Common Ground for the Control of Multidrug-Resistant *Salmonella* in Ground Beef

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A strategy to combat multidrug-resistant (MDR) *Salmonella* in ground beef is urgently needed. A national multi-disciplinary meeting reviewed the epidemiology of MDR *Salmonella* infection and contamination in humans, animals, and retail meat. In spite of a recent overall decrease in human MDR *Salmonella* isolates, certain types, such as *Salmonella enterica* serotype Newport multidrug-resistant–AmpC strain and *Salmonella enterica* serotype Typhimurium definitive type (DT) 104, have persisted, and several recent large outbreaks of human infection have occurred. Key agencies that contribute to a safe ground beef supply were represented at the meeting and contributed to the discussion of possible control strategies from the farm to the table. Several of the control strategies suggested are unpopular to some, including restricting the use of antimicrobial agents in food animals, designation of multidrug-resistant *Salmonella* as an adulterant in ground beef, and improving the mechanisms for product trace-back investigations. Nevertheless, enhanced farm-based animal infection control, judicious veterinary and human antibiotic use, regulatory controls, and consumer practices will lead to important industry, veterinary, and public health outcomes.

The clinical syndrome associated with nontyphoidal *Salmonella* infection, called salmonellosis, may include cramps, diarrhea, nausea, vomiting, and fever. Although salmonellosis is usually self-limiting, an estimated 3%–10% of reported laboratory-confirmed cases result in bacteremia; young, elderly, and immunocompromised patients are at particular risk [1, 2]. Recent studies have shown that, compared with patients infected with drug-susceptible *Salmonella* species, patients infected with multidrug-resistant (MDR) *Salmonella* (defined as resistance to >1 antimicrobial agent) are at greater risk of bacteremia, hospitalization, and death [3–6]. Recent outbreaks in the United States have demonstrated that meat products, particularly ground beef, are an important source of MDR *Salmonella*.

**RECENT OUTBREAKS**

Several recent outbreaks of MDR *Salmonella* infection in the United States associated with cattle products or exposure to farms are shown in table 1. Because ∼38 persons are infected with *Salmonella* for each person with a laboratory-confirmed infection in the United States [8], the human health burden of these outbreaks has been marked. Investigations found that infection was associated with consuming ground beef or dairy products and with having direct contact with cattle or cattle environments [9–14]. Two outbreaks warrant further description.

**2002 Outbreak of *Salmonella enterica* serotype Newport infection.** In 2002, forty-seven laboratory-confirmed cases of *S. Newport* were identified in 5 states [9]. Disease was severe in several cases; hospitalization was required for 17 patients (37%), and there was 1 death. Isolates from patients were indistinguishable by PFGE and were MDR, with resistance to amoxicillin-clavulanic acid, ampicillin, cefoxitin, cefetiam, cephalothin, chloramphenicol, streptomycin, sulfamethoxazole, and tetracycline. Some isolates, referred to as *S. Newport* MDR–AmpC, were also resistant to kanamycin and had decreased susceptibility to ceftriaxone [11]. A case-control study comparing exposures of 36 patients with 85 neighborhood-matched control subjects found an association between *S. Newport* MDR–AmpC and the consumption of raw or undercooked ground beef. The United States Department of Agriculture (USDA) was notified. A trace-back investigation was conducted, and the ground beef eaten by patients was deter-

<table>
<thead>
<tr>
<th>Year</th>
<th>State</th>
<th><em>Salmonella enterica</em> serotype</th>
<th>Resistance pattern</th>
<th>Implicated vehicle</th>
<th>No. of laboratory-confirmed cases of infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>California</td>
<td>Newport</td>
<td>ACKSSuT</td>
<td>Ground beef</td>
<td>45</td>
</tr>
<tr>
<td>1985</td>
<td>Illinois</td>
<td>Typhimurium</td>
<td>AKSSuT</td>
<td>Milk</td>
<td>12,624</td>
</tr>
<tr>
<td>1997</td>
<td>Washington</td>
<td>Typhimurium</td>
<td>ACSSuT</td>
<td>Cheese (queso fresco)</td>
<td>54</td>
</tr>
<tr>
<td>1997</td>
<td>Vermont</td>
<td>Typhimurium</td>
<td>ACSSuT</td>
<td>Milk (raw)</td>
<td>9</td>
</tr>
<tr>
<td>1998</td>
<td>Ohio</td>
<td>Typhimurium</td>
<td>AKSSuT</td>
<td>Farm exposure</td>
<td>19</td>
</tr>
<tr>
<td>1999</td>
<td>Massachusetts</td>
<td>Newport</td>
<td>MDR-AmpC</td>
<td>Farm exposure</td>
<td>32</td>
</tr>
<tr>
<td>2000</td>
<td>Pennsylvania, New Jersey</td>
<td>Typhimurium</td>
<td>AKSSuT</td>
<td>Milk</td>
<td>23</td>
</tr>
<tr>
<td>2002</td>
<td>Northeast</td>
<td>Newport</td>
<td>MDR-AmpC</td>
<td>Ground beef</td>
<td>47</td>
</tr>
<tr>
<td>2003</td>
<td>Virginia</td>
<td>Typhimurium</td>
<td>ACSSuT</td>
<td>Beef roast</td>
<td>59</td>
</tr>
<tr>
<td>2003</td>
<td>Wisconsin</td>
<td>Newport</td>
<td>ACSSuT</td>
<td>Ground beef</td>
<td>12</td>
</tr>
<tr>
<td>2003</td>
<td>Alaska (AK)</td>
<td>Typhimurium</td>
<td>ACSSuT</td>
<td>Ground beef</td>
<td>47</td>
</tr>
<tr>
<td>2003–2004</td>
<td>Northeast</td>
<td>Typhimurium</td>
<td>ACSSuT</td>
<td>Ground beef</td>
<td>59</td>
</tr>
</tbody>
</table>

**NOTE.** Adapted from [7] and data from the Centers for Disease Control and Prevention (F. Angulo, unpublished data). A, ampicillin; C, chloramphenicol; K, kanamycin; MDR, multidrug-resistant; MDR-AmpC, ACSSuT plus amoxicillin-clavulanic acid, cephalothin, cefoxitin, ceftiofur, ceftriaxone (reduced susceptibility); S, streptomycin; Su, sulfamethoxazole; T, tetracycline.

mined to have derived from a single slaughterhouse. However, by the time the plant was implicated, the ground beef produced during the outbreak period was not available for testing, and investigators could not identify the affected production lot of ground beef. No ground beef was recalled from the market or consumers’ homes. The USDA issued a public health alert reminding consumers about food safety guidelines, including the need to thoroughly cook ground beef. Despite this action, patients infected with the outbreak strain were identified for months after the initial investigation, suggesting that contaminated ground beef continued to be distributed by the implicated plant. Because previous *S*. Newport MDR-AmpC outbreaks have been associated with dairy products [14] and dairy cattle are an important source of ground beef, this outbreak supports the conclusion that dairy cattle are an important source of human *S*. Newport MDR-AmpC infection.

**2003 Outbreak of *S*. enterica serotype Typhimurium DT104 infection.** In 2003, fifty-nine laboratory-confirmed cases of MDR *S*. Typhimurium definitive type (DT) 104 infection were identified in 9 states [10]. Isolates from patients were indistinguishable by PFGE and were resistant to ampicillin, chloramphenicol, streptomycin, sulfamethoxazole, and tetracycline (R-type ACSSuT). Illness was severe in this outbreak, with 41% of interviewed patients hospitalized for a mean duration of 4.2 days. A case-control study comparing exposures of 27 patients with 71 age- and geographically-matched control subjects found an association between MDR *S*. Typhimurium DT104 infection and the consumption of ground beef. Ground beef was purchased by patients from several grocery stores. A traceback investigation of the ground beef supplied to these grocery stores indicated that the ground beef originated from the same large slaughterhouse implicated in the S. Newport MDR-AmpC infection outbreak described above. As in the previous outbreak, ground beef produced during the outbreak was not available for testing, and investigators were unable to identify the affected lot of ground beef. The USDA again issued a public health alert, but no ground beef was recalled from the market or consumers’ homes. Again, patients infected with the outbreak strain were identified for months after the initial investigation, suggesting that the implicated plant continued to distribute contaminated ground beef.

**REPORT OF A NATIONAL MEETING ON MDR SALMONELLA IN GROUND BEEF**

These outbreaks prompted the organization of a national multi-disciplinary meeting of physicians, public health officials, federal regulatory and health agency officials, industry group representatives, veterinarians, and consumer interest group representatives. The meeting, “Ground Beef Contaminated with Multidrug-resistant *Salmonella*: An Emerging Public Health Concern,” took place in March 2005 and was hosted by Tufts University School of Veterinary Medicine at their campus in Grafton, Massachusetts; financial support was provided by the Council of State and Territorial Epidemiologists (CSTE).

The purpose of the meeting was to review the epidemiology and microbiology of MDR *Salmonella* and discuss potential solutions to mitigate the human health consequences of MDR *Salmonella* infection. The meeting included 5 sessions: Human Health Perspective, Veterinary Perspective, Regulatory Perspective, Consumer Perspective, and Industry Perspective. Each session included presentations from speakers followed by discussion directed by a speaker panel. A full list of speakers and their affiliations appears at the end of this article.
US Epidemiology of MDR Salmonella. Prior to 1996, the Centers for Disease Control and Prevention (CDC) monitored the prevalence of MDR Salmonella infection in humans through studies in selected counties. Since 1996, the prevalence of MDR Salmonella infection has been monitored by the National Antimicrobial Resistance Monitoring System (NARMS) through resistance data obtained from isolates collected from humans, animals, and retail meat sources. NARMS is maintained through joint collaboration of the CDC (isolates from humans), the USDA (isolates from animals), and the US Food and Drug Administration (FDA) (isolates from retail meat).

Human surveillance. In 1979–1980, the prevalence of multidrug resistance in Salmonella isolated from humans was 12% (62 of 511 isolates) [15]. In 1984–1985, the prevalence of multidrug resistance increased to 15% (72 of 485 isolates) [15], and, in 1996, it increased to 31% (404 of 1326 isolates) [16]. Since 1996, however, the prevalence of multidrug resistance in Salmonella has decreased. In 1997, a total of 328 (25%) of 1301 isolates were MDR, and in 2002, a total of 321 (16%) of 2009 isolates were MDR [16]. S. Typhimurium is the most commonly isolated serotype from humans in the United States. The ACSSuT resistance pattern among S. Typhimurium isolates was 0.6% (1 of 162 isolates) in 1979–1980, 5% (7 of 135 isolates) in 1984–1985, 7% (8 of 108 isolates) in 1989–1990, and 19% (31 of 166 isolates) in 1994–1995 [17]. According to more-recent 2002 NARMS data, MDR S. Typhimurium (R-type ACSSuT, AKSSuT [ampicillin, kanamycin, streptomycin, sulfamethoxazole, and tetracycline], or ACKSuT [ampicillin, chloramphenicol, kanamycin, streptomycin, sulfamethoxazole, and tetracycline]) accounts for 98 (25%) of 393 S. Typhimurium isolates [16]. Analogous to multidrug resistance in S. Typhimurium, multidrug resistance in S. Newport has also increased. In 1998, 1 (1%) of 78 S. Newport isolates were S. Newport MDR-AmpC, compared with 53 (22%) of 239 in 2002 [16].

Animal surveillance. In 1997, the USDA conducted the National Animal Health Monitoring System Beef Study, designed to determine the prevalence of antimicrobial-resistant Salmonella shedding by beef cows on cattle farms throughout the United States. Of the 5049 fecal samples collected, 1.4% yielded Salmonella, of which, 13% were drug resistant [18]. In 1999 and 2000, the USDA also conducted the National Animal Health Monitoring System Feedlot Study of cattle in feedlots [20]. Salmonella was isolated from 654 (6%) of 10,714 fecal samples, of which 82 (12%) were MDR [19]. Among all 654 Salmonella isolates, 59 (9%) were S. Newport, of which 58 (98%) with susceptibility data were MDR. Three percent were S. Typhimurium, of which 5 (26%) of 19 were MDR [19].

A USDA analysis of the Salmonella isolated from healthy animals on farms and in slaughterhouses for NARMS in 2000 found that 183 of the Salmonella isolates were S. Newport, of which 146 (80%) were MDR [20]. Although this analysis included isolates from chickens, turkeys, swine, and cattle, 98% of the MDR isolates came from cattle, indicating that cattle may be a more important source of MDR S. Newport than other food animals. Furthermore, the USDA data indicate that the prevalence of resistance to several antimicrobial agents among Salmonella isolated from cattle is increasing. For example, in isolates obtained from cattle intended for slaughter, the prevalence of amoxicillin resistance was 8% in 1997 and 21% in 2003; the prevalence of chloramphenicol resistance was 11% in 1997 and 25% in 2003, and the prevalence of tetracycline resistance 31% in 1997 and 36% in 2003 [21].

Retail meat surveillance. Research studies and FDA NARMS surveillance data consistently show that MDR Salmonella contaminates meat available for retail purchase. A 1999 survey of ground chicken, ground beef, ground turkey, and ground pork in the area of Washington, D.C., found that 20% of meat purchased in grocery stores was contaminated with Salmonella; 82% of strains isolated were MDR [22]. Although only 3 (6%) of 50 ground beef samples were contaminated with Salmonella in this survey, 2 of these 3 samples were contaminated with MDR Salmonella [22]. In 2002, national surveillance found that 9 (1.4%) of 642 ground beef samples obtained from grocery stores were contaminated with Salmonella; 22% of the strains isolated were resistant to ≥9 antimicrobial agents [23]. Therefore, ~0.3% of ground beef purchased in grocery stores in 2002 was contaminated with MDR Salmonella [23].

REGULATORY JURISDICTIONS

Several federal, state, and local agencies are responsible for ensuring a safe ground beef supply. The USDA Food Safety and Inspection Service is responsible for the safety of the meat supply. In 1996, following Escherichia coli O157:H7 infection outbreaks associated with ground beef, the USDA implemented requirements to control microbial threats in meat and poultry products. This system of regulation, called Pathogen Reduction/Hazard Analysis Critical Control Points, introduced product sampling with microbiologic testing to the traditional methods of visual inspections of carcasses.

As part of the Pathogen Reduction/Hazard Analysis Critical Control Points regulation, the USDA set Salmonella performance standards (the maximum proportion of samples that can yield Salmonella) for slaughterhouses and processing plants. Salmonella was selected because it is commonly associated with meat and poultry products and is present in all major species of animal destined for the meat supply. Interventions targeting Salmonella will likely lead to concurrent reduction of other enteric pathogens in raw meat and poultry.

Other agencies that contribute to the safety of the ground beef supply include the USDA Animal Plant Health Inspection Service, which oversees animal health on farms, and the Agricultural Research Service, which conducts food safety re-
search. The FDA Center for Veterinary Medicine licenses antimicrobial agents used in food animals, including beef and dairy cattle. Although all ground beef intended for interstate sale is subject to USDA regulation, individual state food protection agencies have additional authorities to embargo and recall meat when a health threat is determined to be imminent.

**OPPORTUNITIES FOR CONTROL**

Meeting attendees proposed and prioritized activities for the prevention of MDR *Salmonella* infection among humans. These activities range from the farm to the table (table 2) and may yield benefits in addition to human health, such as improvements in animal health and animal production. Several prevention activities are highlighted below.

**On the farm and feedlot.** Currently, at least 17 classes of antimicrobial agents are approved by the FDA for animal growth promotion and production efficiency on US farms, including tetracyclines, penicillins, macrolides, lincomycin (an analog of clindamycin), and virginiamycin (an analog of quinupristin-dalfopristin) [24]. Multiple types of evidence have demonstrated that farm use of antimicrobial agents promotes the emergence and dissemination of resistance genes among *Salmonella* and other enteric bacterial pathogens, such as *Campylobacter* species [25–27].

Public health officials and consumer groups advocate the elimination of the overuse and misuse of antimicrobial agents in food animals. Furthermore, discontinuing the nontherapeutic use (i.e., use for growth promotion and feed efficiency) of agents used in humans (i.e., penicillin, tetracycline, and others) is of paramount importance. The World Health Organization has called for a risk-based evaluation to determine the human health safety from all antimicrobial agents used in food animals and for the discontinuation of the use of agents that have not been shown to be safe [28]. Furthermore, the World Health Organization has judged several antimicrobial agents to be critically important for human medicine (i.e., fluoroquinolones and third-generation cephalosporins) and has called for restricted use of such agents in food animals [29]. The US Institute of Medicine has also called for a reduction of antimicrobial agents used in food animals [24]. In 1998, the European Union implemented a ban on the use of 4 antimicrobial agents used by humans for the purpose of animal growth promotion. Preliminary research shows that this ban is having favorable effects on human health with regard to reducing the community reservoir of certain bacteria, such as vancomycin-resistant enterococci [30, 31].

The FDA modified its process for the evaluation of the safety of human health with regard to antimicrobial agents used in food animals by requiring a qualitative risk assessment prior to giving approval [32]. However, the process of evaluating antimicrobial agents that are already approved may take years [33]. The World Health Organization advises that priority for such evaluations should be given to products considered to be most important in human medicine [28, 29].

**In the slaughterhouse and during production.** Cattle slaughter and ground beef production are commonly centralized in relatively few large facilities. Meat—from hundreds to

<table>
<thead>
<tr>
<th>Table 2. Farm-to-table opportunities for prevention of human multidrug-resistant (MDR) <em>Salmonella</em> infections resulting from contaminated ground beef.</th>
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<tbody>
<tr>
<td><strong>On the farm and feedlot</strong></td>
</tr>
<tr>
<td>Reduce use of antibiotics for agricultural growth promotion and production efficiency</td>
</tr>
<tr>
<td>Reduce veterinary antibiotic use for antibiotics with human treatment indications</td>
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<tr>
<td>Institute animal infection control policies to reduce intraherd clonal strain colonization and interherd clonal strain transfer</td>
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<tr>
<td>Improve animal tracking systems to improve trace-back investigations</td>
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<tr>
<td><strong>In the slaughterhouse and during production</strong></td>
</tr>
<tr>
<td>Sanitize work surfaces</td>
</tr>
<tr>
<td>Modify slaughter techniques to reduce fecal contamination of hides, such as use of acid rinses, chemical dehairing, hide washing cabinets, and steam vacuuming</td>
</tr>
<tr>
<td>Conduct additional <em>Salmonella</em> laboratory testing and antimicrobial susceptibility testing to augment HACCP procedures</td>
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<tr>
<td>Irradiate finished product</td>
</tr>
<tr>
<td>Improved record keeping to aid outbreak strain characterization and lot identification</td>
</tr>
<tr>
<td>Distributors and retailers</td>
</tr>
<tr>
<td>Sanitize work surfaces and grinders</td>
</tr>
<tr>
<td>Improve record keeping to aid outbreak strain characterization and lot identification</td>
</tr>
<tr>
<td>Establish guarantees from suppliers that ground beef is free of MDR <em>Salmonella</em></td>
</tr>
<tr>
<td><strong>Consumers</strong></td>
</tr>
<tr>
<td>Thoroughly wash hands after handling raw or undercooked meat</td>
</tr>
<tr>
<td>Avoid cross contamination through sanitation of cutting boards and other surfaces</td>
</tr>
<tr>
<td>Thoroughly cook ground beef to an internal temperature of $\geq 160^\circ F$ ($71^\circ C$)</td>
</tr>
<tr>
<td><strong>Regulatory agencies</strong></td>
</tr>
<tr>
<td>Notify widely when an outbreak of MDR salmonellosis associated with ground beef occurs</td>
</tr>
<tr>
<td>Designate <em>Salmonella</em> an adulterant when found in the context of human illness</td>
</tr>
<tr>
<td>Improve record keeping to aid outbreak strain characterization and lot identification of USDA collected HACCP-based <em>Salmonella</em> isolates</td>
</tr>
<tr>
<td><strong>Public health authorities</strong></td>
</tr>
<tr>
<td>Ensure timely outbreak investigations</td>
</tr>
<tr>
<td>Standardize surveillance</td>
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<tr>
<td>Increase trace back capacity</td>
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<tr>
<td><strong>Clinicians</strong></td>
</tr>
<tr>
<td>Adhere to IDSA guidelines for management of infectious diarrhea, including microbiologic confirmation for patients with suspect infectious diarrhea</td>
</tr>
<tr>
<td>Advocate for above activities</td>
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</tbody>
</table>

**NOTE.** HACCP, Pathogen Reduction/Hazard Analysis Critical Control Points; IDSA, Infectious Diseases Society of America; USDA, United States Department of Agriculture.
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Salmonella to reduce MDR
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Salmonella. These guarantees should be extended to
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purchased by consumers at grocery stores. Grocery stores and
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In 2001, the Public Health Ac-

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thousands of carcasses—is often comingled to produce each
lot of ground beef. During slaughter, enteric bacteria from the
intestinal contents of even 1 animal infected with MDR Salmonella can be mixed throughout a large batch of the final product, potentially resulting in the contamination of many tons of meat from a single contaminated carcass.

Recent successful industry and regulatory interventions to control E. coli O157:H7 provide a model for the control of MDR Salmonella. Extensive industry-based microbial sampling and testing programs have been enacted, along with additional voluntary steps by the industry to implement process improvements to reduce fecal contamination during slaughter. These slaughter process improvements, aimed at preventing contamina-
tion of beef by E. coli O157:H7, include the use of acid rinses, chemical dehairing, hide washing cabinets, and steam vacuuming [34–37]. Recent data attest to the success of these approaches to control E. coli O157:H7, demonstrating a 42% reduction in illness [38] and a 50% reduction in isolates found in raw ground beef [39]. Concomitant reductions in the presence of Yersinia, Campylobacter, and S. Typhimurium isolates have also been noted.

Irradiation is a well-recognized means of reducing microbial contamination [40] and is approved by the USDA and the FDA for implementation in the ground beef production process. The CDC estimates that 330,000 cases of Salmonella infection, 6000 cases of reactive arthropathy, 4000 hospitalizations, and 140 deaths each year could be prevented if 50% of the meat and poultry consumed in the United States was irradiated [41]. Unfortunately, despite decades of experience showing safety, some groups maintain that irradiation may reduce product taste and nutritional quality or may result in negative human health consequences. Therefore, significant national market penetration has occurred slowly.

Distributors and retailers. Contaminated ground beef in-
volved in recent outbreaks of MDR Salmonella infection was purchased by consumers at grocery stores. Grocery stores and other retailers commonly require quality assurance guarantees from their suppliers. These guarantees should be extended to specify that ground beef provided is free of MDR Salmonella. This would provide important market incentives for producers to reduce MDR Salmonella contamination of their ground beef supply.

Consumers. With the recognition that current production methods do not render ground beef free of microbial contam-
ination, the USDA, the CDC, and many other organizations and agencies have encouraged consumers to eat only ground beef that has been cooked to an internal temperature of \(\geq 160^\circ\text{F} \) (71°C). However, 1%–3% of consumers eat pink ground beef each week [42]; 29% of persons who prepare food report usu-
ally serving undercooked ground beef; and one-third of con-
sumers use unsafe food-handling practices, such as not washing their hands and not taking precautions to prevent cross-con-
tamination in the kitchen [43]. Therefore, although an effective education campaign far beyond the scope of current efforts might be useful, preventing MDR Salmonella infection in hu-
mans clearly requires preconsumer interventions.

Regulatory agencies. E. coli O157:H7 is considered to be an adulterant by USDA regulation, and as such, its presence in the ground beef supply is subject to the highest level of industry, regulatory, and public health monitoring. However, USDA regulations regard enteric bacterial pathogens other than E. coli O157:H7 to be inherent in raw ground beef. Accordingly, MDR Salmonella in ground beef is not considered to be an adulterant, which limits some regulatory actions. In spite of a relatively low prevalence of Salmonella contamination in ground beef and laudable reductions in the overall burden of E. coli O157:H7 in the beef supply, the persistence of and outbreaks associated with S. Newport MDR- AmpC and S. Typhi-
murium DT104 in ground beef mandate novel approaches to regulation. Strong consideration should be given to designating MDR Salmonella as an adulterant, either routinely or in the context of an outbreak of Salmonella infection. In addition, public health alerts that occur in response to an outbreak should include identification of the organism and its MDR status.

Public health authorities. In 2001, the Public Health Ac-
tion Plan to Combat Antimicrobial Resistance [44] proposed steps to control MDR Salmonella contamination and infection, including improvement of national surveillance of antimicro-
bial drug use and resistance, new research, and modification of existing FDA approval of antimicrobial agents used in food animals. Although some of these steps have been implemented, in view of continued pervasiveness of Salmonella and in rec-
ognition of several recent large outbreaks of MDR Salmonella infection, more-urgent action is needed. Mandatory veterinary antimicrobial use reporting, which has been implemented in several European countries, would be particularly useful in in-
terpreting antimicrobial resistance surveillance data and tar-
geting focused interventions.

Currently, all 50 states and US territories have statutes that mandate the reporting of Salmonella infection and the sub-
mission of isolates to public health agencies to identify trends and clusters. PulseNet, the CDC-based national molecular sub-
typing network for foodborne disease surveillance, has im-
proved laboratory methods for detection of clusters of human illness. When paired with epidemiologic investigation, PulseNet provides the critical link necessary to detect large or multi-state outbreaks. However, the utility of this program depends on real-time analysis of patient isolates, case interviews, and linkage of results to provide epidemiological context for clusters of illness detected by PulseNet. Despite its central role in disease surveillance and detection of foodborne bioterrorism, PulseNet functions unequally across the nation. Additionally, the CDC’s
capacity as a reference laboratory and national repository for exchange of PulseNet information must be supported with adequate resources. Certainly, recent investments in state and local public health agencies have helped improve the capacity for epidemiologic investigation, including enteric disease cluster investigation and standardization of disease surveillance [45]; however, the capacity to respond to the findings of an investigation remains elusive.

Trace-back investigations are the cornerstone of public health response when an epidemiologic investigation implicates food, such as ground beef, in an outbreak of MDR salmonellosis. Trace-back investigations serve at least 3 important goals: (1) they increase the specificity of association between product and illness; (2) they determine possible source, mode, and extent of contamination of an implicated product; and (3) they prevent further cases of illness through regulatory action. The USDA, FDA, CDC, and state and local health agency roles vary substantially by jurisdiction, geographic distribution of the product, and product type. There are examples of successful collaborations among agencies that have prevented additional cases of illness and deaths. However, effective trace-back investigations are often hindered by the complexity of product pathways, lack of product package information, standardization of timeframes for investigation, and, in some instances, product patent protections. As demonstrated by the S. Newport and DT104 outbreaks described above, when trace-back investigations cannot be completed or acted on, cases of illness may continue to occur, and public health authorities may be unable to act. In response to some of these concerns, professional organizations advocate for improved trace-back investigational capacity [46–50].

Clinicians. Diarrhea is a common clinical presentation, and it is often treated empirically or symptomatically. However, the lack of specific diagnosis can hinder appropriate management [51]. For example, antibiotic treatment of unrecognized, uncomplicated salmonellosis can prolong the carrier state and lead to a higher relapse rate [51]. Appropriate antibiotic therapy can be life-saving for persons with invasive salmonellosis (e.g., that may occur in immunocompromised patients), but choice of antibiotic is difficult without susceptibility testing of a cultured isolate. In addition, identification of a specific organism, such as MDR Salmonella, permits interventions to protect contacts and identify an outbreak of infection, and subsequently, permits public health action, such as source identification and control. Therefore, according to the Infectious Diseases Society of America, any patient with community-acquired diarrhea lasting ≥1 day, especially if accompanied by fever, bloody stool, systemic illness, recent use of antibiotics, day-care center attendance, hospitalization, or dehydration, should have a stool sample cultured for the presence of Salmonella, Shigella, and Campylobacter species and, in certain circumstances, E. coli O157:H7 and Clostridium difficile [51].

Clinicians should consider advocating activities that may reduce the prevalence of MDR Salmonella, such as prudent clinical antibiotic use, farm-based reduction of antibiotic use, and irradiation of meat. Clinicians also have an immediate responsibility to continue to educate patients regarding proper ground beef cooking and hand washing.

CONCLUSIONS

A national strategy to combat MDR Salmonella contamination in ground beef is urgently needed. Despite the low prevalence of contamination of ground beef by MDR Salmonella, large outbreaks causing significant morbidity continue to occur. Control of MDR Salmonella may be achieved with its designation as an adulterant in ground beef, granting it the same industry and regulatory attention given to E. coli O157:H7. Farm-based animal infection control, judicious veterinary and human antibiotic use, regulatory controls, and consumer practices should complement a producer-oriented approach that will lead to important industry, veterinary, and public health outcomes.

SPEAKERS AT THE “GROUND BEEF CONTAMINATED WITH MULTIDRUG-RESISTANT SALMONELLA: AN EMERGING PUBLIC HEALTH CONCERN” MEETING (GRAFTON, MA)

This list of speakers is provided to demonstrate agency representation, but it does not imply that the persons listed endorse all viewpoints presented in this article.

Helen Aceto (University of Pennsylvania School of Veterinary Medicine, Kennett Square), Sean Altekruse (USDA, Food Safety Inspection Service, Washington, DC), Frederick Angulo (CDC, Atlanta, Georgia), Thomas Chiller (CDC, Atlanta, Georgia), Paula Fedorka Cray (USDA, Agricultural Research Service, Athens, Georgia), David Dargatz (USDA, Animal Plant Health Inspection Service, Fort Collins, Colorado), Amy Dechet (CDC, Atlanta, Georgia), Kathleen F. Gensheimer (Maine Bureau of Health, Augusta, Maine), Barbara Gerzonich (New York State Department of Health, Troy, New York), Giselle C. Hicks (Center for Science in the Public Interest, Washington, DC), Rebecca Irwin (Public Health Agency of Canada, Guelph, Ontario), Margaret Mellon (Union of Concerned Scientists, Washington, DC), Karen Taylor Mitchell (Safe Tables Our Priority, Burlington, Vermont), Dale Morse (New York State Department of Health, Albany, New York), Thomas F. O’Brien (B Brigham and Women’s Hospital and Harvard Medical School, Boston, Massachusetts), Michelle Rossman (National Cattlemen’s Beef Association, Centennial, Colorado), Jeremy Russell (National Meat Association, Oakland, California), David Smith (American Association of Bovine Practitioners, Lincoln, Nebraska),
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