% 1	18.2% 18	22.3% 27	25.0% 31	22.8% 55	21.1% 47	14.7% 28	12.6% 26	10.6% 23
Resistance to quinolone** and cephalosporin††	0.0% 0	0.0% 0	1.3% 1	0.0% 0	0.0% 0	0.0% 0	0.4% 1	0.0% 0	0.5% 1	0.0% 0	0.5% 1

*CLSI: Clinical and Laboratory Standards Institute

†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline

‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole

§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur

¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)

**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)

††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

D. *Salmonella* ser. I 4,[5],12:i:-

In 2006, *Salmonella* ser. I 4,[5],12:i:- was the fourth most common non-Typhi *Salmonella* serotype in NARMS. Most *Salmonella* ser. I 4,[5],12:i:- isolates had no detected resistance and multidrug resistance was rare.

In 2006, *Salmonella* ser. I 4,[5],12:i:- was the fourth most commonly isolated non-Typhi *Salmonella* serotype in NARMS, accounting for 4.8% (105/2,184) of non-Typhi *Salmonella* isolates (Table 1.04). In 2005, I 4,[5],12:i:- was the 12th most commonly reported serotype among NARMS submissions, making up 1.6% of the non-Typhi *Salmonella*. *Salmonella* ser. I 4,[5],12:i:- isolates were most commonly resistant to sulfisoxazole and tetracycline (8.6%), ampicillin (6.7%), gentamicin (4.8%), streptomycin, amoxicillin-clavulanic acid, ceftiofur, and cefoxitin (3.8%) (Table 1.15). The prevalence of resistance among clinically important antimicrobial subclasses was 1.7% for quinolones (represented by nalidixic acid) and 5.1% for third-generation cephalosporins (represented by ceftiofur) (Table 1.20).

Most I 4,[5],12:i:- isolates had no detected resistance. The percentage of I 4,[5],12:i:- isolates with no detected resistance increased from 80.6% in 2004 to 87.9% in 2005, but has slightly decreased to 85.7% in 2006 (Table 1.16).

Multidrug-resistance was not common among I 4,[5],12:i:- isolates (Table 1.16). However, 2 isolates (1.9%) with resistance to at least ACSSuT were identified in 2006.

Table 1.14: Minimum inhibitory concentrations (MICs) and resistance of *Salmonella* ser. I 4,[5],12:i:- isolates to antimicrobial agents, 2006 (N=105)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–3.5]						2.9	75.2	20.0	1.9							
		Gentamicin	0.0	4.8	[1.6–10.8]					59.0	36.2					3.8	1.0				
		Streptomycin	NA	3.8	[1.0–9.5]												96.2	1.9	1.9		
	Aminopenicillins	Ampicillin	0.0	6.7	[2.7–13.3]							87.6	5.7					6.7			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	1.0	3.8	[1.0–9.5]							93.3			1.9	1.0		3.8			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	3.8	[1.0–9.5]				1.0		67.6	27.6				3.8					
		Ceftriaxone	3.8	0.0	[0.0–3.5]					96.2						3.8					
	Quinolones	Ciprofloxacin	0.0	0.0	[0.0–3.5]	97.1	1.9			1.0											
		Nalidixic acid	NA	1.0	[0.0–5.2]								70.5	28.6				1.0			
II	**Aminoglycosides**	Kanamycin	0.0	0.0	[0.0–3.5]										100.0						
	Cephamycins	Cefoxitin	0.0	3.8	[1.0–9.5]						1.0	48.6	46.7				3.8				
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	0.0	[0.0–3.5]				95.2	4.8											
	Phenicols	Chloramphenicol	0.0	1.9	[0.2–6.7]									84.8	13.3			1.9			
	Sulfonamides	Sulfisoxazole	NA	8.6	[4.0–15.6]											11.4	65.7	14.3			8.6
	Tetracyclines	Tetracycline	0.0	8.6	[4.0–15.6]									91.4		1.9	1.9	4.8			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 1.07: Antimicrobial resistance pattern for *Salmonella* ser. I 4,[5],12:i:-, 2006

Table 1.15: Percentage and number of *Salmonella* ser. I 4,[5],12:i:- isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			3	3	0	8	13	14	35	37	36	33	105
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin (MIC ≥ 64)	Not Tested	0.0% 0		0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	7.1% 1	0.0% 0	5.4% 2	5.6% 2	0.0% 0	4.8% 5
		Streptomycin (MIC ≥ 64)	0.0% 0	66.7% 2		0.0% 0	7.7% 1	14.3% 2	2.9% 1	8.1% 3	5.6% 2	3.0% 1	3.8% 4
	Aminopenicillins	Ampicillin (MIC ≥ 32)	0.0% 0	0.0% 0		0.0% 0	7.7% 1	7.1% 1	8.6% 3	8.1% 3	5.6% 2	6.1% 2	6.7% 7
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	0.0% 0	2.9% 1	5.4% 2	2.8% 1	3.0% 1	3.8% 4
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	7.1% 1	2.9% 1	5.4% 2	2.8% 1	3.0% 1	3.8% 4
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	2.8% 1	0.0% 0	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Nalidixic acid (MIC ≥ 32)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	0.0% 0	0.0% 0	2.7% 1	2.8% 1	0.0% 0	1.0% 1
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	7.1% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	7.1% 1	2.9% 1	5.4% 2	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	Not Tested		Not Tested	0.0% 0	0.0% 0	2.9% 1	5.4% 2	2.8% 1	3.0% 1	3.8% 4
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	7.1% 1	2.9% 1	0.0% 0	2.8% 1	0.0% 0	0.0% 0
	Phenicols	Chloramphenicol (MIC ≥ 32)	0.0% 0	0.0% 0		0.0% 0	0.0% 0	7.1% 1	2.9% 1	0.0% 0	2.8% 1	0.0% 0	1.9% 2
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	0.0% 0	100.0% 3		12.5% 1	0.0% 0	14.3% 2	2.9% 1	5.4% 2	11.1% 4	0.0% 0	8.6% 9
	Tetracyclines	Tetracycline (MIC ≥ 16)	0.0% 0	0.0% 0		0.0% 0	7.7% 1	7.1% 1	5.7% 2	0.0% 0	11.1% 4	3.0% 1	8.6% 9

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 1.16: Resistance patterns of *Salmonella* ser. I 4,[5],12:i:- isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	3	3	0	8	13	14	35	37	36	33	105
	%	%	%	%	%	%	%	%	%	%	%
	n	n	n	n	n	n	n	n	n	n	n
No resistance detected	100.0%	0.0%		87.5%	92.3%	78.6%	91.4%	78.4%	80.6%	87.9%	85.7%
	3	0		7	12	11	32	29	29	29	90
Resistance ≥ 1 CLSI subclass*	0.0%	100.0%		12.5%	7.7%	21.4%	8.6%	21.6%	19.4%	12.1%	14.3%
	0	3		1	1	3	3	8	7	4	15
Resistance ≥ 2 CLSI subclasses*	0.0%	66.7%		0.0%	7.7%	14.3%	8.6%	10.8%	13.9%	3.0%	11.4%
	0	2		0	1	2	3	4	5	1	12
Resistance ≥ 3 CLSI subclasses*	0.0%	0.0%		0.0%	7.7%	7.1%	5.7%	5.4%	11.1%	3.0%	9.5%
	0	0		0	1	1	2	2	4	1	10
Resistance ≥ 4 CLSI subclasses*	0.0%	0.0%		0.0%	0.0%	7.1%	2.9%	0.0%	2.8%	0.0%	3.8%
	0	0		0	0	1	1	0	1	0	4
Resistance ≥ 5 CLSI subclasses*	0.0%	0.0%		0.0%	0.0%	7.1%	2.9%	0.0%	2.8%	0.0%	2.9%
	0	0		0	0	1	1	0	1	0	3
At least ACSSuT†	0.0%	0.0%		0.0%	0.0%	7.1%	2.9%	0.0%	2.8%	0.0%	1.9%
	0	0		0	0	1	1	0	1	0	2
At least ACSuTm‡	0.0%	0.0%		0.0%	0.0%	7.1%	2.9%	0.0%	0.0%	0.0%	0.0%
	0	0		0	0	1	1	0	0	0	0
At least ACSSuTAuCf§	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0		0	0	0	0	0	0	0	0
At least MDR-AmpC¶	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0		0	0	0	0	0	0	0	0
Resistance to quinolone** and cephalosporin††	0.0%	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0		0	0	0	0	0	0	0	0

*CLSI: Clinical and Laboratory Standards Institute
†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline
‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole
§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur
¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)
**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)
††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

E. *Salmonella* ser. Heidelberg

In 2006, *Salmonella* ser. Heidelberg was the fifth most commonly isolated non-Typhi *Salmonella* serotype in NARMS, accounting for 4.7% (102/2,184) of non-Typhi *Salmonella* isolates (Table 1.04). Serotype Heidelberg isolates were most commonly resistant to ampicillin (18.6%), tetracycline (13.7%), streptomycin (11.8%), amoxicillin-clavulanic acid and ceftiofur (9.8%), kanamycin and cefoxitin (8.8%), and sulfisoxazole and gentamicin (4.9%) (Table 1.18).

Ceftiofur resistance was first noted in one isolate (1.4%) in 1996. Resistance increased to ten isolates (9.8%) in 2006 (Table 1.18). Heidelberg was the third most common serotype (12.7%) among ceftiofur-resistant non-Typhi *Salmonella* (Table 1.20).

In contrast to other common serotypes, the percentage of Heidelberg isolates with no detected resistance increased from 54.1% in 1996 to 67.6% in 2006 (Table 1.19). In addition, resistance to at least five CLSI subclasses of antimicrobial agents decreased from 3.2% in 2004 to 2.0% in 2006.

Table 1.17: Minimum inhibitory concentrations (MICs) and resistance of *Salmonella* ser. Heidelberg isolates to antimicrobial agents, 2006 (N=102)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–3.6]						17.6	64.7	16.7	1.0							
		Gentamicin	1.0	4.9	[1.6–11.1]					66.7	25.5		1.0	1.0	1.0	2.0	2.9				
		Streptomycin	NA	11.8	[6.2–19.6]												88.2	8.8	2.9		
	Aminopenicillins	Ampicillin	0.0	18.6	[11.6–27.6]							70.6	8.8	2.0				18.6			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	2.0	9.8	[4.8–17.3]							76.5	3.9	1.0	6.9	2.0	4.9	4.9			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	9.8	[4.8–17.3]						56.9	32.4	1.0		1.0	8.8					
		Ceftriaxone	7.8	0.0	[0.0–3.6]					90.2				1.0	1.0	5.9	2.0				
	Quinolones	Ciprofloxacin	0.0	0.0	[0.0–3.6]	98.0	2.0														
		Nalidixic acid	NA	0.0	[0.0–3.6]								24.5	75.5							
II	**Aminoglycosides**	Kanamycin	0.0	8.8	[4.1–16.1]										90.2	1.0			8.8		
	Cephamycins	Cefoxitin	1.0	8.8	[4.1–16.1]							52.9	33.3	2.9	1.0	1.0	5.9	2.9			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	0.0	[0.0–3.6]				94.1	5.9											
	Phenicols	Chloramphenicol	1.0	0.0	[0.0–3.6]									60.8	38.2	1.0					
	Sulfonamides	Sulfisoxazole	NA	4.9	[1.6–11.1]											36.3	50.0	7.8	1.0		4.9
	Tetracyclines	Tetracycline	0.0	13.7	[7.7–22.0]									86.3		1.0	1.0	11.8			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 1.08: Antimicrobial resistance pattern for *Salmonella* ser. Heidelberg, 2006

Table 1.18: Percentage and number of *Salmonella* ser. Heidelberg isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			74	75	101	88	79	102	105	96	93	125	102
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin (MIC ≥ 64)	Not Tested	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	23.0% 17	17.3% 13	16.8% 17	14.8% 13	8.9% 7	7.8% 8	3.8% 4	5.2% 5	4.3% 4	6.4% 8	4.9% 5
		Streptomycin (MIC ≥ 64)	40.5% 30	24.0% 18	30.7% 31	23.9% 21	22.8% 18	25.5% 26	17.1% 18	12.5% 12	15.1% 14	13.6% 17	11.8% 12
	Aminopenicillins	Ampicillin (MIC ≥ 32)	14.9% 11	13.3% 10	16.8% 17	6.8% 6	10.1% 8	9.8% 10	12.4% 13	10.4% 10	25.8% 24	20.0% 25	18.6% 19
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	2.7% 2	1.3% 1	1.0% 1	1.1% 1	3.8% 3	2.9% 3	9.5% 10	5.2% 5	10.8% 10	8.8% 11	9.8% 10
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	1.4% 1	0.0% 0	0.0% 0	0.0% 0	3.8% 3	2.9% 3	7.6% 8	5.2% 5	9.7% 9	8.8% 11	9.8% 10
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Nalidixic acid (MIC ≥ 32)	0.0% 0	0.0% 0	1.0% 1	1.1% 1	1.3% 1	0.0% 0	0.0% 0	1.0% 1	0.0% 0	0.8% 1	0.0% 0
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	14.9% 11	8.0% 6	12.9% 13	9.1% 8	15.2% 12	19.6% 20	10.5% 11	8.3% 8	8.6% 8	12.8% 16	8.8% 9
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	6.8% 5	2.7% 2	5.9% 6	3.4% 3	5.1% 4	3.9% 4	10.5% 11	7.3% 7	Not Tested	Not Tested	0.0% 0
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	Not Tested	Not Tested	Not Tested	2.5% 2	2.9% 3	8.6% 9	5.2% 5	8.6% 8	8.8% 11	8.8% 9
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	0.0% 0	0.0% 0	2.0% 2	1.1% 1	1.3% 1	2.0% 2	1.0% 1	2.1% 2	0.0% 0	0.8% 1	0.0% 0
	Phenicols	Chloramphenicol (MIC ≥ 32)	1.4% 1	0.0% 0	1.0% 1	1.1% 1	1.3% 1	1.0% 1	1.0% 1	0.0% 0	1.1% 1	0.8% 1	0.0% 0
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	17.6% 13	21.3% 16	21.8% 22	18.2% 16	11.4% 9	8.8% 9	6.7% 7	7.3% 7	7.5% 7	8.0% 10	4.9% 5
	Tetracyclines	Tetracycline (MIC ≥ 16)	20.3% 15	12.0% 9	19.8% 20	18.2% 16	21.5% 17	24.5% 25	19.0% 20	16.7% 16	19.4% 18	18.4% 23	13.7% 14

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 1.19: Resistance patterns of *Salmonella* ser. Heidelberg isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	74	75	101	88	79	102	105	96	93	125	102
	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	54.1% 40	66.7% 50	56.4% 57	68.2% 60	63.3% 50	64.7% 66	67.6% 71	68.8% 66	55.9% 52	62.4% 78	67.6% 69
Resistance ≥ 1 CLSI subclass*	45.9% 34	33.3% 25	43.6% 44	31.8% 28	36.7% 29	35.3% 36	32.4% 34	31.3% 30	44.1% 41	37.6% 47	32.4% 33
Resistance ≥ 2 CLSI subclasses*	33.8% 25	26.7% 20	33.7% 34	26.1% 23	26.6% 21	29.4% 30	25.7% 27	17.7% 17	23.7% 22	24.8% 31	23.5% 24
Resistance ≥ 3 CLSI subclasses*	12.2% 9	12.0% 9	13.9% 14	10.2% 9	7.6% 6	7.8% 8	11.4% 12	10.4% 10	14.0% 13	15.2% 19	12.7% 13
Resistance ≥ 4 CLSI subclasses*	4.1% 3	1.3% 1	4.0% 4	4.5% 4	3.8% 3	2.0% 2	1.9% 2	2.1% 2	4.3% 4	4.8% 6	2.0% 2
Resistance ≥ 5 CLSI subclasses*	2.7% 2	1.3% 1	1.0% 1	0.0% 0	3.8% 3	2.0% 2	1.9% 2	0.0% 0	3.2% 3	2.4% 3	2.0% 2
At least ACSSuT†	1.4% 1	0.0% 0	0.0% 0	0.0% 0	1.3% 1	1.0% 1	1.0% 1	0.0% 0	1.1% 1	0.0% 0	0.0% 0
At least ACSuTm‡	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.0% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0
At least ACSSuTAuCf§	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.3% 1	1.0% 1	1.0% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0
At least MDR-AmpC¶	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.3% 1	1.0% 1	1.0% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0
Resistance to quinolone** and cephalosporin††	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.8% 1	0.0% 0

*CLSI: Clinical and Laboratory Standards Institute

†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline

‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole

§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur

¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)

**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)

††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

F. Specific Drug Resistance Phenotypes

The multidrug–resistant phenotypes ACSSuT, MDR-AmpC, and resistance to nalidixic acid and Ceftiofur were detected in several other serotypes in 2006 (Table 1.20).

In 2006, 121 (5.5%) non-Typhi *Salmonella* isolates were resistant to at least ACSSuT. Of these isolates, 66.1% were serotype Typhimurium; 21.5% Newport; 3.3% Agona; 2.5% Paratyphi B var. L(+) tartrate+; 1.7% I 4,[5],12:i:-; and 0.8% were serotypes Saintpaul, Stanley, and Tennessee (Table 1.20). Forty-three (2.0%) non-Typhi *Salmonella* isolates were resistant to at least MDR-AmpC of which 53.5% were serotype Newport; 27.9% Typhimurium; 9.3% Agona; and 2.3% Saintpaul. Sixty (2.7%) non-Typhi *Salmonella* isolates were nalidixic acid resistant, 48.3% of which were Enteritidis; 5.0% Typhimurium; and 1.7% for serotypes Newport, I 4,[5],12:i:-, Muenchen, Agona, Braenderup, Stanley, Hadar, and Tennessee. Seventy-nine (3.6%) non-Typhi *Salmonella* isolates were ceftiofur resistant, of which 34.2% were serotype Newport; 21.5% Typhimurium; 12.7% Heidelberg; 6.3% Agona; 5.1% I 4[5]12:i:- and 2.5% Enteritidis.

Table 1.20: Number and percentage of ACSSuT-, MDR-AmpC-, nalidixic acid-, and ceftiofur-resistant isolates among the 20 most common non-Typhi *Salmonella* serotypes isolated in NARMS, 2006

			ACSSuT*		MDRAmpC†		Nalidixic Acid		Ceftiofur	
Rank	**Serotype**	**N**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**
1	Enteritidis	412	0	(0.0%)	0	(0.0%)	**29**	**(48.3%)**	**2**	**(2.5%)**
2	Typhimurium	407	**80**	**(66.1%)**	**12**	**(27.9%)**	**3**	**(5.0%)**	**17**	**(21.5%)**
3	Newport	217	**26**	**(21.5%)**	**23**	**(53.5%)**	**1**	**(1.7%)**	**27**	**(34.2%)**
4	I 4,[5],12:i:-	105	**2**	**(1.7%)**	0	(0.0%)	**1**	**(1.7%)**	**4**	**(5.1%)**
5	Heidelberg	102	0	(0.0%)	0	(0.0%)	0	(0.0%)	**10**	**(12.7%)**
6	Javiana	80	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
7	Montevideo	62	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
8	Paratyphi B var. L(+) tartrate+	49	**3**	**(2.5%)**	0	(0.0%)	0	(0.0%)	**1**	**(1.3%)**
9	Oranienburg	48	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
10	Muenchen	45	0	(0.0%)	0	(0.0%)	**1**	**(1.7%)**	0	(0.0%)
11	Agona	42	**4**	**(3.3%)**	**4**	**(9.3%)**	**1**	**(1.7%)**	**5**	**(6.3%)**
12	Saintpaul	30	**1**	**(0.8%)**	**1**	**(2.3%)**	0	(0.0%)	**1**	**(1.3%)**
13	Braenderup	29	0	(0.0%)	0	(0.0%)	**1**	**(1.7%)**	0	(0.0%)
14	Thompson	26	0	(0.0%)	0	(0.0%)	0	(0.0%)	**1**	**(1.3%)**
15	Stanley	25	**1**	**(0.8%)**	0	(0.0%)	**1**	**(1.7%)**	0	(0.0%)
16	Mississippi	24	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
17	Infantis	22	0	(0.0%)	0	(0.0%)	0	(0.0%)	0	(0.0%)
18	Hadar	22	0	(0.0%)	0	(0.0%)	**1**	**(1.7%)**	0	(0.0%)
19	Tennessee	21	**1**	**(0.8%)**	0	(0.0%)	**1**	**(1.7%)**	0	(0.0%)
20	Berta	19	0	(0.0%)	0	(0.0%)	0	(0.0%)	**1**	**(1.3%)**
	Subtotal	**1787**	**118**	**(97.5%)**	**40**	**(93.0%)**	**40**	**(66.7%)**	**69**	**(87.3%)**
	All Other Serotypes	397	3	(2.5%)	3	(7.0%)	20	(33.3%)	10	0.0%
	Total	**2184**	**121**	**(100.0%)**	**43**	**(100.0%)**	**60**	**(100.0%)**	**79**	**(100.0%)**

*ACSSuT: ampicillin, chloramphenicol, streptomycin, sulfisoxazole, tetracycline

† MDR-AmpC: ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2µg/mL)

2. *Salmonella* ser. Typhi

Among *Salmonella* ser. Typhi isolates, resistance to nalidixic acid increased from 19.2% in 1999 to 54.0% in 2006. Resistance to most of the antimicrobial agents tested increased from 2005 to 2006. The percentage of isolates with no detected resistance decreased from 48.1% in 2005 to 40.4% in 2006.

During 2006, *Salmonella* ser. Typhi were most commonly resistant to nalidixic acid (54.0%), trimethoprim-sulfamethoxazole, sulfisoxazole, and ampicillin (20.7%), chloramphenicol (19.4%), and streptomycin (18.8%) (Table 2.02). Resistance to most of the antimicrobial agents tested increased from 2005 to 2006 (Table 2.02). Nalidixic acid resistance increased from 19.2% in 1999 to 54.0% in 2006; a statistically significant increase (OR=5.2, 95% CI [3.3, 8.1]). Ciprofloxacin resistance increased from 0.3% in 2005 to 0.9% in 2006.

The percentage of isolates with no detected resistance decreased from 48.1% in 2005 to 40.4% in 2006. Resistance to greater than five CLSI subclasses increased from 11.9% in 2005 to 16.4% in 2006. *Salmonella* ser. Typhi isolates with the resistance phenotype ACSuTm increased from 12.6 % to 18.5% between 1999 and 2006 (Table 2.03). A single isolate exhibited both quinolone and third-generation cephalosporin resistance in 2006.

Table 2.01: Minimum inhibitory concentrations (MICs) and resistance of *Salmonella* ser. Typhi isolates to antimicrobial agents, 2006 (N=324)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–1.1]						25.9	69.8	4.0	0.3							
		Gentamicin	0.0	0.0	[0.0–1.1]					95.7	4.0	0.3									
		Streptomycin	NA	18.8	[14.7–23.5]												81.2	0.3	18.5		
	Aminopenicillins	Ampicillin	0.0	20.7	[16.4–25.5]							69.1	9.3	0.9			0.3	20.4			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	0.3	0.3	[0.0–1.7]							78.1	0.6	7.7	13.0	0.3		0.3			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	0.0	[0.0–1.1]				0.9	9.3	80.2	9.0	0.6								
		Ceftriaxone	0.0	0.0	[0.0–1.1]					100.0											
	Quinolones	Ciprofloxacin	0.0	0.9	[0.2–2.7]	42.9	0.3	2.2	11.7	39.5	2.5				0.9						
		Nalidixic acid	NA	54.0	[48.4–59.5]						0.3	2.8	37.7	3.7	1.2	0.3	0.6	53.4			
II	**Aminoglycosides**	Kanamycin	0.0	0.0	[0.0–1.1]										100.0						
	Cephamycins	Cefoxitin	0.0	0.3	[0.0–1.7]						3.1	31.5	13.0	44.4	7.7			0.3			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	20.7	[16.4–25.5]				73.1	6.2				0.3	20.4						
	Phenicols	Chloramphenicol	0.6	19.4	[15.3–24.2]								3.4	64.2	12.3	0.6		19.4			
	Sulfonamides	Sulfisoxazole	NA	20.7	[16.4–25.5]											38.3	24.7	13.3	3.1		20.7
	Tetracyclines	Tetracycline	0.0	8.3	[5.6–11.9]									91.7				8.3			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 2.01: Antimicrobial resistance pattern for *Salmonella* ser. Typhi, 2006

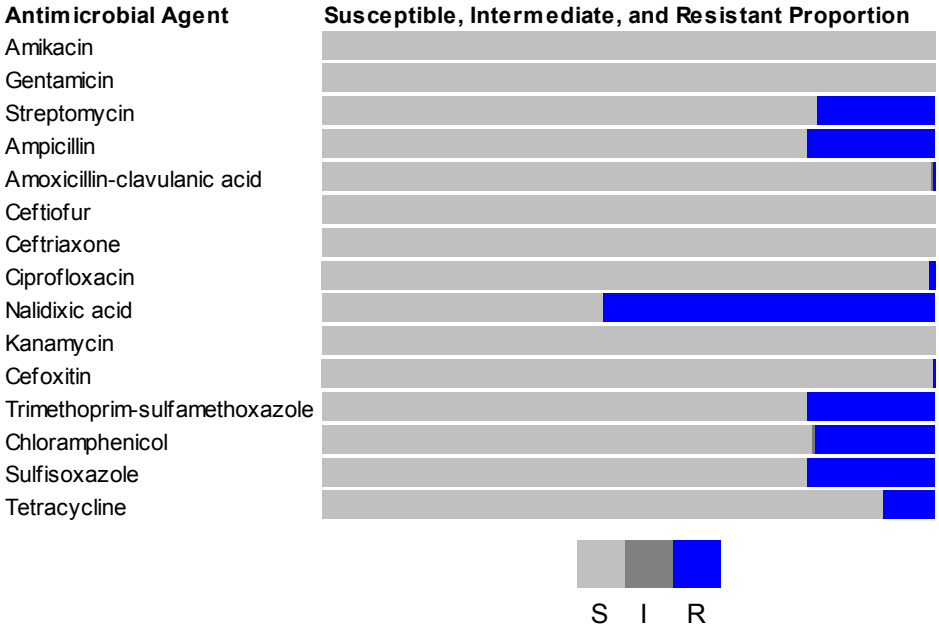

Table 2.02: Percentage and number of *Salmonella* ser. Typhi isolates resistant to antimicrobial agents, 1999–2006

Year Total Isolates			1999 167	2000 177	2001 197	2002 195	2003 334	2004 304	2005 318	2006 324
Rank*	Subclass	Antibiotic (Resistance breakpoint)								
I	Aminoglycosides	Amikacin (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Streptomycin (MIC ≥ 64)	13.8% 23	9.0% 16	20.3% 40	7.2% 14	14.4% 48	11.8% 36	13.2% 42	18.8% 61
	Aminopenicillins	Ampicillin (MIC ≥ 32)	13.2% 22	9.0% 16	20.3% 40	5.6% 11	16.2% 54	11.8% 36	13.2% 42	20.7% 67
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	0.6% 1	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.3% 1
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.6% 1	0.0% 0	0.0% 0	0.0% 0	0.6% 2	0.0% 0	0.0% 0	0.0% 0
		Ceftriaxone (MIC ≥ 64)	0.6% 1	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.3% 1	0.9% 3
		Nalidixic acid (MIC ≥ 32)	19.2% 32	22.0% 39	29.9% 59	23.6% 46	37.7% 126	41.8% 127	48.4% 154	54.0% 175
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.0% 0	0.0% 0	0.5% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	2.4% 4	1.1% 2	0.5% 1	1.5% 3	0.6% 2	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	0.6% 1	0.5% 1	0.0% 0	0.9% 3	0.0% 0	0.0% 0	0.3% 1
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	13.2% 22	9.0% 16	20.8% 41	6.7% 13	16.8% 56	13.2% 40	14.5% 46	20.7% 67
	Phenicols	Chloramphenicol (MIC ≥ 32)	12.6% 21	10.7% 19	20.8% 41	6.2% 12	16.5% 55	13.2% 40	13.2% 42	19.4% 63
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	16.8% 28	11.3% 20	20.8% 41	6.2% 12	17.1% 57	11.8% 36	14.2% 45	20.7% 67
	Tetracyclines	Tetracycline (MIC ≥ 16)	9.6% 16	9.6% 17	20.8% 41	6.7% 13	15.6% 52	8.9% 27	10.1% 32	8.3% 27

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 2.03: Resistance patterns of *Salmonella* ser. Typhi isolates, 1999–2006

Year Total Isolates	1999 167	2000 177	2001 197	2002 195	2003 334	2004 304	2005 318	2006 324
	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	71.3% 119	72.9% 129	59.4% 117	74.4% 145	56.6% 189	56.6% 172	48.1% 153	40.4% 131
Resistance ≥ 1 CLSI subclass*	28.7% 48	27.1% 48	40.6% 80	25.6% 50	43.4% 145	43.4% 132	51.9% 165	59.6% 193
Resistance ≥ 2 CLSI subclasses*	15.0% 25	10.7% 19	22.8% 45	7.2% 14	18.0% 60	13.2% 40	14.5% 46	21.6% 70
Resistance ≥ 3 CLSI subclasses*	13.2% 22	9.6% 17	22.8% 45	6.7% 13	17.7% 59	12.8% 39	13.8% 44	20.4% 66
Resistance ≥ 4 CLSI subclasses*	13.2% 22	9.0% 16	21.8% 43	6.7% 13	16.8% 56	12.5% 38	12.9% 41	19.1% 62
Resistance ≥ 5 CLSI subclasses*	12.6% 21	9.0% 16	18.8% 37	5.6% 11	15.9% 53	11.8% 36	11.9% 38	16.4% 53
At least ACSSuT†	9.6% 16	7.9% 14	16.8% 33	5.6% 11	12.6% 42	7.9% 24	9.1% 29	5.9% 19
At least ACSuTm‡	12.6% 21	9.0% 16	17.8% 35	5.6% 11	15.6% 52	11.8% 36	12.9% 41	18.5% 60
At least ACSSuTAuCf§	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
At least MDR-AmpC¶	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
Resistance to quinolone** and cephalosporin††	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.3% 1

*CLSI: Clinical and Laboratory Standards Institute
†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline
‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole
§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur
¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)
**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)
††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

3. *Shigella*

In 2006, *Shigella sonnei* isolates showed a higher prevalence of resistance to streptomycin compared to *Shigella flexneri.* *S. flexneri* showed a higher prevalence of resistance to tetracycline, sulfisoxazole, ampicillin, trimethoprim-sulfamethoxazole, and chloramphenicol compared to *S. sonnei.* The percentage of isolates with no detected resistance was low in *S. sonnei* (4.7%) and *S. flexneri* (5.4%).

During 2006, 402 *Shigella* isolates were tested, of which 321 (79.9%) were *S. sonnei*; 74 (18.7%), *S. flexneri*; 4 (1.0%), *S. boydii*; and 2 (0.5%), *S. dysenteriae* (Table 3.01). Resistance was highest to ampicillin (62.2%), streptomycin (60.7%), trimethoprim-sulfamethoxazole (58.2%), sulfisoxazole (40.3%), and tetracycline (34.6%) (Table 3.02). Among all *Shigella* spp., resistance decreased from 2005 to 2006 to most of the antimicrobials tested. Ampicillin resistance decreased from 70.7% in 2005 to 62.2% in 2006; streptomycin resistance decreased from 68.7% to 60.7%; and sulfisoxazole resistance decreased from 57.6% to 40.3%. Resistance to at least five CLSI subclasses declined from 1999 to 2006: 40.5% were resistant to at least five subclasses in 1999, compared with 13.7% in 2006 (Table 3.08). Resistance to trimethoprim-sulfamethoxazole increased from 51.5% in 1999 to 58.2% in 2006. One isolate in 2006 exhibited resistance to ciprofloxacin, making this the second ciprofloxacin resistant isolate since 1999. Of isolates tested in all years from 1999 to 2006, more than 90% of isolates, which ranged from 90.9% to 95.6%, were resistant to at least one CLSI subclass.

In 2006, there were differences in resistance to antimicrobial agents between *Shigella sonnei* and *Shigella flexneri* (Tables 3.03 and 3.04). *Shigella sonnei* isolates showed a higher prevalence of resistance to streptomycin than *Shigella flexneri*: 61.7% streptomycin resistance in *S. sonnei*, compared with 58.1% in *S. flexneri.* However, *S. flexneri* showed a higher prevalence of resistance to tetracycline, sulfisoxazole, ampicillin, trimethoprim-sulfamethoxazole, and chloramphenicol than *S. sonnei*: 83.8% tetracycline resistance in *S. flexneri*, compared with 22.7% in *S. sonnei*; 68.9% sulfisoxazole resistance in *S. flexneri*, compared with 33.3% in *S. sonnei;* and 63.5% ampicillin resistance in *S. flexneri*, compared with 62.3% in *S. sonnei*.

In all years from 1999 to 2006, resistance phenotypes ACSSuT and ACSuTm were higher in *S. flexneri* compared with *S. sonnei* (Tables 3.09 and 3.10). The percentage of isolates with no detected resistance among *S. sonnei* and S. *flexneri* remained low in all years from 1999 to 2006; it was 4.7% in *S. sonnei* and 5.4% in *S. flexneri* in 2006.

Table 3.01: Frequency of *Shigella* species isolated in NARMS, 2006

Species	2006	
	n	(%)
Shigella sonnei	321	(79.9%)
Shigella flexneri	74	(18.4%)
Shigella boydii	4	(1.0%)
Shigella dysenteriae	2	(0.5%)
Other	1	(0.2%)
Total	**402**	**(100.0%)**

Table 3.02: Minimum inhibitory concentrations (MICs) and resistance of *Shigella* isolates to antimicrobial agents, 2006 (N=402)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–0.9]						1.5	4.5	51.0	41.0	2.0						
		Gentamicin	0.0	0.2	[0.0–1.4]					3.7	39.1	55.5	1.5				0.2				
		Streptomycin	NA	60.7	[55.7–65.5]												39.3	28.9	31.8		
	Aminopenicillins	Ampicillin	1.0	62.2	[57.2–66.9]							7.7	23.6	4.2	1.2	1.0	0.5	61.7			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	16.7	1.5	[0.5–3.2]							3.2	6.7	27.9	44.0	16.7	1.5				
	Cephalosporins (3rd generation)	Ceftiofur	0.0	0.2	[0.0–1.4]				22.4	67.7	9.0	0.7				0.2					
		Ceftriaxone	0.2	0.0	[0.0–0.9]					99.3	0.5						0.2				
	Quinolones	Ciprofloxacin	0.0	0.2	[0.0–1.4]	95.8	0.2	1.2	1.2	0.2	0.7	0.2		0.2							
		Nalidixic acid	NA	3.5	[1.9–5.8]						4.7	70.9	18.4	2.2	0.2		1.2	2.2			
II	**Aminoglycosides**	Kanamycin	0.0	0.0	[0.0–0.9]										99.5	0.5					
	Cephamycins	Cefoxitin	1.2	0.0	[0.0–0.9]						0.7	19.7	63.4	14.7	0.2	1.2					
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	58.2	[53.2–63.1]				20.6	6.2	1.7	6.0	7.2	8.7	49.5						
	Phenicols	Chloramphenicol	2.0	10.9	[8.1–14.4]								17.4	65.4	4.2	2.0	3.0	8.0			
	Sulfonamides	Sulfisoxazole	NA	40.3	[35.5–45.3]											48.8	8.5	2.0	0.5		40.3
	Tetracyclines	Tetracycline	0.2	34.6	[29.9–39.5]									65.2	0.2	1.2	7.7	25.6			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 3.01: Antimicrobial resistance pattern for *Shigella*, 2006

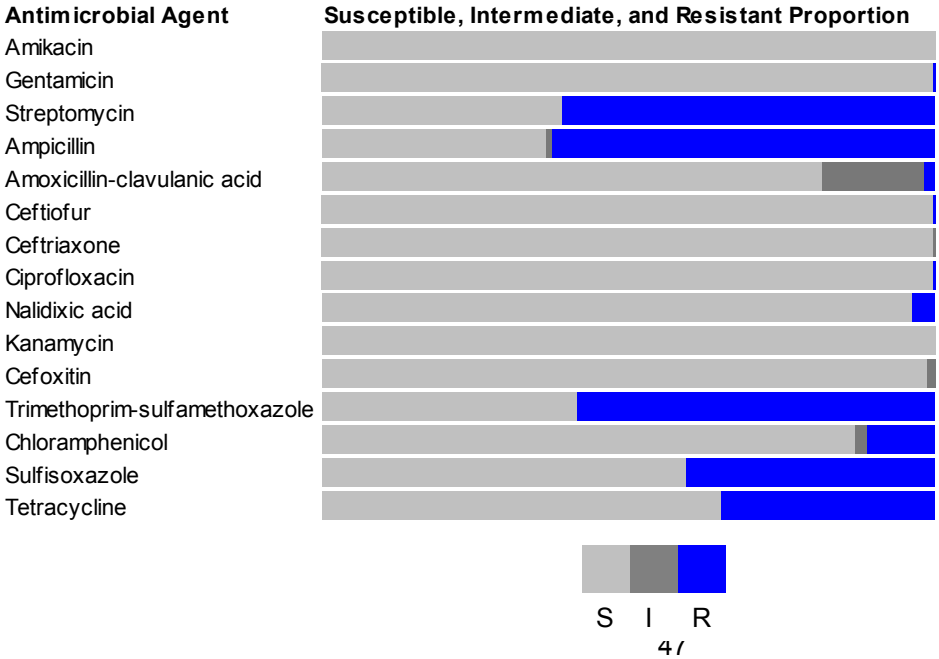

Table 3.03: Minimum inhibitory concentrations (MICs) and resistance of *Shigella sonnei* isolates to antimicrobial agents, 2006 (N=321)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–1.1]						1.6	4.4	59.2	32.7	2.2						
		Gentamicin	0.0	0.0	[0.0–1.1]					3.4	43.3	51.4	1.9								
		Streptomycin	NA	61.7	[56.1–67.0]												38.3	34.0	27.7		
	Aminopenicillins	Ampicillin	1.2	62.3	[56.8–67.6]							4.4	25.9	5.3	0.9	1.2	0.6	61.7			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	10.0	1.9	[0.7–4.0]							2.5	2.5	32.4	50.8	10.0	1.9				
	Cephalosporins (3rd generation)	Ceftiofur	0.0	0.0	[0.0–1.1]				15.9	73.8	9.7	0.6									
		Ceftriaxone	0.0	0.0	[0.0–1.1]					99.4	0.6										
	Quinolones	Ciprofloxacin	0.0	0.0	[0.0–1.1]	96.6	0.3	0.9	1.6	0.3		0.3									
		Nalidixic acid	NA	2.8	[1.3–5.3]						5.3	72.6	17.4	1.6	0.3		1.2	1.6			
II	**Aminoglycosides**	Kanamycin	0.0	0.0	[0.0–1.1]										99.7	0.3					
	Cephamycins	Cefoxitin	1.6	0.0	[0.0–1.1]						0.6	23.4	65.7	8.4	0.3	1.6					
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	57.9	[52.3–63.4]				19.9	4.0	1.9	7.2	9.0	10.9	47.0						
	Phenicols	Chloramphenicol	2.2	0.9	[0.2–2.7]								11.8	80.1	5.0	2.2	0.3	0.6			
	Sulfonamides	Sulfisoxazole	NA	33.3	[28.2–38.8]											53.9	10.3	2.2	0.3		33.3
	Tetracyclines	Tetracycline	0.0	22.7	[18.3–27.7]									77.3		0.6	7.8	14.3			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 3.02: Antimicrobial resistance pattern for *Shigella sonnei*, 2006

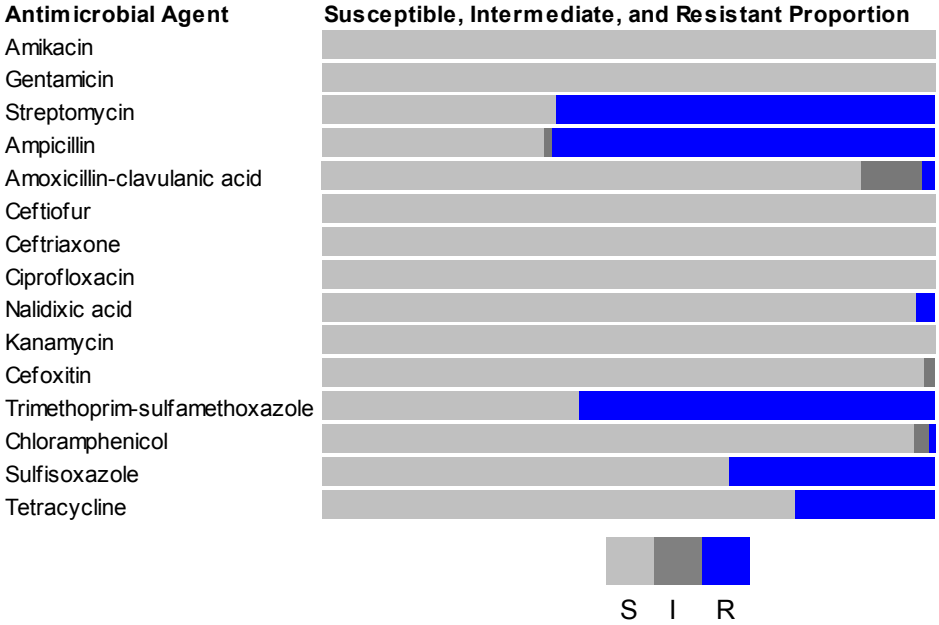

Table 3:04: Minimum inhibitory concentrations and resistance of *Shigella flexneri* isolates to antimicrobial agents, 2006 (N=74)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–4.9]						1.4	4.1	18.9	74.3	1.4						
		Gentamicin	0.0	1.4	[0.0–7.3]					4.1	24.3	70.3					1.4				
		Streptomycin	NA	58.1	[46.1–69.5]												41.9	9.5	48.6		
	Aminopenicillins	Ampicillin	0.0	63.5	[51.5–74.4]							21.6	12.2		2.7			63.5			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	44.6	0.0	[0.0–4.9]							4.1	25.7	8.1	17.6	44.6					
	Cephalosporins (3rd generation)	Ceftiofur	0.0	1.4	[0.0–7.3]				47.3	44.6	5.4	1.4				1.4					
		Ceftriaxone	1.4	0.0	[0.0–4.9]					98.6							1.4				
	Quinolones	Ciprofloxacin	0.0	1.4	[0.0–7.3]	93.2		1.4			4.1			1.4							
		Nalidixic acid	NA	5.4	[1.5–13.3]						2.7	64.9	23.0	4.1				5.4			
II	**Aminoglycosides**	Kanamycin	0.0	0.0	[0.0–4.9]										98.6	1.4					
	Cephamycins	Cefoxitin	0.0	0.0	[0.0–4.9]						1.4	4.1	56.8	37.8							
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	59.5	[47.4–70.7]				23.0	14.9	1.4	1.4			59.5						
	Phenicols	Chloramphenicol	1.4	54.1	[42.1–65.7]								36.5	8.1		1.4	14.9	39.2			
	Sulfonamides	Sulfisoxazole	NA	68.9	[57.1–79.2]											28.4	1.4	1.4			68.9
	Tetracyclines	Tetracycline	1.4	83.8	[73.4–91.3]									14.9	1.4	4.1	6.8	73.0			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 3.03: Antimicrobial resistance pattern for *Shigella flexneri*, 2006

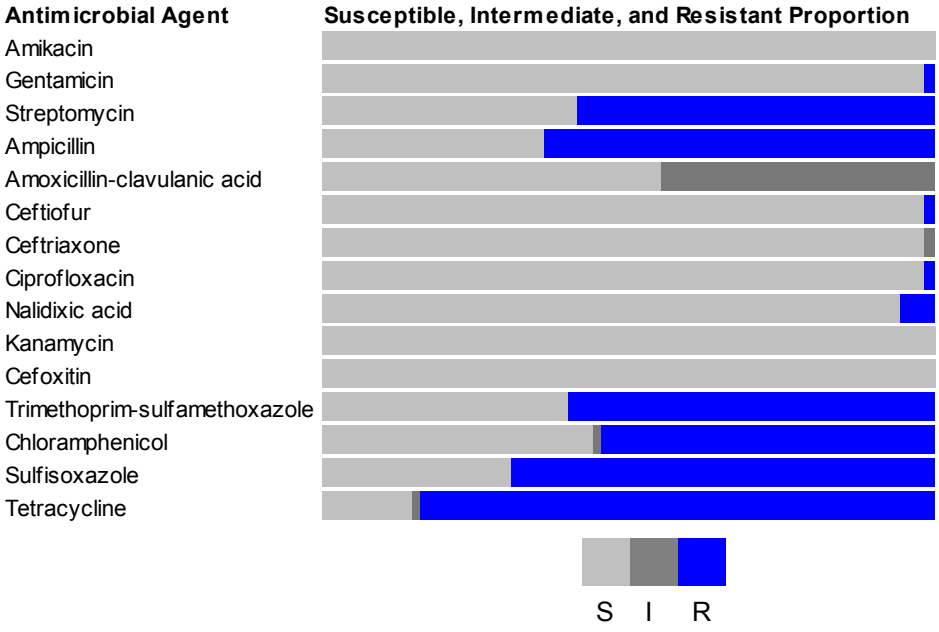

Table 3.05: Percentage and number of *Shigella* isolates resistant to antimicrobial agents, 1999–2006

Year			1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			375	450	344	620	495	315	396	402
Rank*	Subclass	Antibiotic (Resistance breakpoint)								
I	Aminoglycosides	Amikacin (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	0.3% 1	0.2% 1	0.0% 0	0.2% 1	0.0% 0	0.0% 0	1.0% 4	0.2% 1
		Streptomycin (MIC ≥ 64)	55.7% 209	57.1% 257	53.2% 183	54.4% 337	57.0% 282	61.0% 192	68.7% 272	60.7% 244
	Aminopenicillins	Ampicillin (MIC ≥ 32)	77.6% 291	79.1% 356	79.7% 274	76.6% 475	79.4% 393	77.8% 245	70.7% 280	62.2% 250
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	1.1% 4	2.2% 10	4.4% 15	2.6% 16	1.4% 7	1.6% 5	1.0% 4	1.5% 6
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.0% 0	0.0% 0	0.2% 1	0.2% 1	0.3% 1	0.5% 2	0.2% 1
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.5% 2	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.2% 1
		Nalidixic acid (MIC ≥ 32)	1.6% 6	0.9% 4	1.7% 6	1.6% 10	1.0% 5	1.6% 5	1.5% 6	3.5% 14
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.5% 2	1.3% 6	0.6% 2	0.8% 5	0.4% 2	0.0% 0	0.8% 3	0.0% 0
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	3.2% 12	8.0% 36	9.0% 31	6.6% 41	9.3% 46	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	0.2% 1	1.2% 4	0.3% 2	0.0% 0	0.3% 1	0.3% 1	0.0% 0
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	51.5% 193	52.9% 238	46.8% 161	37.3% 231	38.6% 191	51.4% 162	58.6% 232	58.2% 234
	Phenicols	Chloramphenicol (MIC ≥ 32)	17.3% 65	14.0% 63	21.5% 74	7.6% 47	8.5% 42	14.9% 47	10.9% 43	10.9% 44
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	56.0% 210	55.8% 251	56.4% 194	31.8% 197	33.9% 168	52.4% 165	57.6% 228	40.3% 162
	Tetracyclines	Tetracycline (MIC ≥ 16)	57.3% 215	44.9% 202	59.3% 204	30.6% 190	29.1% 144	49.2% 155	38.4% 152	34.6% 139

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 3.06: Percentage and number of *Shigella sonnei* isolates resistant to antimicrobial agents, 1999–2006

Year			1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			275	366	239	536	434	241	340	321
Rank*	Subclass	Antibiotic (Resistance breakpoint)								
I	Aminoglycosides	Amikacin (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	0.4% 1	0.3% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.2% 4	0.0% 0
		Streptomycin (MIC ≥ 64)	52.0% 143	56.0% 205	54.0% 129	55.4% 297	56.5% 245	58.1% 140	70.3% 239	61.7% 198
	Aminopenicillins	Ampicillin (MIC ≥ 32)	79.6% 219	80.6% 295	82.8% 198	77.6% 416	79.7% 346	79.3% 191	70.6% 240	62.3% 200
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	0.4% 1	1.9% 7	4.6% 11	2.2% 12	1.4% 6	1.7% 4	1.2% 4	1.9% 6
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.4% 1	0.6% 2	0.0% 0
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.4% 1	0.6% 2	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Nalidixic acid (MIC ≥ 32)	1.5% 4	1.1% 4	0.8% 2	1.5% 8	0.5% 2	1.7% 4	1.2% 4	2.8% 9
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.7% 2	1.6% 6	0.4% 1	0.4% 2	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	2.9% 8	8.7% 32	12.6% 30	7.3% 39	10.1% 44	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	0.3% 1	1.7% 4	0.4% 2	0.0% 0	0.4% 1	0.3% 1	0.0% 0
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	53.1% 146	54.9% 201	50.6% 121	37.9% 203	38.5% 167	53.1% 128	61.2% 208	57.9% 186
	Phenicols	Chloramphenicol (MIC ≥ 32)	1.8% 5	2.7% 10	1.3% 3	0.2% 1	1.2% 5	2.5% 6	2.4% 8	0.9% 3
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	54.5% 150	56.0% 205	54.4% 130	29.9% 160	31.3% 136	49.0% 118	57.9% 197	33.3% 107
	Tetracyclines	Tetracycline (MIC ≥ 16)	46.2% 127	34.4% 126	44.8% 107	23.5% 126	22.1% 96	36.1% 87	29.4% 100	22.7% 73

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 3.07: Percentage and number of *Shigella flexneri* isolates resistant to antimicrobial agents, 1999–2006

Year			1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			87	75	91	73	51	61	52	74
Rank*	Subclass	Antibiotic (Resistance breakpoint)								
I	Aminoglycosides	Amikacin (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	0.0% 0	0.0% 0	0.0% 0	1.4% 1	0.0% 0	0.0% 0	0.0% 0	1.4% 1
		Streptomycin (MIC ≥ 64)	63.2% 55	61.3% 46	47.3% 43	43.8% 32	60.8% 31	72.1% 44	57.7% 30	58.1% 43
	Aminopenicillins	Ampicillin (MIC ≥ 32)	77.0% 67	77.3% 58	72.5% 66	75.3% 55	84.3% 43	82.0% 50	75.0% 39	63.5% 47
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	3.4% 3	4.0% 3	4.4% 4	5.5% 4	2.0% 1	1.6% 1	0.0% 0	0.0% 0
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.0% 0	0.0% 0	1.4% 1	2.0% 1	0.0% 0	0.0% 0	1.4% 1
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	1.1% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.4% 1
		Nalidixic acid (MIC ≥ 32)	1.1% 1	0.0% 0	3.3% 3	2.7% 2	5.9% 3	1.6% 1	3.8% 2	5.4% 4
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.0% 0	0.0% 0	1.1% 1	4.1% 3	3.9% 2	0.0% 0	3.8% 2	0.0% 0
	Cephalosporin (1st generation)	Cephalothin (MIC ≥ 32)	4.6% 4	2.7% 2	1.1% 1	2.7% 2	3.9% 2	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	48.3% 42	42.7% 32	34.1% 31	28.8% 21	39.2% 20	45.9% 28	44.2% 23	59.5% 44
	Phenicols	Chloramphenicol (MIC ≥ 32)	64.4% 56	69.3% 52	74.7% 68	63.0% 46	68.6% 35	60.7% 37	65.4% 34	54.1% 40
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	58.6% 51	53.3% 40	57.1% 52	41.1% 30	52.9% 27	65.6% 40	55.8% 29	68.9% 51
	Tetracyclines	Tetracycline (MIC ≥ 16)	92.0% 80	92.0% 69	94.5% 86	78.1% 57	82.4% 42	95.1% 58	94.2% 49	83.8% 62

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 3.08: Resistance patterns of *Shigella* isolates, 1999–2006

Year	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	375	450	344	620	495	315	396	402
	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	9.1% 34	7.3% 33	4.9% 17	8.2% 51	8.5% 42	4.4% 14	4.5% 18	5.2% 21
Resistance ≥ 1 CLSI subclass*	90.9% 341	92.7% 417	95.1% 327	91.8% 569	91.5% 453	95.6% 301	95.5% 378	94.8% 381
Resistance ≥ 2 CLSI subclasses*	63.7% 239	64.7% 291	69.8% 240	55.3% 343	57.8% 286	66.7% 210	73.7% 292	71.4% 287
Resistance ≥ 3 CLSI subclasses*	61.1% 229	62.0% 279	61.3% 211	41.8% 259	41.4% 205	62.2% 196	62.9% 249	51.0% 205
Resistance ≥ 4 CLSI subclasses*	54.1% 203	56.7% 255	54.1% 186	31.0% 192	32.5% 161	52.1% 164	55.6% 220	35.8% 144
Resistance ≥ 5 CLSI subclasses*	40.5% 152	26.2% 118	36.0% 124	20.5% 127	22.4% 111	27.6% 87	15.7% 62	13.7% 55
At least ACSSuT†	8.5% 32	5.6% 25	6.4% 22	1.8% 11	3.2% 16	6.0% 19	4.0% 16	5.0% 20
At least ACSuTm‡	9.9% 37	6.9% 31	7.0% 24	2.7% 17	3.6% 18	6.7% 21	6.3% 25	6.0% 24
At least ASuTm§	44.3% 166	44.4% 200	37.5% 129	29.8% 185	33.7% 167	37.8% 119	39.9% 158	34.1% 137
At least ANSuTm¶	0.3% 1	0.0% 0	0.6% 2	0.3% 2	0.8% 4	0.6% 2	0.5% 2	0.5% 2
At least ACSSuTAuCf**	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
At least MDR-AmpC††	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
Resistance to quinolone‡‡ and cephalosporin§§	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.2% 1	0.3% 1	0.3% 1	0.2% 1

*CLSI: Clinical and Laboratory Standards Institute

†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline

‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole

§ASuTm: resistance to ampicillin, trimethoprim-sulfamethoxazole

¶ANSuTm: resistance to ASuTm + naladixic acid

**ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur

††MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)

‡‡Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)

§§Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

Table 3.09: Resistance patterns of *Shigella sonnei* isolates, 1999–2006

Year	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	**275**	**366**	**239**	**536**	**434**	**241**	**340**	**321**
	%	%	%	%	%	%	%	%
	n	n	n	n	n	n	n	n
No resistance detected	10.5%	7.7%	5.4%	7.1%	8.5%	5.0%	4.4%	4.7%
	29	28	13	38	37	12	15	15
Resistance ≥ 1 CLSI subclass*	89.5%	92.3%	94.6%	92.9%	91.5%	95.0%	95.6%	95.3%
	246	338	226	498	397	229	325	306
Resistance ≥ 2 CLSI subclasses*	56.0%	60.7%	60.7%	52.1%	54.1%	59.8%	72.6%	67.9%
	154	222	145	279	235	144	247	218
Resistance ≥ 3 CLSI subclasses*	54.5%	57.7%	53.1%	36.6%	36.2%	54.4%	60.0%	43.6%
	150	211	127	196	157	131	204	140
Resistance ≥ 4 CLSI subclasses*	50.5%	54.1%	49.0%	26.7%	28.6%	46.5%	53.5%	29.3%
	139	198	117	143	124	112	182	94
Resistance ≥ 5 CLSI subclasses*	38.5%	23.5%	36.0%	19.4%	20.0%	24.9%	11.5%	7.5%
	106	86	86	104	87	60	39	24
At least ACSSuT†	0.4%	0.8%	0.0%	0.0%	0.2%	0.0%	0.3%	0.0%
	1	3	0	0	1	0	1	0
At least ACSuTm‡	1.8%	1.9%	0.8%	0.2%	0.9%	1.7%	2.4%	0.9%
	5	7	2	1	4	4	8	3
At least ASuTm§	45.1%	46.2%	41.0%	30.2%	33.6%	39.4%	40.6%	32.1%
	124	169	98	162	146	95	138	103
At least ANSuTm¶	0.0%	0.0%	0.0%	0.2%	0.2%	0.8%	0.3%	0.0%
	0	0	0	1	1	2	1	0
At least ACSSuTAuCf**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0	0	0	0	0	0	0
At least MDR-AmpC††	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0	0	0	0	0	0	0
Resistance to quinolone** and cephalosporin††	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.3%	0.0%
	0	0	0	0	0	1	1	0

*CLSI: Clinical and Laboratory Standards Institute
†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline
‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole
§ASuTm: resistance to ampicillin, trimethoprim-sulfamethoxazole
¶ANSuTm: resistance to ASuTm + naladixic acid
**ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur
††MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)
‡‡Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)
§§Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

Table 3.10: Resistance patterns of *Shigella flexneri* isolates, 1999–2006

Year	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	**87**	**75**	**91**	**73**	**51**	**61**	**52**	**74**
	%	%	%	%	%	%	%	%
	n	n	n	n	n	n	n	n
No resistance detected	4.6%	4.0%	3.3%	15.1%	7.8%	0.0%	5.8%	5.4%
	4	3	3	11	4	0	3	4
Resistance ≥ 1 CLSI subclass*	95.4%	96.0%	96.7%	84.9%	92.2%	100.0%	94.2%	94.6%
	83	72	88	62	47	61	49	70
Resistance ≥ 2 CLSI subclasses*	83.9%	82.7%	90.1%	76.7%	86.3%	93.4%	80.8%	86.5%
	73	62	82	56	44	57	42	64
Resistance ≥ 3 CLSI subclasses*	80.5%	81.3%	80.2%	75.3%	82.4%	91.8%	80.8%	81.1%
	70	61	73	55	42	56	42	60
Resistance ≥ 4 CLSI subclasses*	67.8%	69.3%	65.9%	58.9%	64.7%	75.4%	69.2%	62.2%
	59	52	60	43	33	46	36	46
Resistance ≥ 5 CLSI subclasses*	49.4%	40.0%	31.9%	28.8%	45.1%	41.0%	44.2%	40.5%
	43	30	29	21	23	25	23	30
At least ACSSuT†	33.3%	29.3%	22.0%	15.1%	29.4%	27.9%	28.8%	27.0%
	29	22	20	11	15	17	15	20
At least ACSuTm‡	34.5%	32.0%	23.1%	21.9%	27.5%	24.6%	32.7%	28.4%
	30	24	21	16	14	15	17	21
At least ASuTm§	44.8%	38.7%	25.3%	27.4%	37.3%	36.1%	38.5%	43.2%
	39	29	23	20	19	22	20	32
At least ANSuTm¶	1.1%	0.0%	1.1%	1.4%	5.9%	0.0%	1.9%	2.7%
	1	0	1	1	3	0	1	2
At least ACSSuTAuCf**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0	0	0	0	0	0	0
At least MDR-AmpC††	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	0	0	0	0	0	0	0	0
Resistance to quinolone** and cephalosporin††	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	1.4%
	0	0	0	0	1	0	0	1

*CLSI: Clinical and Laboratory Standards Institute
†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline
‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole
§ASuTm: resistance to ampicillin, trimethoprim-sulfamethoxazole
¶ANSuTm: resistance to ASuTm + naladixic acid
**ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur
††MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)
‡‡Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)
§§Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

4. *Escherichia coli* O157

From 1996 to 2006, there was no temporal trend in the percentage of isolates with resistance. Among *E. coli* O157 isolates, resistance to antimicrobial agents was not common and multidrug resistance was rare.

In 2006, CDC received a total of 251 *Escherichia coli* O157 isolates, of which 233 (92.8%) were viable non-duplicates tested for antimicrobial susceptibility (Table II). Resistance to antimicrobial agents was not common. Antimicrobial agents with the highest prevalence of resistance were tetracycline (4.7%), sulfisoxazole (3.0%), ampicillin (2.6%), and streptomycin (2.6%). Three isolates in 2006 were resistant to ceftiofur, whereas no isolates were resistant in 2005 (Table 4.02).

Isolates resistant to at least one CLSI subclass decreased from 12.4% in 2005 to 8.2% in 2006 (Table 4.03). Just as in 2004 and 2005, there were no isolates resistant to at least five subclasses in 2006. From 1996 to 2006, there was no temporal trend in the percentage of isolates with no detected resistance, which ranged from 86.6% to 95.3% during the 11-year surveillance period.

Table 4.01: Minimum inhibitory concentrations (MICs) and resistance of *Escherichia coli* O157 isolates to antimicrobial agents, 2006 (N=233)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–1.6]						6.0	66.1	21.9	5.2	0.9						
		Gentamicin	0.0	0.0	[0.0–1.6]					51.9	42.1	5.6	0.4								
		Streptomycin	NA	2.6	[1.0–5.5]												97.4	1.3	1.3		
	Aminopenicillins	Ampicillin	0.4	2.6	[1.0–5.5]							4.3	78.5	12.9	1.3	0.4		2.6			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	0.4	1.3	[0.3–3.7]							1.7	9.0	86.3	1.3	0.4	0.4	0.9			
	Cephalosporins (3rd generation)	Ceftiofur	0.0	1.3	[0.3–3.7]				1.7	24.5	69.5	3.0				1.3					
		Ceftriaxone	0.4	0.9	[0.1–3.1]					97.9			0.9			0.4		0.9			
	Quinolones	Ciprofloxacin	0.0	0.4	[0.0–2.4]	97.0	0.4		1.3	0.9					0.4						
		Nalidixic acid	NA	2.1	[0.7–4.9]						0.4	2.1	87.1	7.3	0.4	0.4	0.4	1.7			
II	**Aminoglycosides**	Kanamycin	0.0	0.4	[0.0–2.4]										99.1	0.4			0.4		
	Cephamycins	Cefoxitin	0.9	1.3	[0.3–3.7]							2.1	7.3	78.1	10.3	0.9	0.4	0.9			
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	0.4	[0.0–2.4]				94.4	5.2					0.4						
	Phenicols	Chloramphenicol	0.9	1.3	[0.3–3.7]								1.3	27.0	69.5	0.9		1.3			
	Sulfonamides	Sulfisoxazole	NA	3.0	[1.2–6.1]											81.1	14.6	1.3			3.0
	Tetracyclines	Tetracycline	0.0	4.7	[2.4–8.3]									95.3		0.4	1.3	3.0			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure 4.01: Antimicrobial resistance pattern for *Escherichia coli* O157, 2006

Table 4.02: Percentage and number of *Escherichia coli* O157 isolates resistant to antimicrobial agents, 1996–2006

Year			1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			201	161	318	292	407	277	399	157	169	194	233
Rank*	Subclass	Antibiotic (Resistance breakpoint)											
I	Aminoglycosides	Amikacin (MIC ≥ 64)	Not Tested	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.5% 2	0.4% 1	0.0% 0	0.0% 0	0.6% 1	0.5% 1	0.0% 0
		Streptomycin (MIC ≥ 64)	2.0% 4	2.5% 4	1.9% 6	2.7% 8	5.2% 21	1.8% 5	2.3% 9	1.9% 3	1.8% 3	2.1% 4	2.6% 6
	Aminopenicillins	Ampicillin (MIC ≥ 32)	1.5% 3	0.0% 0	2.5% 8	1.4% 4	2.7% 11	2.2% 6	1.5% 6	3.2% 5	1.2% 2	4.1% 8	2.6% 6
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	0.0% 0	0.0% 0	0.0% 0	0.3% 1	1.0% 4	0.7% 2	0.0% 0	1.3% 2	0.0% 0	0.0% 0	1.3% 3
	Cephalosporins (3rd Gen.)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.0% 4	1.1% 3	0.0% 0	1.3% 2	0.0% 0	0.0% 0	1.3% 3
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.9% 2
	Quinolones	Ciprofloxacin (MIC ≥ 4)	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.4% 1
		Nalidixic acid (MIC ≥ 32)	0.0% 0	0.0% 0	0.0% 0	0.7% 2	0.5% 2	1.1% 3	1.0% 4	0.6% 1	1.8% 3	1.5% 3	2.1% 5
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	0.0% 0	0.0% 0	0.3% 1	0.7% 2	1.0% 4	0.0% 0	0.5% 2	0.0% 0	0.0% 0	0.5% 1	0.4% 1
	Cephalosporin (1st Gen.)	Cephalothin (MIC ≥ 32)	1.5% 3	2.5% 4	0.0% 0	0.7% 2	1.2% 5	1.4% 4	1.5% 6	2.5% 4	Not Tested	Not Tested	Not Tested
	Cephamycins	Cefoxitin (MIC ≥ 32)	Not Tested	Not Tested	Not Tested	Not Tested	1.0% 4	0.7% 2	0.0% 0	1.3% 2	0.6% 1	0.0% 0	1.3% 3
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	0.0% 0	0.0% 0	0.6% 2	1.4% 4	0.7% 3	0.7% 2	0.5% 2	0.6% 1	0.0% 0	0.5% 1	0.4% 1
	Phenicols	Chloramphenicol (MIC ≥ 32)	0.5% 1	0.0% 0	0.3% 1	0.0% 0	3.7% 15	1.4% 4	1.3% 5	1.3% 2	0.6% 1	1.0% 2	1.3% 3
	Sulfonamides	Sulfamethoxazole/Sulfisoxazole† (MIC ≥ 512)	11.9% 24	9.9% 16	5.7% 18	8.2% 24	5.9% 24	5.1% 14	3.5% 14	3.8% 6	1.8% 3	6.7% 13	3.0% 7
	Tetracyclines	Tetracycline (MIC ≥ 16)	5.0% 10	3.1% 5	4.4% 14	3.4% 10	7.1% 29	5.4% 15	3.0% 12	5.7% 9	1.8% 3	8.8% 17	4.7% 11

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Sulfamethoxazole, which was tested during 1996-2003 to represent sulfonamides, was replaced by sulfisoxazole in 2004.

Table 4.03: Resistance patterns of *Escherichia coli* O157 isolates, 1996–2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	201	161	318	292	407	277	399	157	169	194	233
	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	86.6% 174	88.8% 143	92.8% 295	89.7% 262	90.4% 368	91.3% 253	94.0% 375	90.4% 142	95.3% 161	87.6% 170	91.8% 214
Resistance ≥ 1 CLSI subclass*	13.4% 27	11.2% 18	7.2% 23	10.3% 30	9.6% 39	8.7% 24	6.0% 24	9.6% 15	4.7% 8	12.4% 24	8.2% 19
Resistance ≥ 2 CLSI subclasses*	5.0% 10	3.7% 6	5.3% 17	3.4% 10	6.6% 27	5.4% 15	3.8% 15	5.1% 8	1.2% 2	5.2% 10	3.4% 8
Resistance ≥ 3 CLSI subclasses*	1.5% 3	0.6% 1	1.9% 6	3.1% 9	4.7% 19	2.2% 6	2.0% 8	3.2% 5	0.6% 1	1.0% 2	3.0% 7
Resistance ≥ 4 CLSI subclasses*	0.5% 1	0.0% 0	0.9% 3	1.0% 3	3.7% 15	1.8% 5	1.0% 4	1.3% 2	0.6% 1	0.5% 1	1.7% 4
Resistance ≥ 5 CLSI subclasses*	0.5% 1	0.0% 0	0.0% 0	0.7% 2	1.5% 6	0.7% 2	0.3% 1	0.6% 1	0.0% 0	0.0% 0	0.0% 0
At least ACSSuT†	0.5% 1	0.0% 0	0.0% 0	0.0% 0	1.2% 5	0.4% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.9% 2
At least ACSuTm‡	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.2% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
At least ACSSuTAuCf§	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.0% 4	0.4% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
At least MDR-AmpC¶	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.0% 4	0.4% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0
Resistance to quinolone** and cephalosporin††	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	1.3% 3

*CLSI: Clinical and Laboratory Standards Institute

†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline

‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole

§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur

¶MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)

**Resistance to nalidixic acid (MIC ≥ 32) or decreased susceptibility to ciprofloxacin (MIC ≥ 0.12)

††Decreased susceptibility to ceftiofur (MIC ≥ 2) or ceftriaxone (MIC ≥ 2)

5. *Campylobacter*

Among all *Campylobacter* isolates tested, ciprofloxacin resistance increased from 12.9% in 1997 to 21.7 in 2005 and decreased to 19.6% in 2006. Resistance to erythromycin remained low during the period from 1997 to 2006. A decrease in ciprofloxacin resistance in *C. jejuni* was observed similar to the trend in all *Campylobacter*. The percentage of resistance to most antimicrobial agents tested, including ciprofloxacin and erythromycin, was higher in *C. coli* compared with *C. jejuni*.

In 2006, CDC received 920 *Campylobacter* isolates, of which 816 (88.7%) were viable non-duplicates tested for antimicrobial susceptibility. A total of 709 (86.9%) were *C. jejuni*, 97 (11.9%) were *C. coli*, and 10 (1.2%) were other species (Table 5.01).

Of the *Campylobacter* isolates tested in 2006 (Table II), resistance was highest to tetracycline (46.0%), nalidixic acid (20.1%), and ciprofloxacin (19.6%) (Table 5.02). Of the isolates tested, none were resistant to florfenicol, which replaced chloramphenicol to represent the phenicol antimicrobial subclass.

The percentage of *Campylobacter* isolates resistant to ciprofloxacin significantly increased from 12.9% in 1997 to 19.6% in 2006 (OR=2.0, 95% CI [1.3, 3.1]). Resistance to erythromycin remained low at 2.1% or less from 1997 to 2006. It increased from 0.3% in 2004 to 1.7% in 2006 (Table 5.03).

In 2006, 56.1% of *Campylobacter* isolates were resistant to one or more CLSI subclass, compared with 51.6% in 2005 (Table 5.04). In 2006, 12.0% of *Campylobacter* isolates were resistant to two or more subclasses, compared with 13.6% in 2005.

The antimicrobial agent with the highest prevalence of resistance among the 709 *C. jejuni* isolates was tetracycline (47.4%), followed by ciprofloxacin (19.5%), and nalidixic acid (19.0%) (Table 5.05). Of note, 0.0% and 0.8% of *C. jejuni* isolates were resistant to gentamicin and erythromycin, respectively.

The percentage of *C. jejuni* isolates resistant to ciprofloxacin increased from 12.4% in 1997 to 19.5% in 2006 (Table 5.06); this increase was statistically significant (OR=2.0, 95% CI [1.3, 3.3]). Erythromycin resistance was low at 1.9% or less from 1997 to 2006.

The percentage of resistance to most agents tested, including ciprofloxacin and erythromycin, was higher in *C. coli* compared with *C. jejuni*. In 2006, the highest levels of resistance among the 97 *C. coli* isolates were to tetracycline (39.2%), nalidixic acid (23.7%), and ciprofloxacin (21.6%) (Table 5.07). The percentage of *C. coli* isolates resistant to ciprofloxacin was 33.3% in 1997, not detected in 1998, but ranged from 12.0% to 47.1% from 1999 to 2006; it was 21.6% in 2006 (Table 5.08). Resistance to erythromycin was not detected in 1997, 12.5% in 1998, ranged from 4.0% to 10.0% during 1999 to 2003, decreased to 0.0% in 2004, and increased to 8.2% in 2006.

Table 5.01: Frequency of *Campylobacter* species isolated in NARMS, 2006

Species	2006	
	n	(%)
Campylobacter jejuni	709	(86.9%)
Campylobacter coli	97	(11.9%)
Other	10	(1.2%)
Total	**816**	**(100.0%)**

Table 5.02: Minimum inhibition concentrations (MICs) and resistance of *Campylobacter* isolates to antimicrobial agents, 2006 (N=816)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Gentamicin	0.0	0.1	[0.0–0.7]				7.6	33.5	51.7	6.7	0.4					0.1			
	Ketolide	Telithromycin	0.5	1.6	[0.9–2.7]			0.2	1.6	12.6	30.0	30.4	19.2	3.8	0.5	1.6					
	Macrolides	Azithromycin	0.0	1.7	[0.9–2.9]	3.6	25.4	34.3	25.1	8.8	0.9	0.2							1.7		
		Erythromycin	0.0	1.7	[0.9–2.9]			0.9	7.2	27.7	33.6	22.2	4.8	2.0				0.1	1.6		
	Quinolones	Ciprofloxacin	0.1	19.6	[16.9–22.5]	0.2	5.3	36.2	29.0	8.3	1.2		0.1	2.0	8.3	5.9	2.0	1.2	0.2		
		Nalidixic acid	0.4	20.1	[17.4–23.0]									58.3	18.1	3.1	0.4	2.6	17.5		
II	**Phenicols**	Florfenicol**	N/A	0.0	[0.0–0.5]					2.0	18.4	60.8	16.3	2.6							
	Tetracyclines	Tetracycline	0.5	46.0	[42.5–49.4]			6.0	22.4	17.0	4.5	2.7	0.7	0.1	0.5	1.5	3.2	12.3	29.0		
III	**Lincosamides**	Clindamycin	0.1	2.0	[1.1–3.2]		3.9	21.7	39.8	22.1	7.5	2.0	1.0	0.1	0.2	0.7	1.0				

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the range of dilutions tested for each antimicrobial agent. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest tested concentrations. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints

**CLSI guidelines do not currently define a resistance-breakpoint for florfenicol.

Figure 5.01: Antimicrobial resistance pattern for *Campylobacter*, 2006

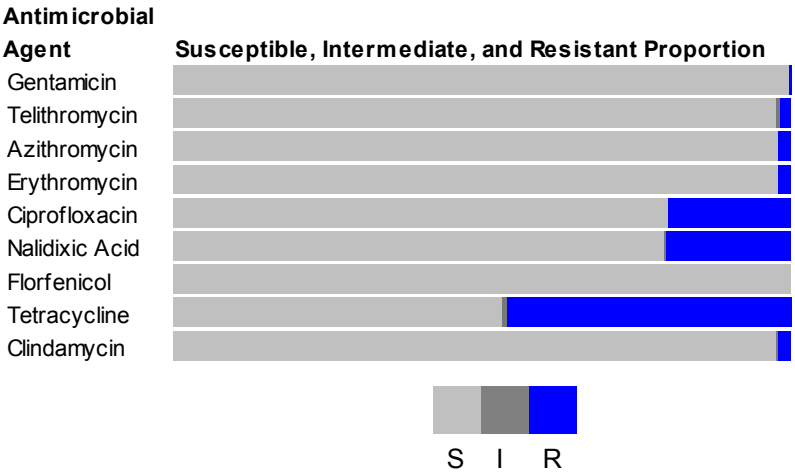

Table 5.03: Percentage and number of *Campylobacter* isolates resistant to antimicrobial agents, 1997–2006

Year			1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			217	310	317	324	384	354	328	347	890	816
Rank*	Subclass	Antibiotic (Resistance breakpoint)										
I	Aminoglycosides	Gentamicin (MIC ≥ 8)	Not Tested	0.3% 1	0.0% 0	0.3% 1	0.0% 0	0.0% 0	0.3% 1	0.3% 1	0.7% 6	0.1% 1
	Ketolides	Telithromycin (MIC ≥ 16)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	1.0% 9	1.6% 13
	Macrolides	Azithromycin (MIC ≥ 8)	Not Tested	0.6% 2	2.2% 7	1.9% 6	2.1% 8	2.0% 7	0.9% 3	0.6% 2	1.9% 17	1.7% 14
		Erythromycin (MIC ≥ 32)	1.8% 4	1.0% 3	1.9% 6	1.2% 4	2.1% 8	1.4% 5	0.9% 3	0.3% 1	1.8% 16	1.7% 14
	Quinolones	Ciprofloxacin (MIC ≥ 4)	12.9% 28	13.9% 43	18.3% 58	14.8% 48	19.5% 75	20.1% 71	17.7% 58	19.0% 66	21.7% 193	19.6% 160
		Nalidixic acid (MIC ≥ 64)	14.3% 31	16.8% 52	21.1% 67	16.7% 54	20.3% 78	20.6% 73	18.9% 62	19.6% 68	22.4% 199	20.1% 164
II	Phenicols	Chloramphenicol (MIC ≥ 32)	5.1% 11	2.9% 9	0.6% 2	0.0% 0	0.3% 1	0.3% 1	0.0% 0	1.4% 5	Not Tested	Not Tested
		Florfenicol† Susceptible breakpoint: (MIC < 4)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	0.6% 5	0.0% 0
	Tetracyclines	Tetracycline (MIC ≥ 16)	47.9% 104	45.5% 141	43.8% 139	38.3% 124	40.9% 157	41.2% 146	38.4% 126	46.1% 160	40.6% 361	46.0% 375
III	Lincosamides	Clindamycin (MIC ≥ 8)	1.8% 4	1.3% 4	1.3% 4	0.9% 3	2.1% 8	2.0% 7	0.6% 2	2.0% 7	1.5% 13	2.0% 16

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true. Antimicrobial agents are considered important (Rank III) if neither criterion are true.

† Only a susceptible breakpoint (≤ 4 µg/ml) has been established. In this report, isolates with an MIC ≥ 8 µg/ml are categorized as resistant

Table 5.04: Resistance patterns of *Campylobacter* isolates, 1997–2006

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates	217	310	317	324	384	354	328	347	890	816
	% n	% n	% n	% n	% n	% n	% n	% n	% n	% n
No resistance detected	47.0% 102	45.2% 140	47.3% 150	52.2% 169	49.2% 189	48.3% 171	50.9% 167	46.1% 160	48.4% 431	43.9% 358
Resistance ≥ 1 CLSI subclass*	53.0% 115	54.8% 170	52.7% 167	47.8% 155	50.8% 195	51.7% 183	49.1% 161	53.9% 187	51.6% 459	56.1% 458
Resistance ≥ 2 CLSI subclasses*	15.7% 34	9.7% 30	13.6% 43	8.0% 26	13.3% 51	12.7% 45	8.5% 28	14.1% 49	13.6% 121	12.0% 98
Resistance ≥ 3 CLSI subclasses*	1.8% 4	2.6% 8	1.6% 5	0.9% 3	1.6% 6	1.1% 4	0.9% 3	1.2% 4	1.5% 13	1.5% 12
Resistance ≥ 4 CLSI subclasses*	0.5% 1	0.3% 1	0.9% 3	0.3% 1	0.3% 1	0.0% 0	0.3% 1	0.3% 1	0.3% 3	0.5% 4
Resistance ≥ 5 CLSI subclasses*	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0

*CLSI: Clinical and Laboratory Standards Institute

Table 5.05: Minimum inhibitory concentrations (MICs) and resistance of *Campylobacter jejuni* isolates to antimicrobial agents, 2006, (N=709)

Rank*	Antibiotic		% of isolates %I†	%R‡	[95% CI]§	Percent of all isolates with MIC (µg/mL)¶ 0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Gentamicin	0.0	0.0	[0.0–0.5]				8.5	37.5	49.6	4.1	0.3								
	Ketolide	Telithromycin	0.1	0.8	[0.3–1.8]			0.3	1.7	12.4	31.5	32.6	19.0	1.6	0.1	0.8					
	Macrolides	Azithromycin	0.0	0.8	[0.3–1.8]	4.1	28.1	37.7	22.8	6.1	0.3	0.1							0.8		
		Erythromycin	0.0	0.8	[0.3–1.8]			1.0	8.2	30.9	34.3	20.6	3.5	0.7					0.8		
	Quinolones	Ciprofloxacin	0.1	19.5	[16.6–22.6]	0.3	5.9	39.5	28.2	5.8	0.7		0.1	1.8	8.3	5.8	2.1	1.1	0.3		
		Nalidixic acid	0.4	19.0	[16.2–22.1]									62.3	15.8	2.4	0.4	2.3	16.8		
II	**Phenicols**	Florfenicol**	N/A	0.0	[0.0–0.5]					2.3	20.2	61.6	13.7	2.3							
	Tetracyclines	Tetracycline	0.6	47.4	[43.7–51.1]			6.6	24.3	15.2	3.2	2.0	0.6	0.1	0.6	1.6	3.7	13.8	28.3		
III	**Lincosamides**	Clindamycin	0.0	1.0	[0.4–2.0]		4.4	24.4	43.6	20.0	5.2	0.8	0.6		0.1	0.4	0.4				

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or
†Percent of isolates with intermediate susceptibility
‡Percent of isolates that were resistant
§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method
¶The unshaded areas indicate the range of dilutions tested for each antimicrobial agent. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest tested concentrations. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints
**CLSI guidelines do not currently define a resistance-breakpoint for florfenicol.

Figure 5.02: Antimicrobial resistance pattern for *Campylobacter jejuni*, 2006

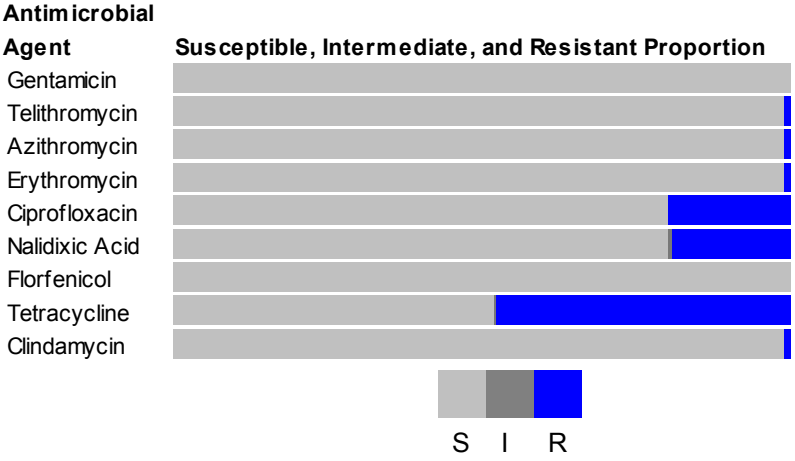

Table 5.06: Percentage and number of *Campylobacter jejuni* isolates resistant to antimicrobial agents, 1997–2006

Year			1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			209	297	293	306	365	329	303	320	791	709
Rank*	Subclass	Antibiotic (Resistance breakpoint)										
I	Aminoglycosides	Gentamicin (MIC ≥ 8)	Not Tested	0.3% 1	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.3% 1	0.5% 4	0.0% 0
	Ketolides	Telithromycin (MIC ≥ 16)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	0.0% 0	0.8% 6
	Macrolides	Azithromycin (MIC ≥ 8)	Not Tested	0.3% 1	1.7% 5	1.6% 5	1.9% 7	1.8% 6	0.3% 1	0.6% 2	1.8% 14	0.8% 6
		Erythromycin (MIC ≥ 32)	1.4% 3	0.7% 2	1.4% 4	1.0% 3	1.9% 7	1.2% 4	0.3% 1	0.3% 1	1.6% 13	0.8% 6
	Quinolones	Ciprofloxacin (MIC ≥ 4)	12.4% 26	13.8% 41	17.7% 52	14.7% 45	18.4% 67	20.7% 68	17.2% 52	18.1% 58	21.5% 170	19.5% 138
		Nalidixic acid (MIC ≥ 64)	13.4% 28	15.5% 46	20.1% 59	16.0% 49	18.9% 69	21.3% 70	17.8% 54	18.4% 59	21.9% 173	19.0% 135
II	Phenicols	Chloramphenicol (MIC ≥ 32)	3.8% 8	1.0% 3	0.7% 2	0.0% 0	0.3% 1	0.3% 1	0.0% 0	1.6% 5	Not Tested	Not Tested
		Florfenicol* Susceptible breakpoint: (MIC < 4)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	0.5% 4	0.0% 0
	Tetracyclines	Tetracycline (MIC ≥ 16)	47.8% 100	46.1% 137	45.4% 133	39.2% 120	40.3% 147	41.3% 136	38.3% 116	46.9% 150	41.8% 331	47.4% 336
III	Lincosamides	Clindamycin (MIC ≥ 8)	1.0% 2	1.0% 3	0.7% 2	0.7% 2	1.9% 7	1.8% 6	0.0% 0	2.2% 7	1.1% 9	1.0% 7

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true. Antimicrobial agents are considered important (Rank III) if neither criterion are true.

† Only a susceptible breakpoint (≤ 4 µg/ml) has been established. In this report, isolates with an MIC ≥ 8 µg/ml are categorized as resistant

Table 5.07: Minimum inhibitory concentrations (MICs) and resistance of *Campylobacter coli* isolates to antimicrobial agents, 2006 (N=97)

Rank*	Antibiotic		% of isolates %I†	%R‡	[95% CI]§	Percent of all isolates with MIC (µg/mL)¶ 0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Gentamicin	0.0	1.0	[0.0–5.6]				2.1	6.2	63.9	25.8	1.0					1.0			
	Ketolide	Telithromycin	2.1	7.2	[3.0–14.3]				1.0	14.4	21.6	14.4	20.6	18.6	2.1	7.2					
	Macrolides	Azithromycin	0.0	8.2	[3.6–15.6]		8.2	11.3	41.2	24.7	5.2	1.0							8.2		
		Erythromycin	0.0	8.2	[3.6–15.6]				1.0	6.2	29.9	29.9	13.4	11.3				1.0	7.2		
	Quinolones	Ciprofloxacin	0.0	21.6	[13.9–31.2]		1.0	15.5	35.1	22.7	4.1			3.1	9.3	7.2	1.0	1.0			
		Nalidixic acid	0.0	23.7	[15.7–33.4]									32.0	36.1	8.2		5.2	18.6		
II	**Phenicols**	Florfenicol**	N/A	0.0	[0.0–3.7]						7.2	54.6	33.0	5.2							
	Tetracyclines	Tetracycline	0.0	39.2	[29.4–49.6]			2.1	9.3	29.9	12.4	5.2	2.1					2.1	37.1		
III	**Lincosamides**	Clindamycin	1.0	9.3	[4.3–16.9]		1.0	3.1	15.5	36.1	22.7	7.2	4.1	1.0	1.0	3.1	5.2				

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or

†Percent of isolates with intermediate susceptibility

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the range of dilutions tested for each antimicrobial agent. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest tested concentrations. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints

**CLSI guidelines do not currently define a resistance-breakpoint for florfenicol.

Figure 5.03: Antimicrobial resistance pattern for *Campylobacter coli*, 2006

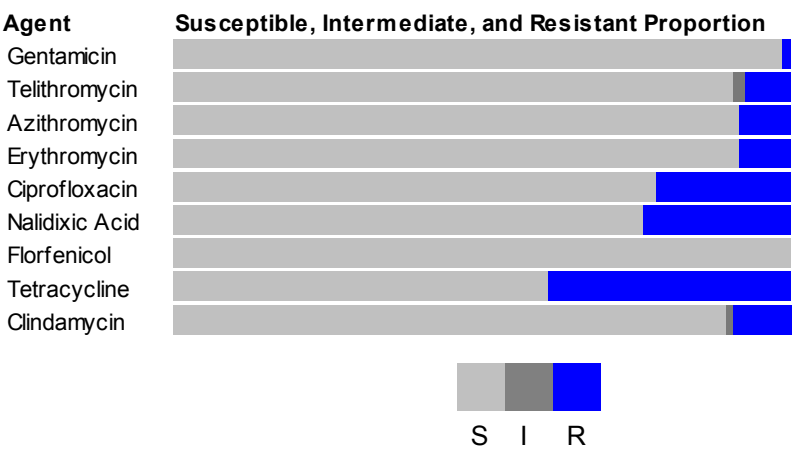

Table 5.08: Percentage and number of *Campylobacter coli* isolates resistant to antimicrobial agents, 1997–2006

Year			1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Isolates			6	8	20	12	17	25	22	26	98	97
Rank*	Subclass	Antibiotic (Resistance breakpoint)										
I	Aminoglycosides	Gentamicin (MIC ≥ 8)	Not Tested	0.0% 0	0.0% 0	8.3% 1	0.0% 0	0.0% 0	4.5% 1	0.0% 0	2.0% 2	1.0% 1
	Ketolides	Telithromycin (MIC ≥ 16)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	4.1% 4	7.2% 7
	Macrolides	Azithromycin (MIC ≥ 8)	Not Tested	12.5% 1	10.0% 2	8.3% 1	5.9% 1	4.0% 1	9.1% 2	0.0% 0	3.1% 3	8.2% 8
		Erythromycin (MIC ≥ 32)	0.0% 0	12.5% 1	10.0% 2	8.3% 1	5.9% 1	4.0% 1	9.1% 2	0.0% 0	3.1% 3	8.2% 8
	Quinolones	Ciprofloxacin (MIC ≥ 4)	33.3% 2	0.0% 0	30.0% 6	25.0% 3	47.1% 8	12.0% 3	22.7% 5	30.8% 8	23.5% 23	21.6% 21
		Nalidixic acid (MIC ≥ 64)	50.0% 3	50.0% 4	30.0% 6	25.0% 3	47.1% 8	12.0% 3	22.7% 5	34.6% 9	26.5% 26	23.7% 23
II	Phenicols	Chloramphenicol (MIC ≥ 32)	50.0% 3	37.5% 3	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	0.0% 0	Not Tested	Not Tested
		Florfenicol* Susceptible breakpoint: (MIC < 4)	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	1.0% 1	0.0% 0
	Tetracyclines	Tetracycline (MIC ≥ 16)	66.7% 4	50.0% 4	30.0% 6	25.0% 3	58.8% 10	40.0% 10	45.5% 10	38.5% 10	30.6% 30	39.2% 38
III	Lincosamides	Clindamycin (MIC ≥ 8)	16.7% 1	12.5% 1	10.0% 2	8.3% 1	5.9% 1	4.0% 1	9.1% 2	0.0% 0	4.1% 4	9.3% 9

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true. Antimicrobial agents are considered important (Rank III) if neither criterion are true.

† Only a susceptible breakpoint (≤ 4 µg/ml) has been established. In this report, isolates with an MIC ≥ 8 µg/ml are categorized as resistant

Limitations to NARMS *Campylobacter* Surveillance

Three limitations are evident in NARMS *Campylobacter* surveillance: (1) the use of sentinel clinical laboratories in FoodNet states, (2) the sampling scheme implemented during 1997 to 2004, and (3) the limited geographic area under surveillance.

Four of the states that participated in NARMS *Campylobacter* surveillance during 1997 to 2004, (California, Colorado, Connecticut, and Oregon), submitted *Campylobacter* isolates to NARMS from one sentinel clinical laboratory within their state. The other six states (Georgia, Maryland, Minnesota, New Mexico, New York, and Tennessee), submitted *Campylobacter* isolates that were selected from most clinical laboratories within a specific geographic area (metro Atlanta area in Georgia; statewide in Maryland, Minnesota, New Mexico, and Tennessee; and the metro Albany and Rochester areas in New York). In California, Colorado, Connecticut, and Oregon, the sentinel clinical laboratory selected the first *Campylobacter* isolate isolated each week for submission to NARMS; if no isolate was isolated in a week, then no isolate was submitted from that laboratory. From the other six FoodNet sites, one *Campylobacter* isolate among isolates received from participating clinical laboratories was also selected each week. Because none of the sentinel clinical laboratories used an isolation procedure that was more or less likely than the procedure of other clinical laboratories in their respective states to yield antimicrobial-resistant *Campylobacter* isolates, use of a sentinel clinical laboratory was unlikely to be associated with a change of antimicrobial resistance among *Campylobacter* isolates submitted to NARMS.

From 1997 to 2004, the participating public health laboratories in Georgia, Maryland, Minnesota, New Mexico, New York, and Tennessee, and sentinel clinical laboratories in all other FoodNet sites selected one *Campylobacter* isolate each week and forwarded the isolate to CDC. When the isolates were selected, the antimicrobial resistance pattern of the isolates was not known. Therefore, the antimicrobial resistance pattern of an isolate was unlikely to influence submission of the isolate to NARMS. However, the one-sample-a-week scheme could have resulted in oversampling or undersampling of antimicrobial-resistant isolates if the prevalence of such resistance was not uniform throughout the year. The impact of oversampling or undersampling can vary among states. In 2005, a representative sampling scheme was initiated in the 10 FoodNet sites.

Campylobacter isolates were forwarded to CDC by 10 states participating in FoodNet during 2006, representing approximately 45 million persons (15% of the U.S. population). Because NARMS 2006 *Campylobacter* surveillance was not nationwide, findings should be generalized to the U.S. population with caution because of possible regional differences in the prevalence of antimicrobial resistance among *Campylobacter*.

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APPENDIX A
Summary of *Escherichia coli* Resistance Surveillance Pilot Study, 2006

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INTRODUCTION

Escherichia coli is a Gram–negative coccobacillus bacterium that is part of the intestinal flora of humans and other animals. Because antimicrobial resistance genes commonly reside in mobile genetic elements that can be transferred horizontally to other bacteria, antimicrobial–resistant bacteria of the intestinal flora, including *E. coli*, constitute an important reservoir of resistance genes for pathogenic bacteria of humans and other animals. Furthermore, when introduced into a normally sterile site, *E. coli* is an important cause of infections, including septicemia, urinary tract infections, and wound infections. The human intestinal tract is the predominant source of *E. coli* causing these infections. Antimicrobial resistance among *E. coli* causing such infections complicates treatment options.

The use of antimicrobial agents creates a selective pressure for the emergence and dissemination of resistant bacteria. Use of antimicrobial agents in food animals selects resistant bacteria, including resistant *E. coli* in the intestinal tract of food animals. These resistant bacteria can be transmitted to humans through the food supply. Therefore, monitoring resistance in *E. coli* isolated from the intestinal flora of humans and animals is important to determining the role of these bacteria as human pathogens and as reservoirs of resistance determinants for human pathogens. The *E. coli* Resistance Surveillance Pilot is designed to determine the prevalence of resistance to clinically important antimicrobial agents among *E. coli* isolated from persons in the community.

SUMMARY OF 2006 SURVEILLANCE DATA

Background

Beginning in 2004, NARMS began to prospectively monitor the prevalence of antimicrobial resistance of *E. coli* isolated from human stool samples in two sites: Maryland and Michigan.

SURVEILLANCE AND LABORATORY TESTING METHODS

Participating laboratories in Maryland and Michigan cultured 10 human stool samples each month for *E. coli* using Eosin Methylene Blue agar. One *E. coli* isolate, if present, from each stool sample was sent to CDC for susceptibility testing to antimicrobial agents using broth microdilution (Sensititre®) to determine the minimum inhibitory concentration (MIC) for each of 15 antimicrobial agents: amikacin, ampicillin, amoxicillin-clavulanic acid, cefoxitin, ceftiofur, ceftriaxone, chloramphenicol, ciprofloxacin, gentamicin, kanamycin, nalidixic acid, streptomycin, sulfonamides, tetracycline, and trimethoprim-sulfamethoxazole (Table A.01).

Interpretive criteria from CLSI were used (Table A.01). The 95% CIs for the percentage of resistant isolates calculated using the Clopper-Pearson exact method, are included in the MIC distribution tables. Similarly, multiclass resistance by CLSI antimicrobial subclass was defined as resistance to two or more subclasses.

RESULTS

In 2006, CDC received and tested 82 viable *E. coli* isolates (Table A.02). MIC was determined for *E. coli* isolates for 15 antimicrobial agents (Table A.03).

Of the *E. coli* isolates, 28.0% were resistant to ampicillin; 17.1%, to sulfonamides; 14.6% to tetracycline; and 11.0% to nalidixic acid (Table A.04).

In 2006, 22.0% of *E. coli* isolates were resistant to two or more CLSI subclasses, and 1.2% were resistant to five or more CLSI subclasses (Table A.05). The level of *E. coli* resistance in this pilot study differs than that observed in NARMS 2005 routine *E. coli* O157. Because of the different sampling methods between this study and NARMS routine surveillance, this observation requires further investigation.

There is a difference in the level of resistance among *E. coli* isolates in this study compared with *E. coli* O157 isolates submitted to NARMS in 2006. Because of the different sampling methods employed between this study and NARMS, this observation requires further investigation.

Multidrug-Resistant *E. coli*

- 22.0% of 82 *E. coli* isolates tested were resistant to two or more subclasses of antimicrobial agents.
- 1.2% of 82 *E. coli* isolates tested were resistant to five or more subclasses of antimicrobial agents.

Clinically Important Resistance

Antimicrobial agents commonly used to treat serious *E. coli* infections in humans include third-generation cephalosporins and fluoroquinolones.

- 0.0% of 82 *E. coli* isolates were resistant to ceftiofur (Table A.04).
- 4.9% of 82 *E. coli* isolates were resistant to ciprofloxacin (Table A.04).

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Table A.01: Antimicrobial agents used for susceptibility testing of *Escherichia coli*, 2006

CLSI Subclass	Antimicrobial Agent	Antimicrobial Agent Concentration Range (µg/mL)	Breakpoints		
			Susceptible	Intermediate	Resistant
Aminoglycosides	Amikacin	0.5 – 64	≤16	32	≥64
	Gentamicin	0.25 – 16	≤4	8	≥16
	Kanamycin	8 – 64	≤16	32	≥64
	Streptomycin	32 – 64	≤32		≥64
Aminopenicillins	Ampicillin	1 – 32	≤8	16	≥32
β-lactamase inhibitor combinations	Amoxicillin–Clavulanic acid	1/0.5 – 32/16	≤8/4	16/8	≥32/16
Cephalosporins (3rd Gen.)	Ceftiofur	0.12– 8	≤2	4	≥8
	Ceftriaxone	0.25 – 64	≤8	16-32	≥64
Cephamycins	Cefoxitin	0.5 – 32	≤8	16	≥32
Folate pathway inhibitors	Trimethoprim–Sulfamethoxazole	0.12/2.4 – 4/76	≤2/38		≥4/76
Phenicols	Chloramphenicol	2 – 32	≤8	16	≥32
Quinolones	Ciprofloxacin	0.015 – 4	≤1	2	≥4
	Nalidixic acid	0.5 – 32	≤16		≥32
Sulfonamides	Sulfisoxazole	16 – 256	≤256		≥512
Tetracyclines	Tetracycline	4 – 32	≤4	8	≥16

Table A.02: *Escherichia coli* isolates received and tested at CDC, by site, 2006

Site	2006 n	(%)
Maryland	27	(32.9%)
Michigan	55	(67.1%)
Total	**82**	**(100.0%)**

Table A.03: Minimum inhibition concentrations (MICs) and resistance of *Escherichia coli* isolates to antimicrobial agents, 2006 (N=82)

Rank*	Antibiotic		% of isolates			Percent of all isolates with MIC (µg/mL)¶														
			%I†	%R‡	[95% CI]§	0.015	0.03	0.06	0.125	0.25	0.50	1	2	4	8	16	32	64	128	256	512
I	**Aminoglycosides**	Amikacin	0.0	0.0	[0.0–2.6]						2.4	42.7	52.4	1.2		1.2					
		Gentamicin	1.2	3.7	[2.2–8.3]					26.8	61.0	4.9		2.4	1.2	1.2	2.4				
		Streptomycin	NA	7.3	[9.6–19.2]												92.7	3.7	3.7		
	Aminopenicillins	Ampicillin	0.0	28.0	[24.1–36.7]							13.4	43.9	12.2	2.4			28.0			
	β-lactamase inhibitor	Amoxicillin-clavulanic acid	2.4	3.7	[1.6–7.2]							3.7	28.0	39.0	23.2	2.4	3.7				
	Cephalosporins (3rd generation)	Ceftiofur	0.0	0.0	[0.0–2.6]				11.0	58.5	28.0	2.4									
		Ceftriaxone	0.0	0.0	[0.0–2.6]					100.0											
	Quinolones	Ciprofloxacin	0.0	4.9	[5.7–13.9]	85.4	2.4		4.9	1.2	1.2				4.9						
		Nalidixic Acid	NA	11.0	[14.0–24.9]							19.5	63.4	3.7	1.2	1.2	1.2	9.8			
II	**Aminoglycosides**	Kanamycin	0.0	0.0	[0.8–5.3]										97.6	2.4					
	Cephamycins	Cefoxitin	2.4	1.2	[1.3–6.6]						1.2	9.8	50.0	28.0	7.3	2.4	1.2				
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole	NA	12.2	[11.2–21.3]				81.7	6.1				1.2	11.0						
	Phenicols	Chloramphenicol	1.2	3.7	[0.5–4.7]								6.1	58.5	30.5	1.2	1.2	2.4			
	Sulfonamides	Sulfisoxazole	NA	17.1	[17.7–29.4]											56.1	25.6	1.2			17.1
	Tetracyclines	Tetracycline	0.0	14.6	[12.4–22.8]									85.4			1.2	13.4			

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire

†Percent of isolates with intermediate susceptibility, NA if no MIC range of intermediate susceptibility exists

‡Percent of isolates that were resistant

§95% confidence intervals (CI) for percent resistant (%R) were calculated using the Clopper-Pearson exact method

¶The unshaded areas indicate the dilution range of the Sensititre plates used to test isolates. Single vertical bars indicate the breakpoints for susceptibility, while double vertical bars indicate breakpoints for resistance. Numbers in the shaded areas indicate the percentages of isolates with MICs greater than the highest concentrations on the Sensititre plate. Numbers listed for the lowest tested concentrations represent the precentages of isolates with MICs equal to or less than the lowest tested concentration. CLSI breakpoints were used when available.

Figure A.01: Antibiotic resistance pattern for *Escherichia coli*, 2006

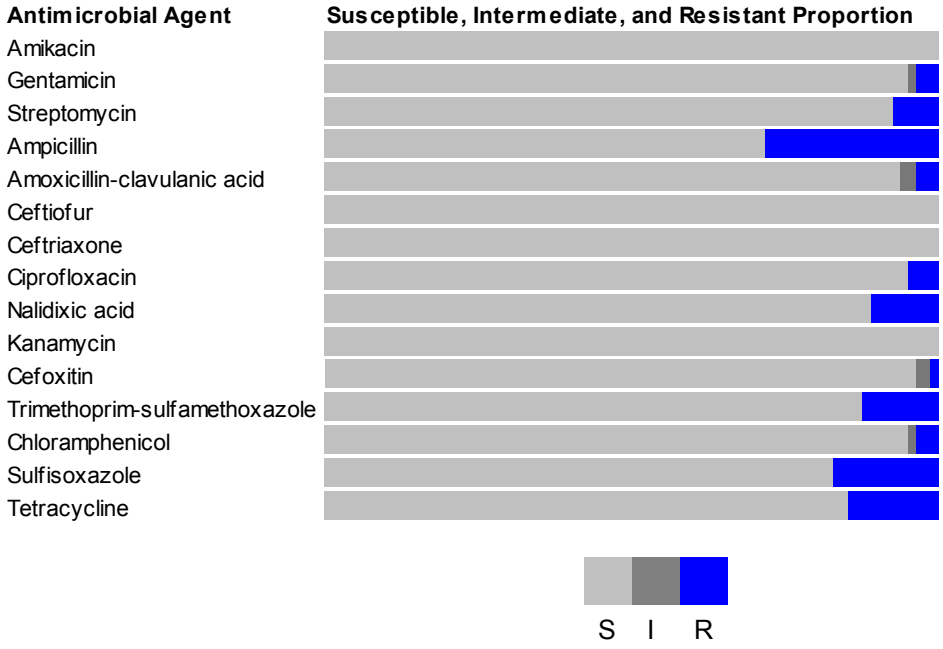

Table A.04: Percentage and number of *Escherichia coli* isolates resistant to antimicrobial agents, 2004–2006

Year			2004	2005	2006
Total Isolates			151	119/114†	82
Rank*	Subclass	Antibiotic (Resistance breakpoint)			
I	Aminoglycosides	Amikacin (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0
		Gentamicin (MIC ≥ 16)	2.0% 3	3.4% 4	3.7% 3
		Streptomycin (MIC ≥ 64)	10.6% 16	14.3% 17	7.3% 6
	Aminopenicillins	Ampicillin (MIC ≥ 32)	24.5% 37	26.1% 31	28.0% 23
	β-lactamase inhibitor combinations	Amoxicillin-clavulanic acid (MIC ≥ 32)	2.6% 4	4.2% 5	3.7% 3
	Cephalosporins (3rd generation)	Ceftiofur (MIC ≥ 8)	0.0% 0	0.8% 1	0.0% 0
		Ceftriaxone (MIC ≥ 64)	0.0% 0	0.0% 0	0.0% 0
	Quinolones	Ciprofloxacin (MIC ≥ 4)	3.3% 5	7.6% 9	4.9% 4
		Nalidixic Acid (MIC ≥ 32)	9.3% 14	9.2% 11	11.0% 9
II	Aminoglycosides	Kanamycin (MIC ≥ 64)	2.0% 3	0.0% 0	0.0% 0
	Cephamycins	Cefoxitin (MIC ≥ 32)	2.6% 4	0.8% 1	1.2% 1
	Folate pathway inhibitors	Trimethoprim-sulfamethoxazole (MIC ≥ 4)	11.3% 17	14.9% 17	12.2% 10
	Phenicols	Chloramphenicol (MIC ≥ 32)	1.3% 2	2.5% 3	3.7% 3
	Sulfonamides	Sulfisoxazole (MIC ≥ 512)	17.9% 27	18.4% 21	17.1% 14
	Tetracyclines	Tetracycline (MIC ≥ 16)	13.2% 20	19.3% 23	14.6% 12

*Rank of antimicrobials based on World Health Organization's categorization of critical importance in human medicine (Table I). Antimicrobial agents are considered critically important (Rank I) as (1) sole therapies or one of the few alternatives to treat serious human diseases and (2) used to treat disease caused by organisms that may be transmitted via non-human sources or diseases caused by organisms that may acquire resistance genes from non-human sources. Antimicrobials are highly important (Rank II) if either criteria (1) or (2) are true.

†Five isolates do not have test results for Trimethoprim-sulfamethoxazole and Sulfamethoxazole/Sulfisoxazole.

Table A.05: Resistance patterns of *Escherichia coli* isolates, 2004–2006

Year	2004	2005	2006
Total Isolates	**151**	**119**	**82**
	% n	% n	% n
No resistance detected	62.9% 95	63.0% 75	63.4% 52
Resistance ≥1CLSI subclass*	37.7% 57	37.0% 44	36.6% 30
Resistance ≥2 CLSI subclasses*	17.9% 27	22.7% 27	22.0% 18
Resistance ≥3 CLSI subclasses*	9.9% 15	14.3% 17	15.9% 13
Resistance ≥4 CLSI subclasses*	5.3% 8	9.2% 11	8.5% 7
Resistance ≥5 CLSI subclasses*	3.3% 5	7.6% 9	1.2% 1
At least ACSSuT†	1.3% 2	0.8% 1	0.0% 0
At least ACSuTm‡	1.3% 2	0.8% 1	1.2% 1
At least ACSSuTAuCf§	0.0% 0	0.0% 0	0.0% 0
At least AAuC¶	0.0% 0	0.0% 0	0.0% 0
At least A3C**	0.0% 0	0.0% 0	0.0% 0
At least MDR-AmpC††	0.0% 0	0.0% 0	0.0% 0
Resistance to quinolone and cephalosporin (3rd generation)	0.0% 0	0.0% 0	0.0% 0

*CLSI: Clinical and Laboratory Standards Institute

†ACSSuT: resistance to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole/sulfisoxazole, tetracycline

‡ACSuTm: resistance to ampicillin, chloramphenicol, trimethoprim-sulfamethoxazole

§ACSSuTAuCf: resistance to ACSSuT + amoxicillin-clavulanic acid, ceftiofur

¶AAuC: resistance to ampicillin, amoxicillin-clavulanic acid, ceftiofur

**A3C: resistance to amikacin, ampicillin, amoxicillin-clavulanic acid

††MDR-AmpC: resistance to ACSSuTAuCf + decreased susceptibility to ceftriaxone (MIC ≥2 µg/mL)

Among isolates of commensal *E. coli* ceftiofur resistance has increased from 0.0% in 2004 to 0.8% in 2005 and decreased to 0.0% in 2006. Ciprofloxacin resistance decreased from 7.6% in 2005 to 4.9% in 2006. A decrease in detected resistance was observed for five drugs; Amoxicillin-clavulanic acid (4.2% to 3.7%), ciprofloxacin (7.6% to 4.9%), streptomycin (14.3%–7.3%), sulfamethoxazole/sulfisoxazole (18.4% to 17.1%) and tetracycline (19.3 to 14.6%).