Antibiotic resistant E.coli infections in people

why animal antibiotic use is important

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Infectious Diseases and Microbiology,
The Canberra Hospital.
Professor, Canberra Clinical School,
Australian National University

E.coli is the most important human bacterial pathogen

RESEARCH

Escherichia coli bacteraemia in Canberra: incidence and clinical features

Karina J Kennedy, Jan L Roberts and Peter J Collignon

Results: During the 5-year period, 515 episodes of *E. coli* bacteraemia occurred in Canberra residents, an incidence of 28 per 100 000 population per year. The highest rate was in men aged ≥ 80 years (463 per 100 000). Overall, *E. coli* bacteraemia occurred in equal numbers in males and females, but incidence was higher in males aged < 1 year and ≥ 60 years. Most episodes occurred in people aged ≥ 60 years (316/511 [62%]) and most were community-associated (347/511 [68%]). Half the infections (257/511) had a genitourinary focus and 28% (141/511) a gastrointestinal focus. The 7-day case-fatality rate was 5%. Prostate biopsies and urinary catheters were notable preventable foci of health care-associated bacteraemia. Resistance of isolates to gentamicin (2.1%), ciprofloxacin (1.8%) and cefotaxime (0.4%) was low.

MJA 2008; 188: 209–213

Canberra; E.coli Blood Stream Infections incidence 28 per 100 000 population per year

- RESULTS: During the 5-year period, 515 episodes of E. coli bacteraemia occurred in Canberra residents, an incidence of 28 per 100 000 population per year. The highest rate was in men aged > or = 80 years (463 per 100 000). Overall, E. coli bacteraemia occurred in equal numbers in males and females, but incidence was higher in males aged < 1 year and > or = 60 years. Most episodes occurred in people aged > or = 60 years (316/511 [62%]) and most were community-associated(347/511 [68%]). Half the infections (257/511) had a genitourinary focus and 28% (141/511) a gastrointestinal focus. The 7-day case-fatality rate was 5%. Prostate biopsies and urinary catheters were notable preventable foci of healthcare-associated bacteraemia. Resistance of isolates to gentamicin (2.1%),ciprofloxacin (1.8%) and cefotaxime (0.4%) was low.

- CONCLUSIONS: E. coli is the most common cause of bacteraemia in Canberra, and incidence increases with age. Most cases have a community onset, but many episodes are related to health care procedures. Ongoing surveillance is important for identifying risk factors that may be modified to reduce disease.

Kennedy KJ, Roberts JL, Collignon PJ. .Escherichia coli bacteraemia in Canberra: incidence and clinical features. .Med J Aust. 2008 Feb 18;188(4):209-13.

EARSS E.coli Blood Stream Infections

Denmark rate 60.5; Sweden 60.6 per 100,000

Denmark

General Information about EARSS participating laboratories and hospitals

Table 1. Reference data of 2008, based on laboratories/hospitals providing denominator data

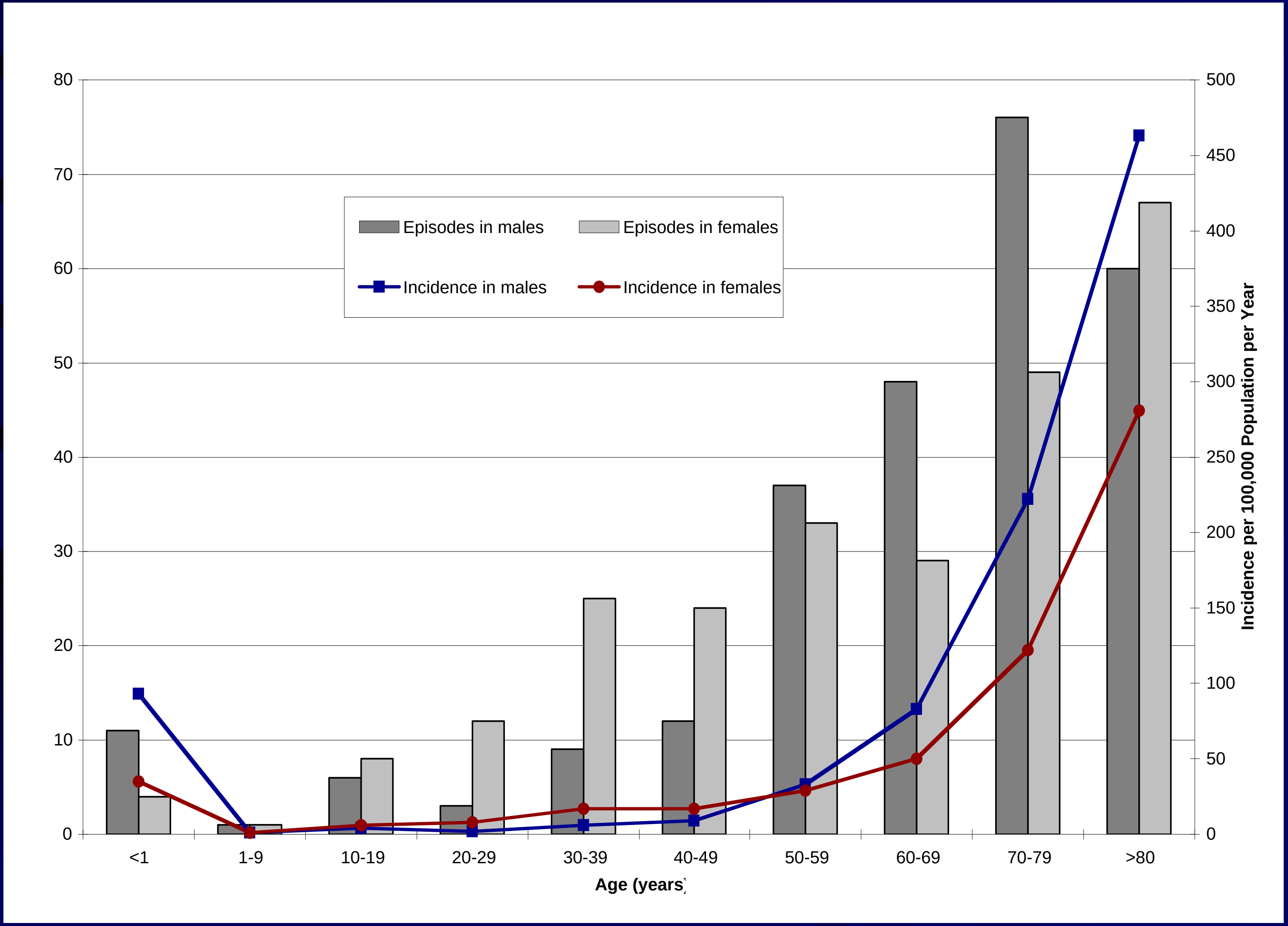
	Total
Labs providing denom.data/ reporting data to EARSS	11/15
Hosps providing denom.data/ reporting data to EARSS	0/71
Number of blood culture sets	184,306
Number of hospital beds	19,086
Patient-days	4,878,249
Average occupancy rate (%)	na
Median length of stay (days)	4
Estimated catchment population	5,427,367
% total population covered	100%
Type of participating hospitals	
Regional/Tertiary	na
Provincial/Secondary	na
District/Primary	na

Figure 1. Geographic distribution of laboratories in 2008

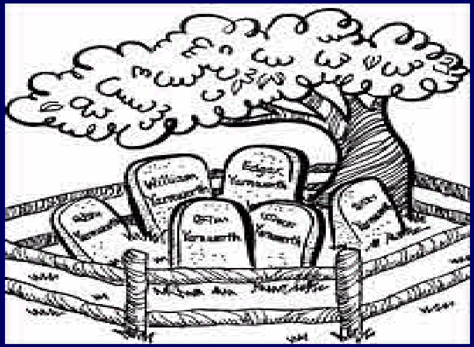
Table 2. Number of laboratories and number of isolates reported for the period 2001-2008

Year	*S. pneumoniae*		*S. aureus*		*E. coli*		Enterococci		*K. pneumoniae*		*P. aeruginosa*	
	Labs	Isolates	Labs	Isolates	Labs	Isolates	Labs	Isolates	Labs	Isolates	Labs	Isolates
2001	5	506	4	52[illegible]	0	0	0	0	0	0	0	0
2002	5	366	5	752	0	0	0	0	0	0	0	0
2003	5	606	5	6[illegible]1	0	0	0	0	0	0	0	0
2004	15	1188	15	14[illegible]6	0	0	0	0	0	0	0	0
2005	14	1081	15	135[illegible]	5	1283	0	0	0	0	0	0
2006	15	872	15	1279	11	2723	11	727	11	607	0	0
2007	15	1030	14	1315	12	3021	13	945	13	784	13	417
2008	15	934	15	1295	14	3283	14	1005	14	793	14	420

Number of Episodes and Incidence of *E.coli* Bacteremia in Residents of Canberra, 2000-2004.



Resistance is a growing problem



- Some no therapy, for most therapy difficult and expensive
- A large proportion animals via food
- E.coli NDM (resistant to just about everything)

BSI ESBL Mortality 26%

ANTIMICROBIAL AGENTS AND CHEMOTHERAPY, Dec. 2004, p. 4574–4581 Vol. 48, No. 12
0066-4804/04/$08.00+0 DOI: 10.1128/AAC.48.12.4574–4581.2004

Bloodstream Infections Due to Extended-Spectrum β-Lactamase-Producing *Escherichia coli* and *Klebsiella pneumoniae*: Risk Factors for Mortality and Treatment Outcome, with Special Emphasis on Antimicrobial Therapy

Cheol-In Kang,[1] Sung-Han Kim,[1] Wan Beom Park,[1] Ki-Deok Lee,[1] Hong-Bin Kim,[1] Eui-Chong Kim,[2,3] Myoung-Don Oh,[1,3]* and Kang-Won Choe[1,3]

Departments of Internal Medicine[1] and Laboratory Medicine,[2] Seoul National University College of Medicine, and Clinical Research Institute, Seoul National University Hospital,[3] Seoul, Republic of Korea

total of 133 patients with ESBL-EK bacteremia, including 66 patients with ESBL-producing *K. pneumoniae* and 67 with ESBL-producing *E. coli*, were enrolled. The overall 30-day mortality rate was 25.6% (34 of 133).

Antibiotic resistant bacteria do NOT stay quarantined to one area.

Nor do the genes that encode this resistance.

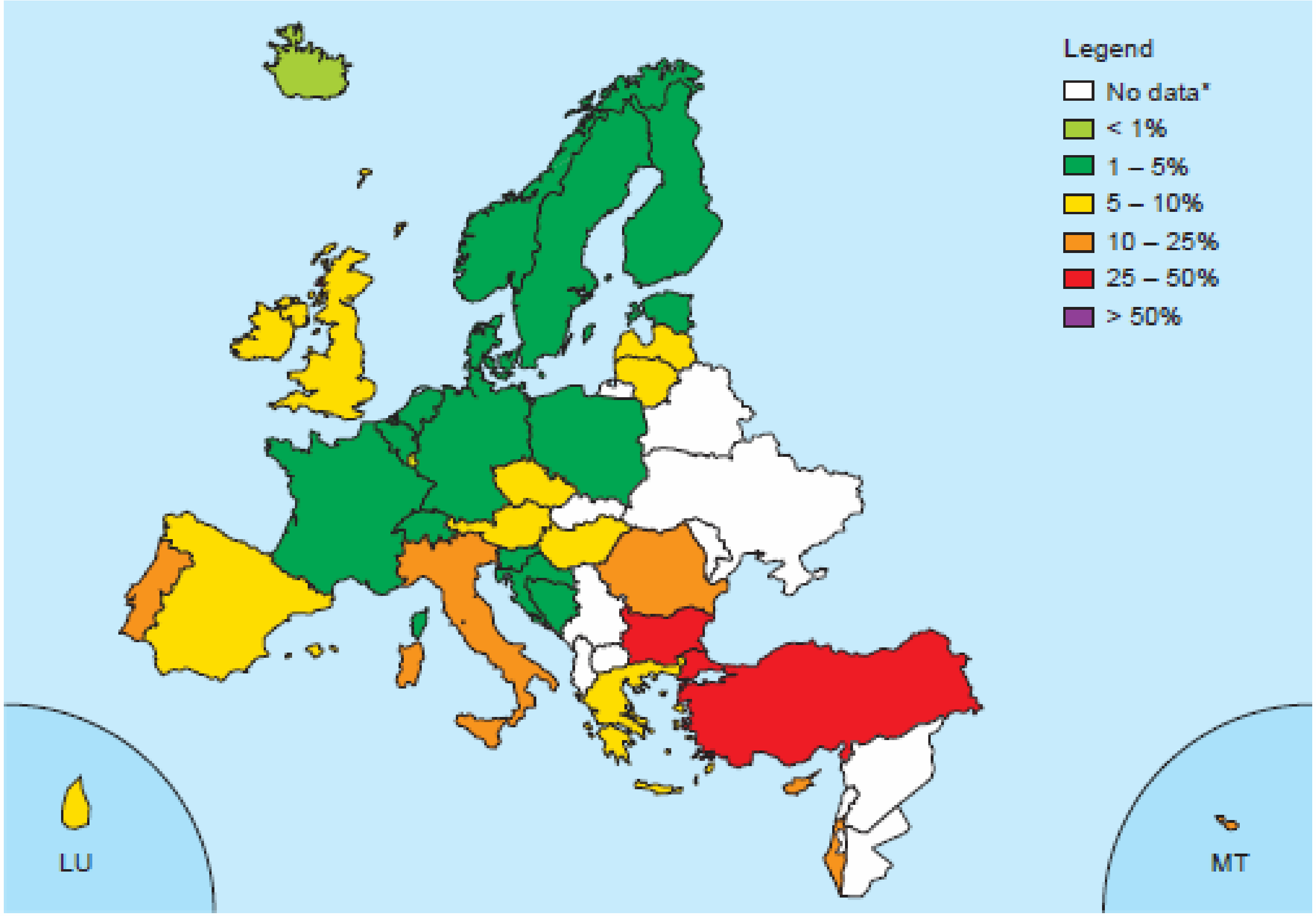


Figure 5.14. *Escherichia coli*: proportion of invasive isolates with resistance to third generation cephalosporins in 2008.
* These countries did not report any data or reported less than 10 isolates.

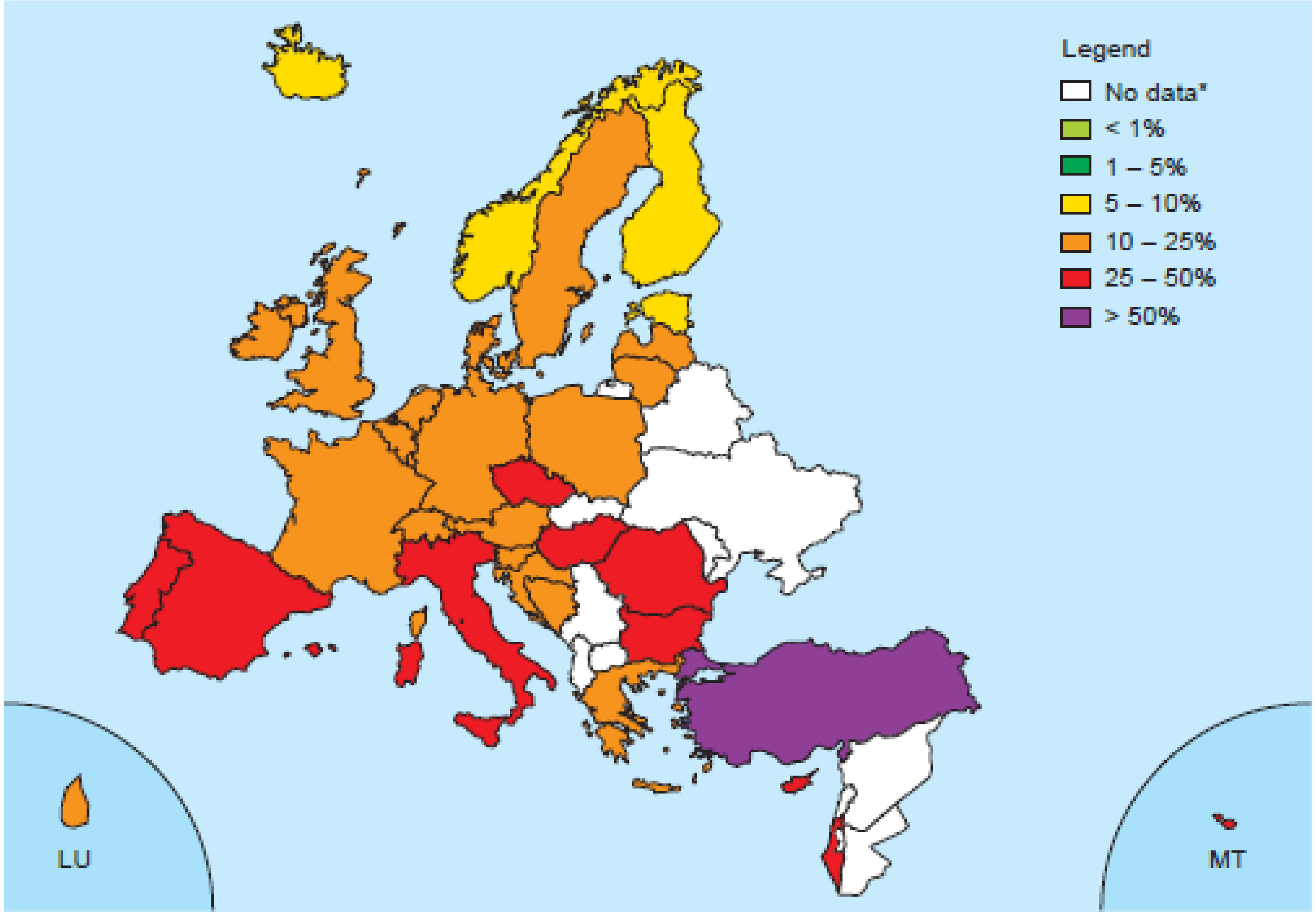
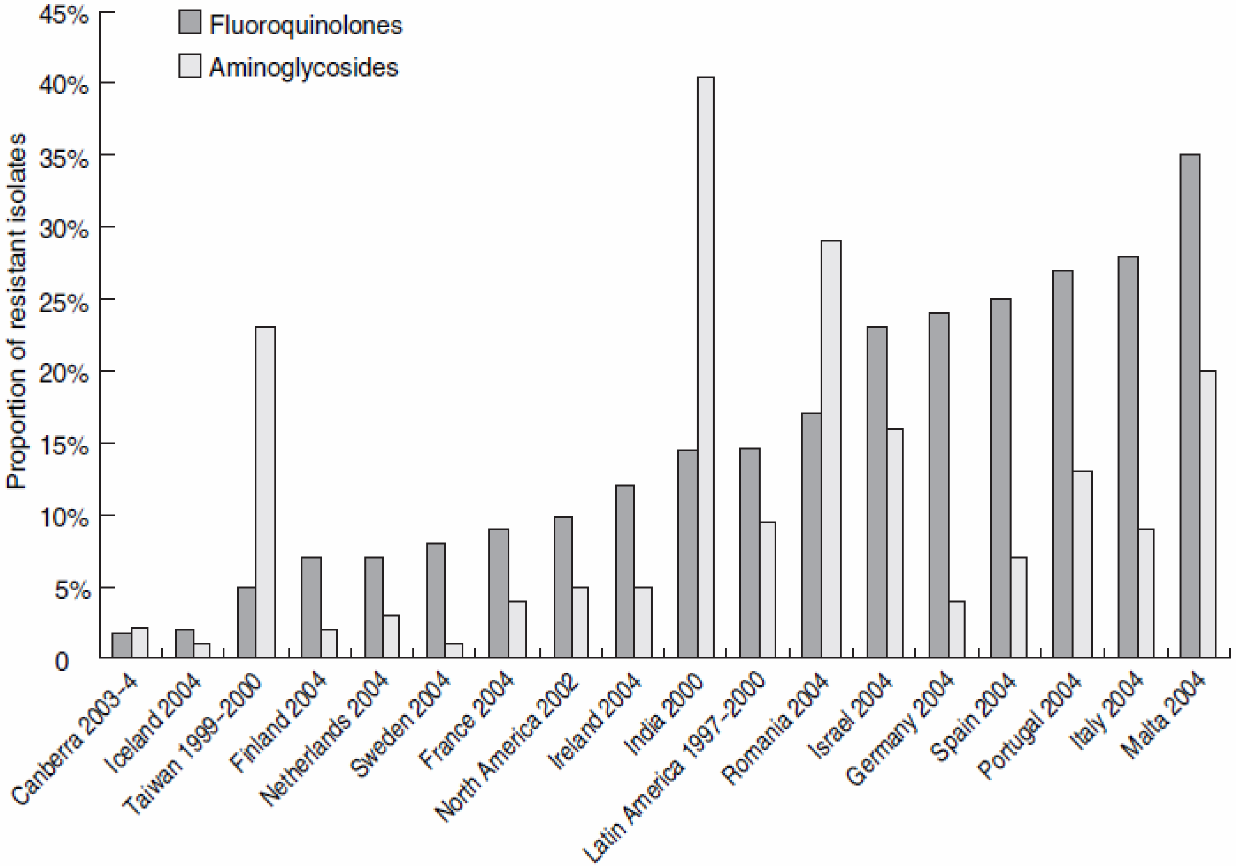


Figure 5.15. *Escherichia coli*: proportion of invasive isolates with resistance to fluoroquinolones in 2008.

* These countries did not report any data or reported less than 10 isolates.

6 International resistance rates of *Escherichia coli* bacteraemia isolates to aminoglycosides and fluoroquinolones*[1,2,25-27]



* The European Antimicrobial Resistance Surveillance System[1] also includes isolates from cerebrospinal fluid. ◆

Resistance is proportional to use

- When you use it, you loose it!
- The more you use then the more resistance
  - cross resistance an issue
  - low dose and topical lead to more resistance
- Need to maintain “last line” or “critically important” antibiotics

Antibiotic Resistance in the Wild

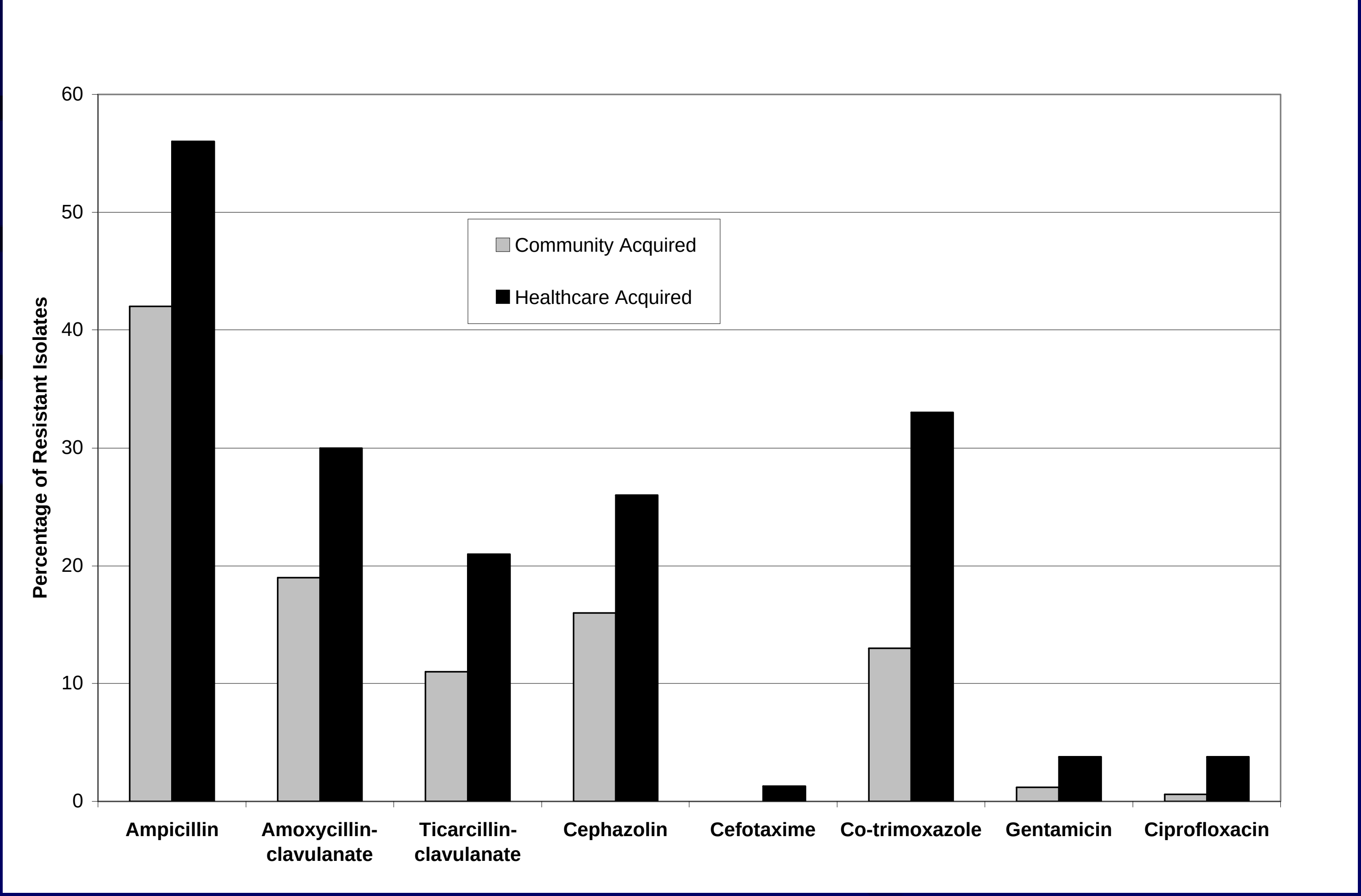
E.coli - Shirley, Gordon and Collignon; ANU and The Canberra Hospital 2000

• ampicillin	2.9%	vs	46%
• tetracycline	0.2%		28%
• chloramphenicol	0.4%		14%
• trimethoprim	0.2%		15%

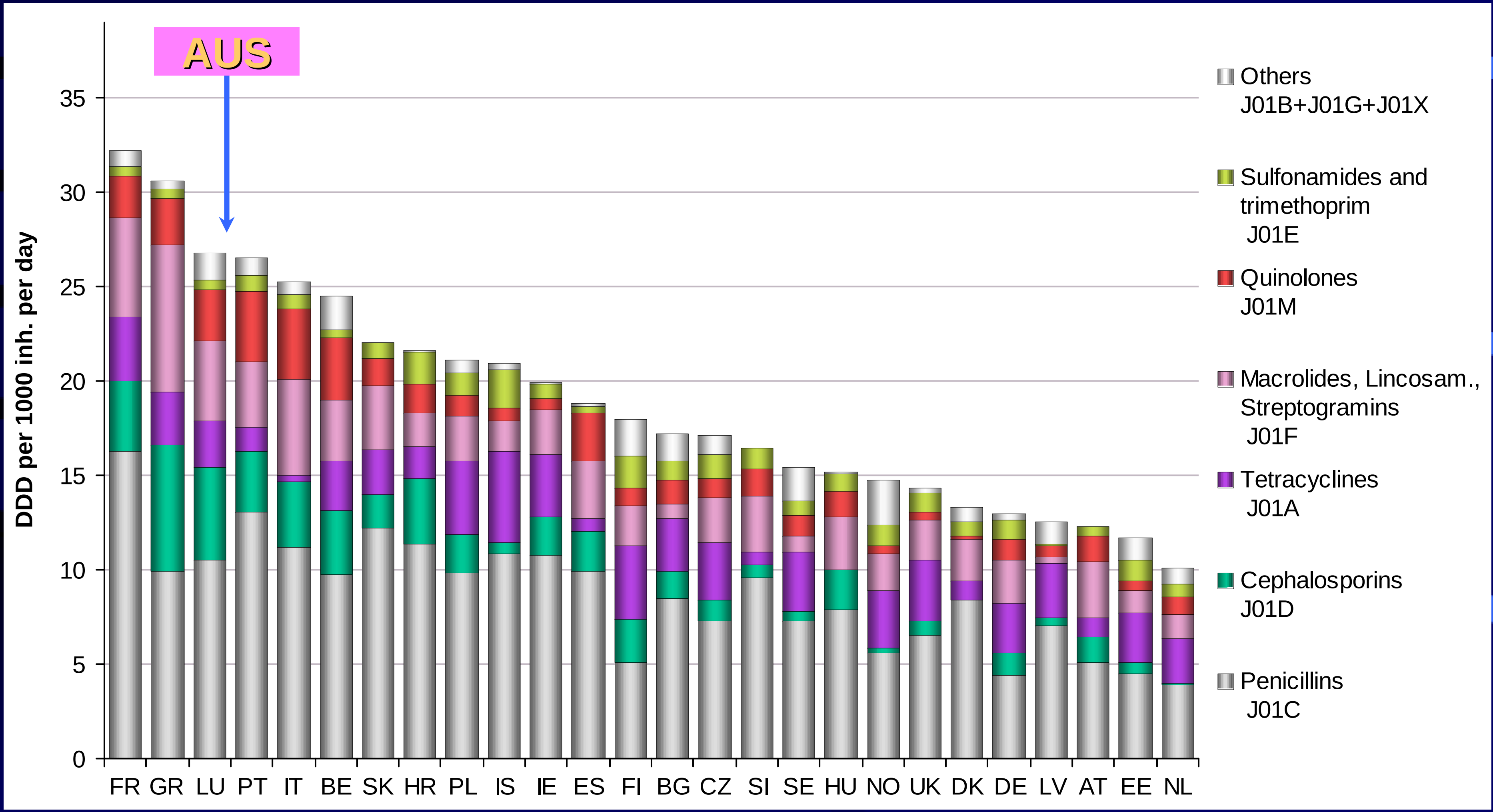
- in man low levels of resistance to
  - cefotaxime, meropenem, naladixic acid, ciproxin, gentamicin (many restricted use)
- Resistance proportionate with use but some nearly always there

Sherley M, Gordon DM, Collignon PJ. Variations in antibiotic resistance profile in Enterobacteriaceae isolated from wild Australian mammals. Environ Microbiol. 2000 Dec;2(6):620-31.

Antibiotic Resistance of *E.coli* Bacteremia Isolates (Canberra)



Total Outpatient antibiotic use in 26 European countries in 2002



Source: ESAC Website

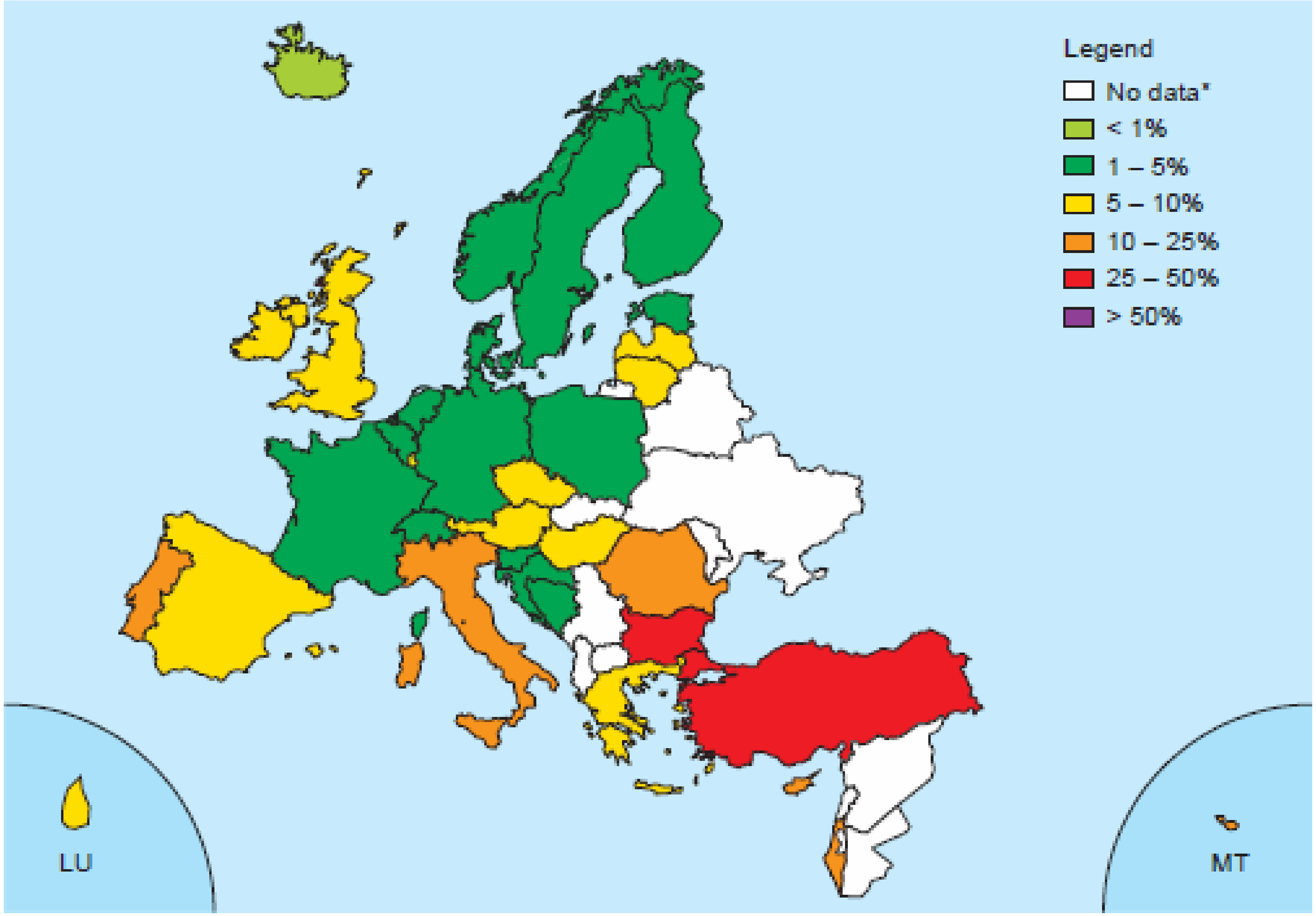


Figure 5.14. *Escherichia coli*: proportion of invasive isolates with resistance to third generation cephalosporins in 2008.
* These countries did not report any data or reported less than 10 isolates.

Journal of Antimicrobial Chemotherapy (2004) **54**, 735–743
DOI: 10.1093/jac/dkh424
Advance Access publication 3 September 2004

JAC

Community and hospital spread of *Escherichia coli* producing CTX-M extended-spectrum β-lactamases in the UK

N. Woodford[1]*, M. E. Ward[1], M. E. Kaufmann[2], J. Turton[2], E. J. Fagan[1], D. James[1], A. P. Johnson[1]†, R. Pike[1], M. Warner[1], T. Cheasty[3], A. Pearson[4], S. Harry[5], J. B. Leach[6], A. Loughrey[7], J. A. Lowes[8], R. E. Warren[9] and D. M. Livermore[1]

Results: Of 291 CTX-M-producing *E. coli* isolates studied from 42 UK centres, 70 (24%) were reportedly from community patients, many of whom had only limited recent hospital contact. Community isolates were referred by 12 centres. Two hundred and seventy-nine (95.9%) producers contained genes encoding group 1 CTX-M enzymes and 12 contained $bla_{CTX\text{-}M\text{-}9}$-like alleles. An epidemic CTX-M-15-producing strain was identified, with 110 community and inpatient isolates referred from six centres. Representatives of four other major strains also produced CTX-M-15, as did several sporadic isolates examined. Most producers were multi-resistant to fluoroquinolones, trimethoprim, tetracycline and aminoglycosides as well as to non-carbapenem β-lactams.

Conclusions: CTX-M-producing *E. coli* are a rapidly developing problem in the UK, with CTX-M-15 particularly common. The diversity of producers and geographical scatter of referring laboratories indicates wide dissemination of $bla_{CTX\text{-}M}$ genes. Because of the public health implications, including for the treatment of community-acquired urinary tract infections, the spread of these strains—and CTX-M-15 β-lactamase in particular—merits close monitoring.

Journal of Antimicrobial Chemotherapy (2008) **61**, 273–281
doi:10.1093/jac/dkm464
Advance Access publication 11 December 2007

JAC

Intercontinental emergence of *Escherichia coli* clone O25:H4-ST131 producing CTX-M-15

Marie-Hélène Nicolas-Chanoine[1,2*], Jorge Blanco[3], Véronique Leflon-Guibout[1], Raphael Demarty[1], Maria Pilar Alonso[4], Maria Manuela Caniça[5], Yeon-Joon Park[6], Jean-Philippe Lavigne[7], Johann Pitout[8] and James R. Johnson[9]

Antibiotic resistance is worse in developing countries; China (1)

- E.coli (community)
  - 60% resistant to fluoroquinolones
  - 56% gentamicin resistant
  - 29% ceftriaxone resistant

Li, Weinstein et al. Beijing 1998-1999 Zhonghua Yi Xue Za Zhi; 2001; Li, Yu et al. Infection. 2001

Antibiotic resistance is worse in developing countries; China (2)

- Zhejiang and Anhui; 519 clinical isolates
  - E.coli, community and hospital; 1999-2000

	% resist			% resist
amp	86%		cipro	70%
ceph	85%		gent	56%
amp/sal	77%		ceftriax	29%
SXT	72%		amik	10%

Li, Yu et al. Infection. 2001

Antimicrobial resistance genes *E. coli*

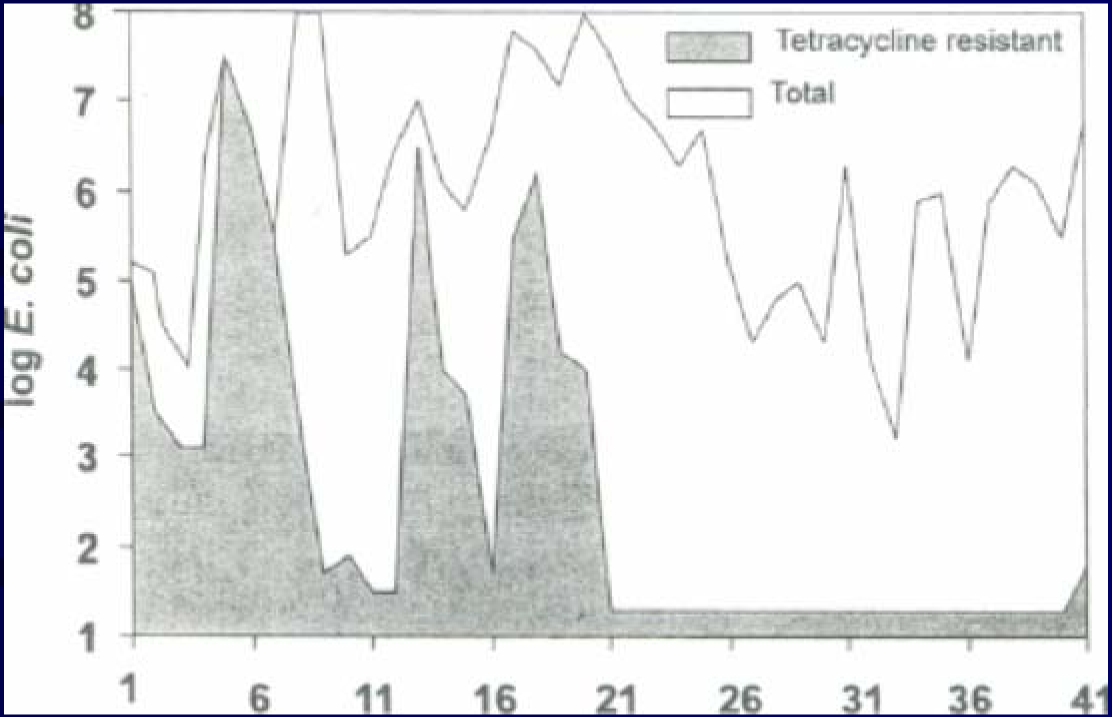
- Commensal *E. coli* can be a source of resistance genes for human pathogenic strains
- Exchange of resistance genes between bacterial clones has been demonstrated experimentally in water, soil, on kitchen towels, on cutting boards, and on the surface of food
- A substantial proportion of resistant *E. coli* in human intestines is derived from food and water
- Human pathogenic *E. coli* strains resistant to ciprofloxacin and 3rd generation cephalosporins (ESBL's) are associated with the use of antimicrobials similar to ciprofloxacin and ceftriaxone (enrofloxacin and ceftiofur) in food animals and especially poultry

ESBL *E. coli* in chickens in China

Yuan L. J Med Microbiol **58** (2009), 1449-1453

- 51 non-replicate *E. coli* isolates from 14 different chicken farms in Henan Province in China from December 2007 to August 2008.
- The prevalence of ESBL-producing *E. coli*, molecular characterization of the ESBL-related *bla* genes, including *bla*TEM, *bla*SHV and *bla*CTX-M, and the susceptibilities of these bacteria to various antimicrobial agents determined.
- Thirty-one of the 51 isolates (62%) were positive for an ESBL phenotype and 29 of these isolates carried one or more *bla* genes.

Many resistant bacteria are ingested



- A study of tetracycline-resistant E.coli in which volunteers were given sterile food for 20 days after a control period of 21 days showed that most came from food (Corpet 1988, 1993).

EMEA found association with animal use

European Medicines Agency
Veterinary Medicines and Inspections

London, 16 March 2009
EMEA/CVMP/SAGAM/81730/2006-Rev.1*

COMMITTEE FOR MEDICINAL PRODUCTS FOR VETERINARY USE (CVMP)

REVISED REFLECTION PAPER ON THE USE OF 3rd AND 4th GENERATION CEPHALOSPORINS IN FOOD PRODUCING ANIMALS IN THE EUROPEAN UNION: DEVELOPMENT OF RESISTANCE AND IMPACT ON HUMAN AND ANIMAL HEALTH

People exposed to resistant E.coli in foods on daily basis

Exposure to resistance genes from bacteria associated with food of animal origin

In the study by Corpet (1988), volunteers eating sterilised food had significantly less coliforms resistant to tetracyclines in their faeces than when eating non-sterilized food. This type of study has not been repeated since, but data on occurrence of resistant *E. coli* on food, including vegetables, indicate that humans ingest resistant bacteria on a daily basis. During the passage through the intestine, such bacteria may transfer their resistance genes to host- adapted bacteria or to zoonotic pathogens. Exchange of resistance genes between bacteria from different sources has also been demonstrated in water, soil, on kitchen towels, on cutting boards and on the surface of food (Kruse & Sørum, 1994). Evidence for horizontal transfer of plasmids or resistance genes other than cephalosporin resistance between bacteria colonising animals and those colonising humans has been documented in several studies (Chaslus-Dancla *et al*., 1991; Hunter *et al*., 1994; Lester *et al*., 2006; Levy *et al*., 1976; Nikolich *et al*., 1994; Tschäpe, 1994).

ESBL and AmpC genes in foods

Genes encoding ESBL- or AmpC- type resistance have been demonstrated, not only in *Salmonella* isolated from food (see above) but also in *E. coli* (Brinas *et al*., 2002; Zhao *et al*., 2001). As discussed, these genes are mostly carried on mobile genetic elements. The number of studies is still limited, as is information on prevalence of resistance to cephalosporins in *E. coli* isolated in meat in Europe (see Table 3). However available information suffices to conclude that humans can be exposed to genes encoding ESBL or AmpC-type resistance via food.

Indistinguishable plasmids or other genetic elements coding for ESBLs or AmpC-type resistance have been described from different bacterial species and different animal and human hosts (Batchelor *et al*., 2005a; Hasman *et al*., 2005; Poppe *et al*., 2005; Winokur *et al*., 2001). Thus, there is evidence that the plasmids carrying genes encoding ESBLs and AmpC-type beta-lactamases are transferred horizontally between different bacterial species of different hosts. Certain plasmids carrying genes encoding CMY-2 are disseminated among both *Salmonella* and *E. coli* from both animals and humans, and the pattern indicates that certain plasmids are epidemic (Hopkins *et al*., 2006, Mulvey *et al*., 2008). Further, there are some reports indicating acquisition of resistance plasmids by *E. coli* and *Salmonella* in the human gut (Su *et al*., 2003; Yan *et al*., 2005). A plasmid encoding ESBL was identified in *E. coli* and *S.* Anatum, both from the same patient. As the resistant isolates had molecular fingerprints identical to those of susceptible isolates of the same species isolated earlier from the same patient, it was

Transfer of resistance genes can occur in intestine

concluded that the acquisition of the same plasmid by two different bacteria had probably occurred in the gut (Su *et al*., 2003). With similar type of evidence, Yan and co-workers reported on a *S.* Hadar with AmpC-type resistance apparently acquired from an *E. coli* from the same patient (Yan *et al*., 2005).

In summary, bacteria of animal origin carrying resistance genes encoding ESBL or AmpC can be present in food. Moreover, at that stage cross-contamination between food-items and human contamination through food processing might also play a role (Anonymous, 2008). Transfer of such genes to bacteria causing disease in humans can occur in the intestine. The present extent of exposure via food is difficult to determine. Any further expansion of the occurrence of ESBL or AmpC resistance among animal bacteria is likely to have an influence on the occurrence in food, and thereby on human exposure.

EMEA Mar 2009 found association with animal use BUT…excuse to do nothing

European Medicines Agency
Veterinary Medicines and Inspections

London, 16 March 2009
EMEA/CVMP/SAGAM/81730/2006-Rev.1*

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The following recommendations are for consideration by Competent Authorities:

- Authorisation of products for prophylactic use of systemically administered cephalosporins should always be limited to specific circumstances and carefully considered in the conditions for authorisation and reflected in the SPCs.
- Use of systemically administered cephalosporins for groups or flocks of animals such as use of oral cephalosporins in feed or drinking water should be strongly discouraged, except in very specific situations, and special attention should be given to the risk of antimicrobial resistance as part of the benefit/risk assessment.

- Prudent use guidelines in all countries should take into account risks related to emergence of resistance to cephalosporins and all Member States should take measures to ensure the implementation of such guidelines.
- Off label use should be strongly discouraged.

Endemic and Epidemic Lineages of *Escherichia coli* that Cause Urinary Tract Infections

Amee R. Manges, Helen Tabor, Patricia Tellis, Caroline Vincent, and Pierre-Paul Tellier

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 14, No. 10, October 2008

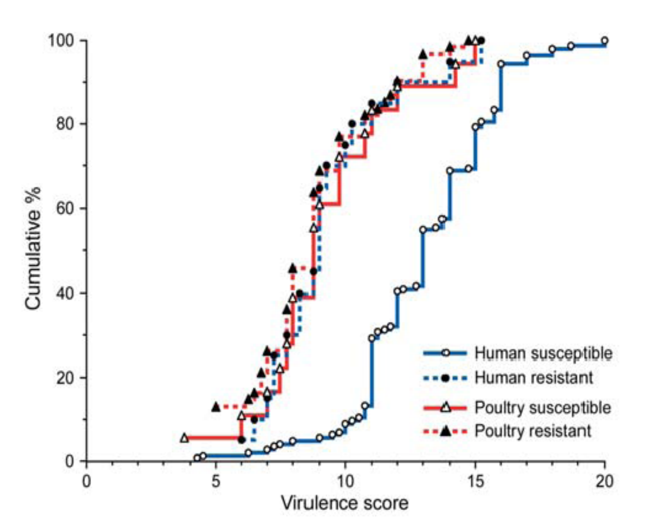
Community-acquired extraintestinal infections with *Escherichia coli* range in frequency from 6 to 8 million cases of uncomplicated cystitis per year to 127,500 cases of sepsis per year in the United States (*1*). Urinary tract infec-

Antimicrobial Drug–Resistant *Escherichia coli* from Humans and Poultry Products, Minnesota and Wisconsin, 2002–2004

James R. Johnson,*† Mark R. Sannes,*†[1] Cynthia Croy,*† Brian Johnston,*† Connie Clabots,*†
Michael A. Kuskowski,*† Jeff Bender,‡ Kirk E. Smith,§ Patricia L. Winokur,¶#
and Edward A. Belongia**

The food supply, including poultry products, may transmit antimicrobial drug–resistant *Escherichia coli* to humans. To assess this hypothesis, 931 geographically and temporally matched *E. coli* isolates from human volunteers (hospital inpatients and healthy vegetarians) and commercial poultry products (conventionally raised or raised without antimicrobial drugs) were tested by PCR for phylogenetic group (A, B1, B2, D) and 60 virulence genes associated with extraintestinal pathogenic *E. coli*. Isolates resistant to trimethoprim-sulfamethoxazole, quinolones, and extended-spectrum cephalosporins (n = 331) were compared with drug-susceptible isolates (n = 600) stratified by source. Phylogenetic and virulence markers of drug-susceptible human isolates differed considerably from those of human and poultry isolates. In contrast, drug-resistant human isolates were similar to poultry isolates, and drug-susceptible and drug-resistant poultry isolates were largely indistinguishable. Many drug-resistant human fecal *E. coli* isolates may originate from poultry, whereas drug-resistant poultry-source *E. coli* isolates likely originate from susceptible poultry-source precursors.

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 13, No. 6, June 2007



Journal of Infection (2008) 57, 441—448

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www.elsevierhealth.com/journals/jinf

Community-onset extended-spectrum β-lactamase (ESBL) producing *Escherichia coli*: Importance of international travel

Kevin B. Laupland [a,b,c,e,*], Deirdre L. Church [a,b,d], Jeanne Vidakovich [a], Melissa Mucenski [a], Johann D.D. Pitout [b,d]

International travel

Increased risk but loose isolates when return home with time

- Colonisation with *Escherichia coli* resistant to “critically important” antibiotics: a high risk for international travellers. Kennedy and Collignon. Eur J Clin Micro and Inf Dis. 2010

- Abstract

Antimicrobial resistance among community-acquired isolates of Escherichia coli is increasing globally, with international travel emerging as a risk for colonisation and infection. The aim was to determine the rate and duration of colonisation with resistant E. coli following international travel. One hundred and two adult hospital staff and contacts from Canberra, Australia, submitted perianal/rectal swabs before and following international travel. Swabs were cultured selectively to identify E. coli resistant to gentamicin, ciprofloxacin and/or third-generation cephalosporins. Those with resistant E. coli post-travel were tested monthly for persistent colonisation. Colonisation with antibiotic-resistant E. coli increased significantly from 7.8% (95% confidence interval [CI] 3.8–14.9) pre-travel to 49% (95% CI 39.5–58.6) post-travel. Those colonised were more likely to have taken antibiotics whilst travelling; however, travel remained a risk independent of antibiotic use. Colonisation with resistant E. coli occurred most frequently following travel to Asia. While over half of those carrying resistant E. coli post-travel had no detectable resistant strains two months after their return, at least 18% remained colonised at six months. Colonisation with antibiotic-resistant E. coli occurs commonly after international travel, and can be persistent. Medical practitioners should be aware of this risk, particularly when managing patients with suspected Gram-negative sepsis.

APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Oct. 2007, p. 6566–6576 Vol. 73, No. 20
0099-2240/07/$08.00+0 doi:10.1128/AEM.01086-07

Impact of Feed Supplementation with Antimicrobial Agents on Growth Performance of Broiler Chickens, *Clostridium perfringens* and *Enterococcus* Counts, and Antibiotic Resistance Phenotypes and Distribution of Antimicrobial Resistance Determinants in *Escherichia coli* Isolates▽

Moussa S. Diarra,[1]* Fred G. Silversides,[1] Fatoumata Diarrassouba,[1] Jane Pritchard,[2] Luke Masson,[3] Roland Brousseau,[3] Claudie Bonnet,[3] Pascal Delaquis,[4] Susan Bach,[4] Brent J. Skura,[5] and Edward Topp[6]

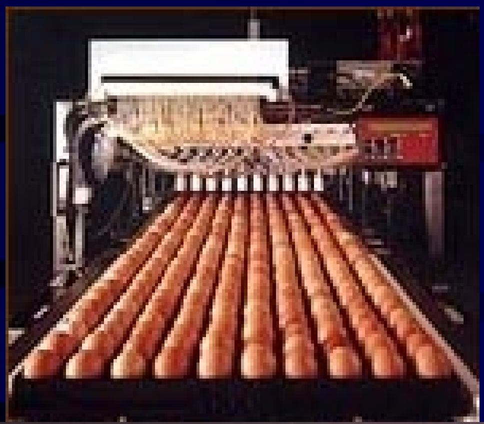
The effects of feed supplementation with the approved antimicrobial agents bambermycin, penicillin, salinomycin, and bacitracin or a combination of salinomycin plus bacitracin were evaluated for the incidence and distribution of antibiotic resistance in 197 commensal *Escherichia coli* isolates from broiler chickens over 35 days. All isolates showed some degree of multiple antibiotic resistance. Resistance to tetracycline (68.5%), amoxicillin (61.4%), ceftiofur (51.3%), spectinomycin (47.2%), and sulfonamides (42%) was most frequent. The levels of resistance to streptomycin, chloramphenicol, and gentamicin were 33.5, 35.5, and 25.3%, respectively. The overall resistance levels decreased from day 7 to day 35 ($P < 0.001$). Comparing treatments, the levels of resistance to ceftiofur, spectinomycin, and gentamicin (except for resistance to bacitracin treatment) were significantly higher in isolates from chickens receiving feed supplemented with salinomycin than from the other feeds ($P < 0.001$). Using a DNA microarray analysis capable of detecting commonly found antimicrobial resistance genes, we characterized 104 tetracycline-resistant *E. coli* isolates from 7- to 28-day-old chickens fed different growth promoters. Results showed a decrease in the incidence of isolates harboring *tet*(B), bla_{TEM}, *sulI*, and *aadA* and class 1 integron from days 7 to 35 ($P < 0.01$). Of the 84 tetracycline-ceftiofur-resistant *E. coli* isolates, 76 (90.5%) were positive for bla_{CMY-2}. The proportions of isolates positive for *sulI*, *aadA*, and integron class 1 were significantly higher in salinomycin-treated chickens than in the control or other treatment groups ($P < 0.05$). These data demonstrate that multiantibiotic-resistant *E. coli* isolates can be found in broiler chickens regardless of the antimicrobial growth promoters used. However, the phenotype and the distribution of resistance determinants in *E. coli* can be modulated by feed supplementation with some of the antimicrobial agents used in broiler chicken production.

Use of antibiotics in animals

- therapeutic
  - sick animals
- prophylaxis
  - prevent infection
  - metaphylaxis
- growth promotion
  - weight gain
  - feed efficiency

Mass injection of Ceftiofur

Mass exposure of poultry



3rd generation cephalosporin resistance

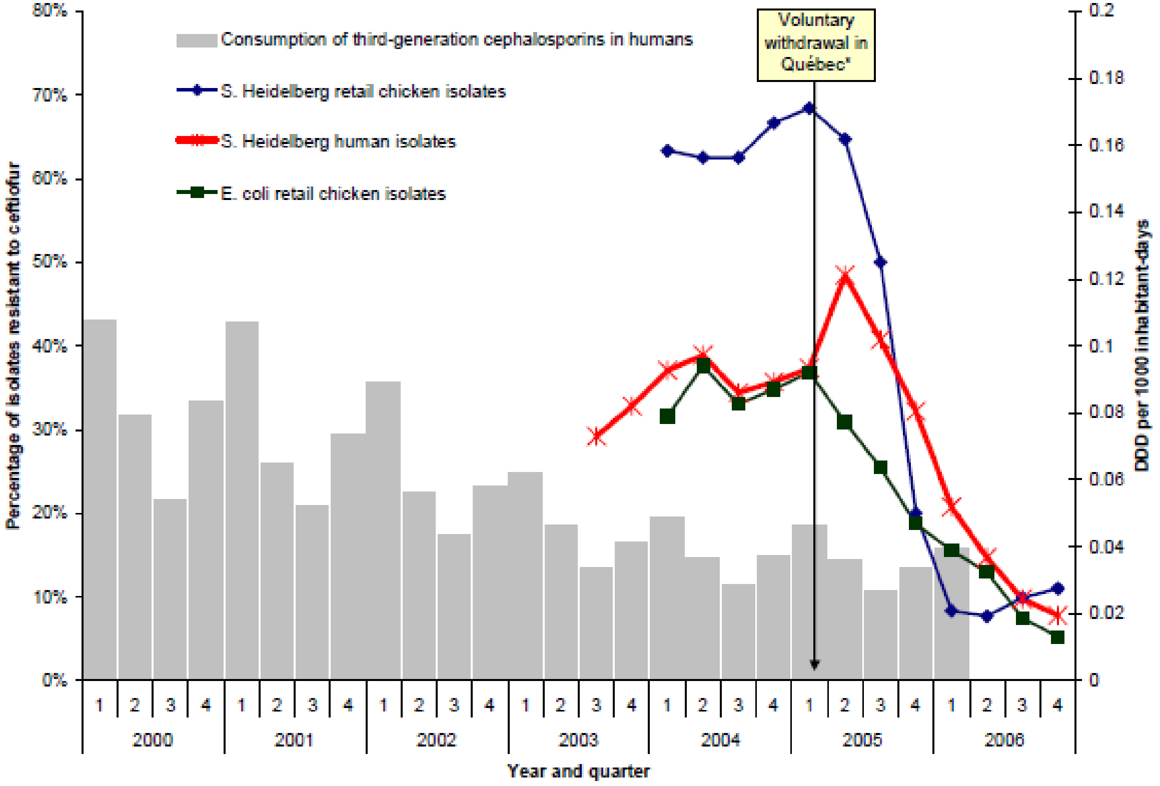
- Extended-spectrum beta-lactamase (eg CMY-2) are increasingly isolated from humans, animals, foods, and environmental sources
- The conjugative plasmid containing the cmy-2 gene can be transferred not only from the donor E. coli to Salmonella but also to other E. coli present in the intestinal tract.
- A nationwide surveillance for antimicrobial susceptibility in Escherichia coli strains isolated from food-producing animals in Japan was conducted from 1999 to 2002. CTX-M-type producing, and CMY-2 producing.
- Identification and expression of cephamycinase bla(CMY) genes in Escherichia coli and Salmonella isolates from food animals and ground meat.

Antimicrob Agents Chemother. 2001 Dec;45(12):3647-50.

Appl Environ Microbiol. 2005 Mar;71(3):1184-92.

Antimicrob Agents Chemother. 2005 Aug;49(8):3533-7.

Figure 1. Past three quarters moving average of the percentage of isolates resistant to ceftiofur for retail chicken *E. coli*, retail chicken and human clinical *S. Heidelberg* isolates, and quarterly human consumption of 3rd generation cephalosporins dispensed at retail pharmacies (*IMS*[2] *Health*) in Québec.



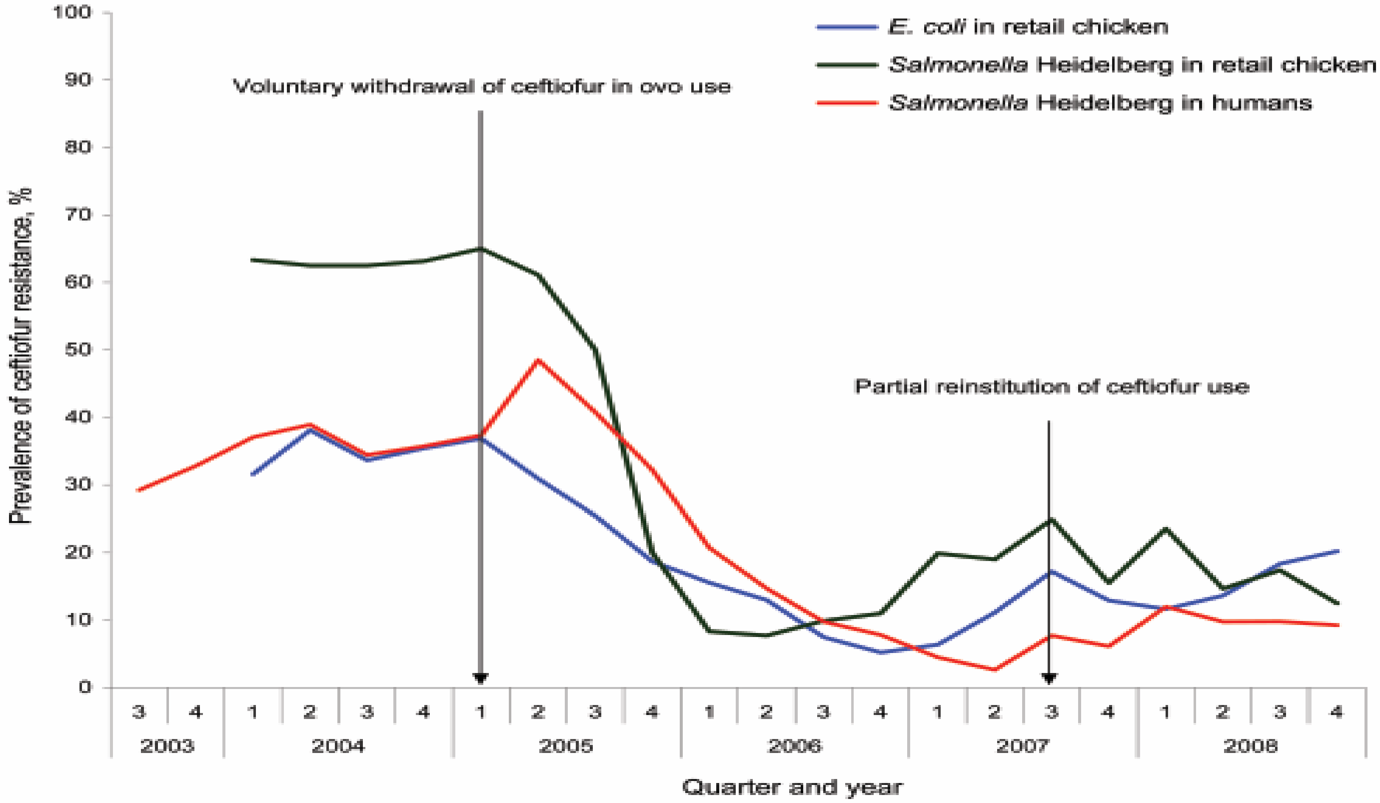


Figure 2. Prevalence of ceftiofur resistance (moving average of the current quarter and the previous 2 quarters) among retail chicken *Escherichia coli*, and retail chicken and human clinical *Salmonella enterica* serovar Heidelberg isolates during 2003–2008 in Québec, Canada.

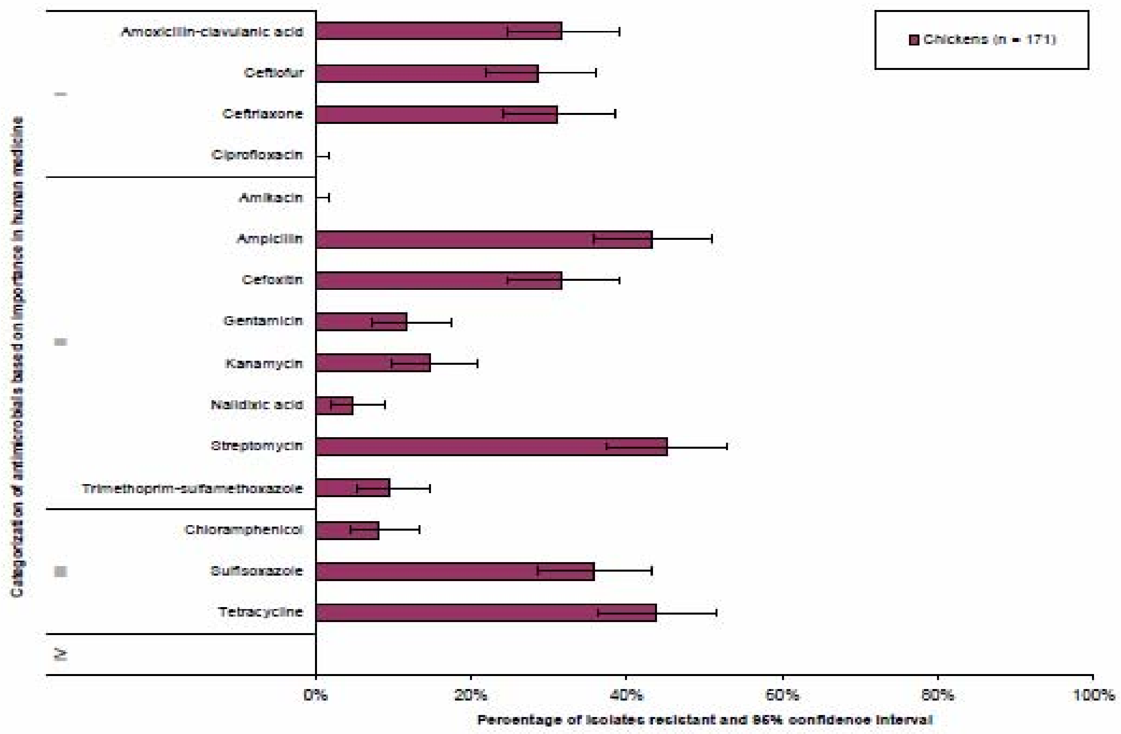
CIPARS 2009 (Canada)

Escherichia coli

Abattoir Surveillance

(n = 171)

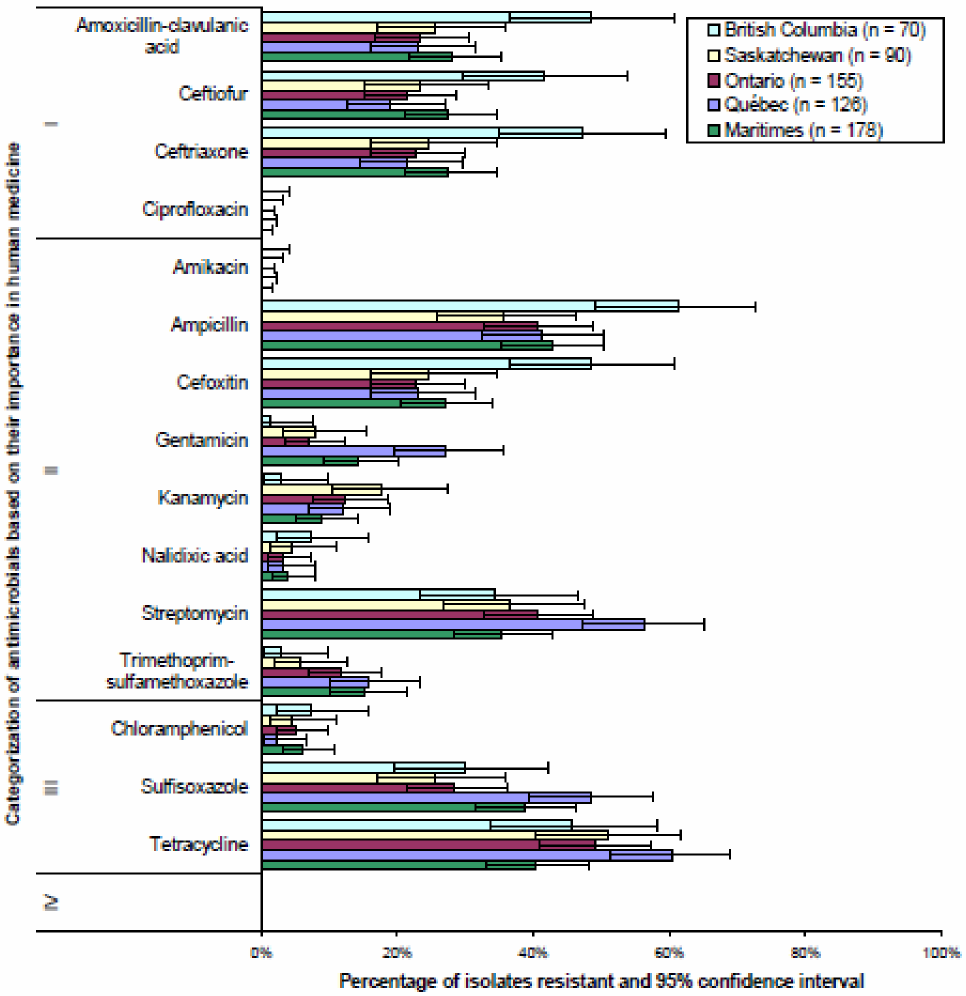
Figure 15. Resistance to antimicrobials in *Escherichia coli* isolates from chickens; *Abattoir Surveillance*, 2009.



Retail Meat Surveillance

(n = 619)

Figure 17. Resistance to antimicrobials in *Escherichia coli* isolates from chicken; *Retail Meat Surveillance*, 2009.



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Advance Access publication 23 May 2006

JAC

Extended-spectrum β-lactamase-producing Enterobacteriaceae in different environments (humans, food, animal farms and sewage)

Raúl Jesús Mesa[1,2], Vanessa Blanc[2], Anicet R. Blanch[3], Pilar Cortés[2], Juan José González[4], Susana Lavilla[4], Elisenda Miró[1], Maite Muniesa[3], Montserrat Saco[5], MªTeresa Tórtola[2,4], Beatriz Mirelis[1,2], Pere Coll[1,2], Montserrat Llagostera[2,6], Guillem Prats[2,4] and Ferran Navarro[1,2]*

Results: An ESBL-producing Enterobacteriaceae prevalence of 1.9% was observed in human infections. A cross-sectional survey of human faecal carriers in the community showed a general prevalence of 6.6% with a temporal distribution. High use of antibiotics in winter coincided with a lower prevalence in carriers. ESBL-producing Enterobacteriaceae were detected in the five samples of human sewage, in samples from 8 of 10 pig farms, 2 of 10 rabbit farms, from all 10 poultry farms and in 3 of 738 food samples studied. Faecal carriage of ESBL-producing Enterobacteriaceae was detected in samples from 19 of 61 food-borne outbreaks evaluated. All food-borne outbreaks were due to enteropathogens. The prevalence of carriers in these outbreaks ranged from 4.4% to 66.6%.

Conclusions: This widespread occurrence of ESBL-producing Enterobacteriaceae suggests that the community could act as a reservoir and that food could contribute to the spread of these strains.

Quinolone resistance

- In Australia fluoroquinolones NOT approved for livestock use
  - <1% resistance in human E.coli (1998, 863 isolates, AGAR) , 2007 4 to 5%
  - nil in food isolates
  - restricted human use of these antibiotics
  - Australia is a “negative” control in worldwide experiment
- In Spain
  - in children, 22% ciprofloxacin resistant
  - in chickens, 90% resistant
- USA FDA tried to stop use
  - but ended up in court for years, with Bayer fighting poultry ban

Escherichia coli

- Multidrug-resistant increasingly frequent problem, particularly in developing countries (e.g. China, Mexico)

- Main reservoir is gastrointestinal tract. Large turnover of *E. coli* each day.

- Food is important source and food animals likely contribute a substantial proportion of the *E. coli* in the human gastrointestinal tract.

But are *E. coli* host specific?

- Most strains relatively host specific, but resistant strains of animal origin (e.g. fluoroquinolone-resistant *E. coli* from chickens) can both colonize and cause infections in people

- Resistance to 3rd generation cephalosporins, fluoroquinolones and/or aminoglycosides in bacteria infecting people is now widespread and rapidly rising in many countries.

- Increasing frequency of community-acquired infections by strains producing extended-spectrum ß-lactamases (ESBL), despite the relative infrequency of 3rd and 4th generation injectable cephalosporins use in treating people in the community

Multi-drug resistant *E. coli*

- Rising numbers of community-acquired ESBL-producing *E. coli* are carried by the population.
- increasing frequencies of resistant isolates in foods around the world.
- In Spain similar bacteria found in humans, food, animal farms and sewage.
- 3^{rd} and 4^{th} generation cephalosporins in food animals select for resistant bacteria, including ESBL-producing strains
- Worldwide spread of resistant bacteria and their transferable genes (eg CTX-M and CMY ß-lactamases).

Similar E.coli in humans, animals and food

FOODBORNE PATHOGENS AND DISEASE
Volume 7, Number 5, 2010

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Escherichia coli Isolates from Broiler Chicken Meat, Broiler Chickens, Pork, and Pigs Share Phylogroups and Antimicrobial Resistance with Community-Dwelling Humans and Patients with Urinary Tract Infection

Lotte Jakobsen,[1] Azra Kurbasic,[1] Line Skjøt-Rasmussen,[1] Karen Ejrnæs,[1] Lone J. Porsbo,[2] Karl Pedersen,[2,*] Lars B. Jensen,[2] Hanne-Dorthe Emborg,[2] Yvonne Agersø,[2] Katharina E.P. Olsen,[1] Frank M. Aarestrup,[2] Niels Frimodt-Møller,[1] and Anette M. Hammerum[1]

EMEA Frequent ESBL

Table 3. Reported resistance to cefotaxime or ceftiofur in *Escherichia coli* isolated in healthy animals in 2007 (number of investigated isolates and percent reported as resistant; based on data in national zoonoses reports submitted to EFSA in accordance with Directive 2003/99/EC, www.efsa.europa.eu. Only entries with results from more than 10 isolates were included).

Country reporting	Method [a]	Cut-off [b]	Cattle		Fowl (*Gallus gallus*)		Pigs	
		mg/l	N[e]	%[g]	N	%	N	%
Austria	DIl	0.25	43	0	43	0	46	0
Denmark	Dil	1 [c]	98	0	114	2.0	150	0.7
Estonia	Dil	0.25	21	4.0			19	0
Finland	Dil	0.25					135	0
France	Dil	2	103	0	101	2.0	126	0.8
Italy	Dil	0.25			37	2.7	149	0.7
The Netherlands	Dil	0.25	152 [f]	0	43	9.0	169	1.2
Norway	Dil	0.25					198	1
Slovenia	DD	NA	22	0			34	2.9
Spain	Dil	0.25	158	0	87	24.1	229	0.9
Sweden	Dil	0.25			296	1.0		
Switzerland	Dil	4 [c]			284	0.4	98	0
United Kingdom	DD	NA	1652	6.7				

[a] Dil = (micro)dilution, DD= disk diffusion; [b] cut-off used to define resistance to cefotaxime unless otherwise indicated; [c] cut-off for ceftiofur; [e] Number of isolates tested; [f] Figure in table is for bovines unspecified. Also reports veal N=87, 1% resistance and dairy cattle N=18 5.6% resistance; [g] Percent of tested isolates reported as resistant;

EMEA

of a strikingly rapid emergence, data on the occurrence of resistance to cefotaxime, defined by the epidemiological cut-off value of EUCAST (>0.25 mg/l), in *E. coli* from healthy broilers, and in *Salmonella* Paratyphi B var. Java from broilers in the Netherlands are shown in Figure 3 (data from MARAN 2005; Dik Mevius, personal communication, 2007).

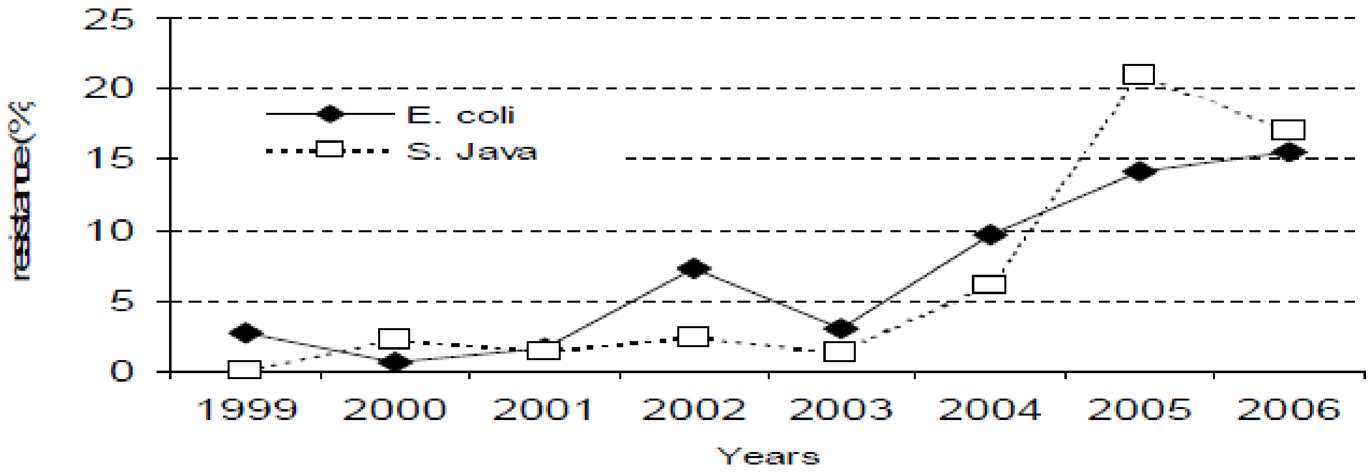

Figure 3. Occurence of resistance to cefotaxime in *E. coli* and *Salmonella* Paratyphi B var. Java from broilers in the Netherlands.

Australia is relatively unique

- Quarantine, so NO fresh meats imported
- NO fluoroquinolones in food animals
- NO 3rd Generation cephalosporins in poultry

Antibiotic Resistance

in Bacteria Isolated From Poultry

A report for the Rural Industries Research and Development Corporation

by Mary D Barton and Jodi Wilkins

2001

Table 11: Distribution of antibiotic resistance in *E coli*

E coli Antibiotic Sensitivity Results							
		Lab A Samples			Lab B Samples		
Antibiotic	Conc ug/ml	Total Organisms	No. Resistant *E coli*	% Resistant	Total Organisms	No. Resistant *E coli*	% Resistant
Ampicillin	8	182	96	**52.7**	47	36	**76.6**
Ampicillin	32	182	69	**37.9**	47	20	**42.6**
Augmentin	8	182	6	**3.3**	47	0	**0**
Augmentin	32	182	0	**0**	47	0	**0**
Cepthalothin	8	182	35	**19.2**	47	3	**6.4**
Cephalothin	32	182	9	**4.9**	47	0	**0**
Ciprofloxacin	1	182	0	**0**	47	0	**0**
Ciprofloxacin	4	182	0	**0**	47	0	**0**
Flavophospholipol	64	182	161	**88.5**	47	44	**93.6**
Gentamicin	4	182	3	**1.6**	47	1	**2.1**
Gentamicin	16	182	0	**0**	47	1	**21**
Lasalocid	4	182	182	**100**	47	47	**100**
Neomycin	6	182	13	**7.1**	47	3	**6.4**
Neomycin	25	182	12	**6.6**	47	1	**2.1**
Spectinomycin	16	182	22	**12.1**	47	13	**27.7**
Spectinomycin	64	182	16	**8.8**	47	11	**23.4**
Streptomycin	4	182	87	**47.8**	47	22	**46.8**
Streptomycin	16	182	61	**33.5**	47	16	**34**
Tetracycline	4	182	158	**86.8**	47	39	**83**
Tetracycline	16	182	107	**58.8**	47	25	**53.2**
Trimethoprim	8	182	84	**46.2**	47	17	**36.2**
Trimethoprim	16	182	84	**46.2**	47	17	**36.2**

Retail poultry Australia

Retail poultry – *E. coli*

A total of 290 *E. coli* were isolated during the 12 month sampling period. The overall prevalence of *E. coli* in retail poultry was 69.0% and ranged during monthly sampling from 51.4% to 80.0%. One hundred *E. coli* isolates were randomly selected for AMR testing.

Antimicrobial drug resistance: The prevalence of multiple drug resistance in *E. coli* is presented in Figure 3. The distribution of MICs and resistance in *E. coli* is presented in Table 16. Resistance to one or more antimicrobials was observed in 65% of isolates. Resistance to tetracycline (47%), ampicillin (38%), trimethoprim / sulfamethoxazole (22%) and streptomycin (19%) were most commonly observed. Resistance to kanamycin and gentamicin was observed in 8% and 4% of isolates respectively. Resistance to amoxicillin / clavulanic acid, cefazolin, florfenicol and chloramphenicol was observed in two or less isolates.

Table 16. Distribution of MICs and resistance in *E. coli* from retail poultry, beef, pork and lettuce.

Antimicrobial	Product	N =	% Resistant	[95% CI]	Distribution (%) of MICs 0.125	0.25	0.5	1	2	4	8	16	32	64	128
Amoxicillin / Clavulanic acid [a]	Poultry	100	1.0	[0.03 – 5.45]				3.0	16.0	57.0	22.0	1.0	1.0		
	Beef	100	3.0	[0.62 – 8.52]				3.0	20.0	63.0	9.0	2.0	2.0	1.0	
	Pork	92	3.3	[0.68 – 9.23]				4.1	7.6	55.4	26.1	6.5	2.2	1.1	
	Lettuce	7	14.3	[0.36 – 57.87]				14.3	42.9		28.6		14.3		
Ampicillin	Poultry	100	38.0	[29.09 – 47.60]					35.0	24.0	1.0	2.0	1.0	3.0	34.0
	Beef	100	11.0	[5.62 – 18.83]					46.0	35.0	3.0	5.0	2.0	2.0	7.0
	Pork	92	28.2	[19.36 – 38.61]					26.1	40.2	3.3	2.2	4.3		23.9
	Lettuce	7	57.2	[18.41 – 90.10]						28.6	14.3			14.3	42.9
Cefazolin	Poultry	100	2.0	[0.24 – 7.04]							96.0	2.0	2.0		
	Beef	100	3.0	[0.62 – 8.52]							90.0	7.0	3.0		
	Pork	92	3.3	[0.68 – 9.23]							90.2	6.5	3.3		
	Lettuce	7	28.6	[3.67 – 70.96]							71.4		28.6		
Cefotaxime	Poultry	100	0.0	[0.00 – 3.62]		100.0									
	Beef	100	0.0	[0.00 – 3.62]		98.0		2.0							
	Pork	92	0.0	[0.00 – 3.93]		100.0									
	Lettuce	7	0.0	[0.00 – 40.96]		71.4	28.6								
Cefoxitin	Poultry	100	0.0	[0.00 – 3.62]					25.0	55.0	17.0	3.0			
	Beef	100	0.0	[0.00 – 3.62]					21.0	55.0	22.0	2.0			
	Pork	92	0.0	[0.00 – 3.93]					8.7	57.6	29.3	4.3			
	Lettuce	7	0.0	[0.00 – 40.96]					42.9	14.3	42.9				
Ceftiofur	Poultry	100	0.0	[0.00 – 3.62]			99.0	1.0							
	Beef	100	0.0	[0.00 – 3.62]			98.0	1.0	1.0						
	Pork	92	0.0	[0.00 – 3.93]			100.0								
	Lettuce	7	0.0	[0.00 – 40.96]			100.0								
Ceftriaxone	Poultry	100	0.0	[0.00 – 3.62]		98.0	2.0								
	Beef	100	0.0	[0.00 – 3.62]		97.0	1.0	2.0							
	Pork	92	0.0	[0.00 – 3.93]		97.8		2.2							
	Lettuce	7	0.0	[0.00 – 40.96]		100.0									
Chloramphenicol	Poultry	100	1.0	[0.03 – 5.45]						37.0	59.0	3.0	1.0		
	Beef	100	0.0	[0.00 – 3.62]					6.0	26.0	67.0	1.0			
	Pork	92	13.0	[6.93 – 21.68]					2.2	18.5	58.7	7.6	8.7	4.3	
	Lettuce	7	0.0	[0.00 – 40.96]					28.6	57.1	14.3				
Ciprofloxacin	Poultry	100	0.0	[0.00 – 3.62]	98.0	2.0									
	Beef	100	0.0	[0.00 – 3.62]	99.0	1.0									
	Pork	92	0.0	[0.00 – 3.93]	97.8	1.1	1.1								
	Lettuce	7	0.0	[0.00 – 40.96]	85.7	14.3									
Florfenicol	Poultry	100	2.0	[0.24 – 7.04]					8.0	62.0	28.0	2.0			
	Beef	100	0.0	[0.00 – 3.62]					7.0	40.0	53.0				
	Pork	92	8.7	[3.83 – 16.42]					3.3	41.3	46.7	8.7			
	Lettuce	7	0.0	[0.00 – 40.96]					42.9	42.9	14.3				
Gentamicin	Poultry	100	4.0	[1.10 – 9.93]				83.0	13.0				4.0		
	Beef	100	0.0	[0.00 – 3.62]				93.0	7.0						
	Pork	92	1.1	[0.03 – 5.91]				87.0	10.9		1.1		1.1		
	Lettuce	7	0.0	[0.00 – 40.96]				100.0							
Kanamycin	Poultry	100	8.0	[3.52 – 15.16]							84.0	8.0			8.0
	Beef	100	2.0	[0.24 – 7.04]							94.0	4.0			2.0
	Pork	92	3.3	[0.68 – 9.23]							83.7	12.0	1.1	1.1	2.2
	Lettuce	7	0.0	[0.00 – 40.96]							85.7	14.3			
Meropenem	Poultry	100	0.0	[0.00 – 3.62]				99.0	1.0						
	Beef	100	0.0	[0.00 – 3.62]				100.0							
	Pork	92	0.0	[0.00 – 3.93]				100.0							
	Lettuce	7	0.0	[0.00 – 40.96]				100.0							
Nalidixic Acid	Poultry	100	0.0	[0.00 – 3.62]					52.0	47.0	1.0				
	Beef	100	0.0	[0.00 – 3.62]					44.0	54.0	2.0				
	Pork	92	0.0	[0.00 – 3.93]					29.3	66.3	4.3				
	Lettuce	7	0.0	[0.00 – 40.96]						85.7	14.3				
Streptomycin	Poultry	100	19.0	[11.84 – 28.07]									81.0	4.0	15.0
	Beef	100	7.0	[2.86 – 13.89]									93.0	4.0	3.0
	Pork	92	17.4	[10.28 – 26.70]									82.6	8.7	8.7
	Lettuce	7	14.3	[0.36 – 57.87]									85.7	14.3	
Tetracycline	Poultry	100	47.0	[36.94 – 57.24]						53.0		5.0	8.0	34.0	
	Beef	100	7.0	[2.86 – 13.89]						91.0	2.0			7.0	
	Pork	92	44.5	[34.19 – 55.30]						54.3	1.1	1.1	4.3	39.1	
	Lettuce	7	28.6	[3.67 – 70.96]						71.4			14.3	14.3	
Trimethoprim / Sulfamethoxazole	Poultry	100	22.0	[14.33 – 31.39]	65.0	9.0	3.0	1.0			22.0				
	Beef	100	5.0	[1.64 – 11.28]	90.0	2.0	2.0		1.0	3.0	2.0				
	Pork	92	13.0	[6.93 – 21.68]	67.4	16.3	3.3			4.3	8.7				
	Lettuce	7	14.3	[0.36 – 57.87]	85.7						14.3				

Imported chicken meat as a potential source of quinolone-resistant *Escherichia coli* producing extended-spectrum β-lactamases in the UK

Journal of Antimicrobial Chemotherapy, JAC Advance Access published online on January 25, 2008 .**R. E. Warren1,*, V. M. Ensor2, P. O'Neill1, V. Butler1, J. Taylor1, K. Nye3, M. Harvey3, D. M. Livermore4, N. Woodford4 and P. M. Hawkey2,3**

- Results: The country of rearing was identified from the packaging for 89 of 129 purchased samples. Only one of the 62 UK-reared chicken samples carried *E. coli* producing a CTX-M-1 enzyme, whereas 10 of 27 samples reared overseas had *E. coli* with CTX-M enzymes. Specifically, 4/10 Brazilian, 3/4 Brazilian/Polish/French, and 2/2 Dutch samples had *E. coli* with CTX-M-2 enzymes. Six of 40 samples for which the country of rearing was not known had producers of CTX-M enzymes, 5 of them with CTX-M-14.

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Extended-spectrum β-lactamase-producing Enterobacteriaceae in different environments (humans, food, animal farms and sewage)

Raúl Jesús Mesa[1,2], Vanessa Blanc[2], Anicet R. Blanch[3], Pilar Cortés[2], Juan José González[4], Susana Lavilla[4], Elisenda Miró[1], Maite Muniesa[3], Montserrat Saco[5], MªTeresa Tórtola[2,4], Beatriz Mirelis[1,2], Pere Coll[1,2], Montserrat Llagostera[2,6], Guillem Prats[2,4] and Ferran Navarro[1,2*]

Results: An ESBL-producing Enterobacteriaceae prevalence of 1.9% was observed in human infections. A cross-sectional survey of human faecal carriers in the community showed a general prevalence of 6.6% with a temporal distribution. High use of antibiotics in winter coincided with a lower prevalence in carriers. ESBL-producing Enterobacteriaceae were detected in the five samples of human sewage, in samples from 8 of 10 pig farms, 2 of 10 rabbit farms, from all 10 poultry farms and in 3 of 738 food samples studied. Faecal carriage of ESBL-producing Enterobacteriaceae was detected in samples from 19 of 61 food-borne outbreaks evaluated. All food-borne outbreaks were due to enteropathogens. The prevalence of carriers in these outbreaks ranged from 4.4% to 66.6%.

Conclusions: This widespread occurrence of ESBL-producing Enterobacteriaceae suggests that the community could act as a reservoir and that food could contribute to the spread of these strains.

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0099-2240/07/$08.00+0 doi:10.1128/AEM.01086-07

Impact of Feed Supplementation with Antimicrobial Agents on Growth Performance of Broiler Chickens, *Clostridium perfringens* and *Enterococcus* Counts, and Antibiotic Resistance Phenotypes and Distribution of Antimicrobial Resistance Determinants in *Escherichia coli* Isolates

Moussa S. Diarra,[1]* Fred G. Silversides,[1] Fatoumata Diarrassouba,[1] Jane Pritchard,[2] Luke Masson,[3] Roland Brousseau,[3] Claudie Bonnet,[3] Pascal Delaquis,[4] Susan Bach,[4] Brent J. Skura,[5] and Edward Topp[6]

TABLE 2. Performance of broiler chickens fed diets containing antimicrobials[a]

Parameter	Period (days)	Value for control	Value for treatment with:					SEM	P value[b]
			BBM	PEN	SAL	BAC	SAL + BAC		
Body wt (g)	Initial	40.69	40.76	40.64	40.71	40.67	40.40	0.232	0.91
	0–14	457.31	459.89	462.87	441.32	451.67	458.77	7.224	0.38
	15–28	1,252.02	1,265.29	1,267.10	1,209.64	1,224.63	1,255.29	14.605	0.09
	29–35	1,815.09	1,811.42	1,805.12	1,783.69	1,776.75	1,825.11	27.805	0.80
Feed intake (g)	0–14	365.90	373.21	363.39	361.82	360.72	368.93	6.272	0.72
	15–28	896.23	906.58	868.70	861.47	870.33	901.47	15.969	0.27
	29–35	1,288.22	1,280.62	1,223.70	1,263.36	1,264.54	1,329.18	23.142	0.12
	0–35	3,215.03	3,237.87	3,084.20	3,118.83	3,125.57	3,239.98	47.916	0.14
Feed efficiency (g of feed/g body wt gain)	0–14	1.21	1.22	1.17	1.24	1.21	1.20	0.014	0.09
	15–28	1.78	1.77	1.69	1.76	1.76	1.77	0.018	0.06
	29–35	2.29	2.35	2.28	2.17	2.30	2.34	0.060	0.37
	0–35	1.78	1.79	1.72	1.75	1.77	1.78	0.015	0.04*
Total mortality (%)	0–35	5.48	12.64	7.12	12.77	7.65	4.47	2.682	0.26

[a] Values indicate performance parameters of broiler chickens fed diets containing bambermycin (BBM), penicillin (PEN), salinomycin (SAL), bacitracin (BAC), and a salinomycin-bacitracin combination (SAL + BAC) at concentrations specified in Materials and Methods.
[b] P values were obtained by analysis of variance. *, values are statistically different ($P < 0.05$).

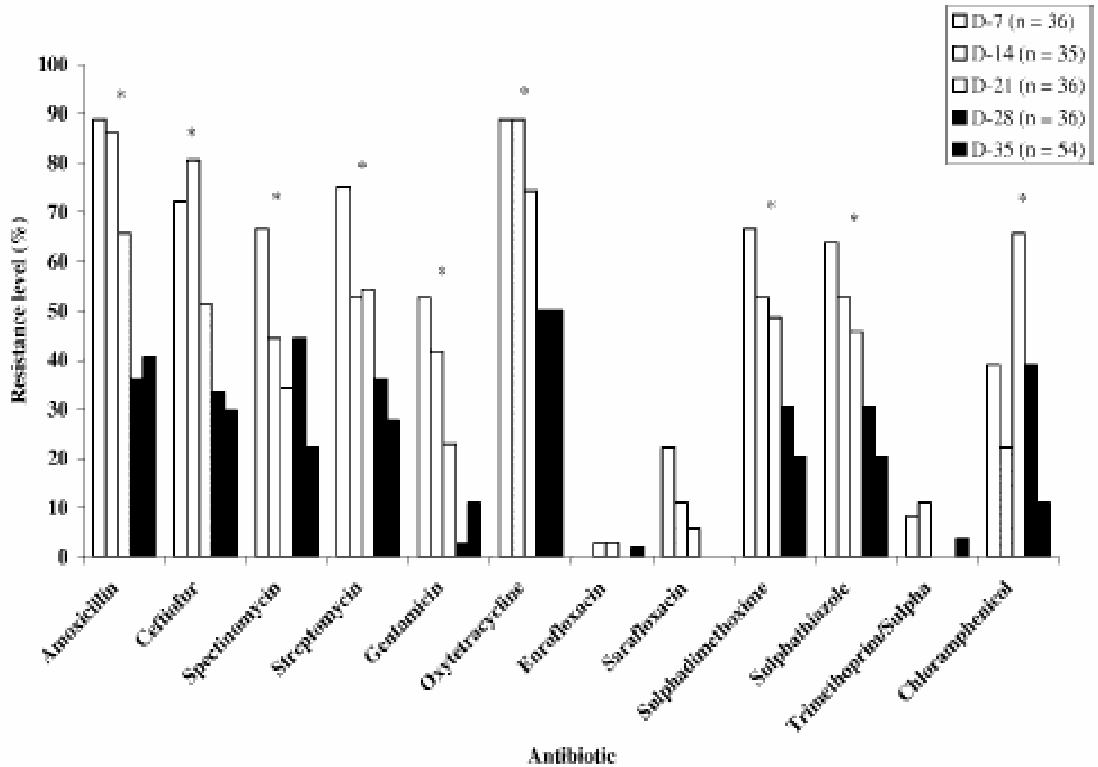

FIG. 1. Effect of age on resistance profiles of 197 *E. coli* isolates from broiler chickens. The percentage of resistance to most antibiotics decreased significantly ($P < 0.001$) from day 7 to day 35). Asterisks indicate the antibiotics against which the resistance percentages between treatments were statistically different ($P < 0.001$).

Table B. **Occurrence of resistance to antimicrobials in *Escherichia coli* from food products (percent resistant isolates)**[a] (Sources: The Community Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents, Antimicrobial Resistance and Foodborne Outbreaks in the European Union in 2005 and national reports)

Country	Year	Food type	Number of isolates	Reported resistance (%)											Data source
				Ampicillin	3rd gen cephalosporin	Chloramphenicol	Ciprofloxacin-/Enrofloxacin	Nalidixic acid	Gentamicin	Neomycin-/Kanamycin	Streptomycin	Sulphonamides	Tetracycline	Trimethoprim	
Austria	2003	beef	40	2	-	2	2*	5	0	0	12	-	12	2	Ramost 2003
Belgium	2005	beef	238	13	2	4	1	2	-	-	12	19	16	11	Zoonoses report 2005
Denmark	2004	beef	196	8	0	1	0*	0	0	2	9	7	9	4	DANMAP 2004
The Netherlands	2005	beef	34	12	3	3	9*	3	0	0	-	15	12	12	MARAN 2005
Norway	2005	beef	90	3	0	0	0	0	0	0	10	3	2	3	Zoonoses report 2005
Austria	2003	poultry	34	26	-	0	30*	32	4	0	35	-	38	18	Ramost 2003
Belgium	2005	broiler	148	37	3	7	3	28	-	-	24	37	39	25	Zoonoses report 2005
Denmark	2004	broiler	216	15	0	<1	0*	6	0	0	1	15	9	3	DANMAP 2004
The Netherlands	2005	poultry	115	54	11	8	30*	33	4	12	-	50	47	43	MARAN 2005
Austria	2003	pork	56	16	-	12	4*	4	0	2	54	-	55	12	Ramost 2003
Belgium	2005	pork	86	10	-	7	1	2	-	-	19	15	21	15	Zoonoses report 2005
Denmark	2004	pork	178	15	0	2	0*	2	2	3	13	18	26	10	DANMAP 2004
The Netherlands	2005	pork, organic	155	16	1	6	0*	0	4	38	-	27	38	17	MARAN 2005
Germany	2005	mixed meat	50	2	0	0	0	-	0	0	10	14	12	4	Zoonoses report 2005
Portugal	2005	cheese	33	30	0	3	6	-	36	42	91	-	58	-	Zoonoses report 2005
Non-EU countries															
Canada QC	2003	broiler	112	50	33	18	0*	1	18	11	48	43	57	-	CIPARS 2003
Canada; ON	2003	broiler	136	35	18	5	2*	2	7	9	32	24	51	-	CIPARS 2003
Canada QC	2003	pork	61	20	2	10	0*	0	2	3	28	31	48	-	CIPARS 2003
Canada ON	2003	pork	91	20	2	8	0*	0	1	6	17	30	55	-	CIPARS 2003
Canada QC**	2003	beef	84	7	0	1	1*	1	1	2	2	7	19	-	CIPARS 2003
Canada ON**	2003	beef	100	8	2	2	0*	0	0	2	6	14	23	-	CIPARS 2003

* cut-off of >0.06 i.e. the same as for DANMAP has been used to define resistance for the compilation of this table; ** ON = Ontario, QC = Quebec

Antimicrobial resistance *E. coli*

- Commensal *E. coli* can be a source of resistance genes for human pathogenic strains and cause disease
- Human pathogenic *E. coli* strains resistant to ciprofloxacin and 3rd generation cephalosporins (ESBL's) are associated with the use of antimicrobials similar to ciprofloxacin and ceftriaxone (enrofloxacin and ceftiofur) in food animals and especially poultry
- Exchange of resistance genes occurs
- A substantial proportion of *E. coli* in human intestines is derived from food and water including resistant strains