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Outbreaks of *Escherichia coli* O157 infections at multiple county agricultural fairs: a hazard of mixing cattle, concession stands and children

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SUMMARY

Escherichia coli O157 infections cause an estimated 60 deaths and 73 000 illnesses annually in the United States. A marked summer peak in incidence is largely unexplained. We investigated an outbreak of *E. coli* O157 infections at an agricultural fair in Ohio and implicated consumption of beverages made with fairground water and sold by a geographically localized group of vendors who were all on the same branch of the fairground water distribution system. To examine county fair attendance as a risk factor for infection, we conducted two further epidemiological studies. In the first, we enhanced surveillance for *E. coli* O157 infections in 15 Northeast Ohio counties during the 2000 agricultural fair season and showed increased risk of *E. coli* O157 infection among fair attendees. In the second study, we examined Ohio Public Health Laboratory Information Service (PHLIS) data for 1999 using a time-varying covariate proportional hazards model and demonstrated an association between agricultural fairs and *E. coli* O157 infections, by county. Agricultural fair attendance is a risk factor for *E. coli* O157 infection in the United States and may contribute to the summer peak in incidence. Measures are needed to reduce transmission of enteric pathogens at agricultural fairs.

BACKGROUND

Escherichia coli O157 (*E. coli* O157), the most common shiga-toxin-producing *E. coli*, causes an estimated 60 deaths and 73 000 illnesses annually in the United States [1]. Healthy cattle are the main recognized animal reservoir for *E. coli* O157 and may harbour the organism as part of the bowel flora [2]. *E. coli* O157 can enter the food chain directly in beef products or by contamination of other foods or water. Furthermore, direct transmission from live animals and their environment to humans has been increasingly recognized

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[3–11]. County agricultural fairs are popular summertime family events in the United States. In many states, each county holds its own annual fair lasting 5–7 days with ticket sales that may exceed 100 000. Concentrating large numbers of people in an agricultural environment while encouraging them to eat and drink creates the potential for transmission of *E. coli* O157. *E. coli* O157 incidence peaks during the summer months in the United States. The causes of the summer peak in incidence are not well understood.

During the month of August 2000, an unexpectedly large number of isolates of shiga-toxin-producing *E. coli* O157 were submitted to the Ohio Department of Health (ODH) from Medina County and surrounding counties in Northeast Ohio. Officials at ODH and the Medina County Combined General Health District instituted active case finding on 14 August, and by 22 August, 30 cases of laboratory-confirmed *E. coli* O157 infection had been reported in the area. Preliminary reports suggested that illness might be associated with attending an agricultural fair that occurred from 30 July to 6 August, and had tickets sales of 120 222. The fair consisted of show competition, demonstration of agricultural animals and produce, carnival activities, and over 100 vendors of food and drink. It was held on a dedicated fairground. The outbreak provided an opportunity to understand the risk factors for *E. coli* O157 transmission at an agricultural fair, and to examine the importance of agricultural fairs as risk factors for *E. coli* O157 outbreaks and sporadic infections.

METHODS

Case finding and hypothesis generation

On 14 August 2000, state and county public health officials contacted physicians and laboratories in seven counties in the Medina area to inform them of the *E. coli* O157 outbreak, to encourage stool culture of patients with diarrhoea on sorbitol–MacConkey agar media to detect *E. coli* O157, and to ask that they promptly report new cases to ODH. Case finding was expanded to a total of 15 counties (population 3 702 960) in Northeast Ohio on 24 August.

For the purpose of epidemiological investigation, a case was defined as diarrhoea ($\geqslant$3 loose stools in a 24-h period) with onset after 30 July, and a stool culture yielding sorbitol-negative *E. coli* in any person living in the 15 counties area.

To develop hypotheses of possible sources of *E. coli* O157 infections, between 24 and 27 August, we interviewed in person 11 randomly selected patients using the CDC standard foodborne illness hypothesis-generating questionnaire [12].

Laboratory investigation

Human faecal samples were plated to sorbitol–MacConkey agar (SMAC) after immunomagnetic bead enrichment. Soil and surface samples were collected by swab and were placed immediately in Carey–Blair transport medium and were cultured within 48 h of collection on SMAC.

Water samples were collected using 150 ml sterile plastic containers with thiosulphate (IDEXX Laboratories Inc., Westbrook, ME, USA) and were processed with the Colilert Quantitray 2000 system (IDEXX Laboratories). A most probable number table will be used for quantification of *E. coli* and total coliform concentrations. Membrane filtration of water samples was used to detect *E. coli* O157 using standard methods [13]. *E. coli* O157 isolates were confirmed serologically, and tested for toxin production by enzyme immunoassay. Molecular subtyping of all *E. coli* O157 isolates by PFGE was performed at the ODH Laboratory [14, 15].

Case-control study

Based on hypothesis-generating interviews and laboratory data suggesting that the outbreak had occurred among persons who attended the Medina County Fair, we conducted a case-control study of fair attendees to identify specific risk factors for infection. For the purposes of the case-control study, a case was defined as diarrhoea ($\geqslant$3 loose stools in a 24-h period) with onset after 30 July and a stool culture yielding *E. coli* O157.

A questionnaire was developed focusing on foods and beverages consumed and activities undertaken at the Medina County Fair. The questionnaire was administered by telephone during the period 31 August to 8 September. It asked specifically what foods or beverages had been consumed, the date of consumption and the vendor where purchased. The vendor was identified by the interviewer from a map of vendors at the fairground. If the patient or control could not adequately locate the vendor, a map was mailed and the individual contacted again after the map had been received to refine the location. Vendor menus were

compiled to aid in the identification of vendors based on the purchase of particular food items. Exposure to animals and specific animal barns at the fair were enquired about. Patients were also asked about their clinical history. If a patient or control was less than 15 years old, the interview was conducted with the guardian.

Controls were persons who attended the Medina County Fair and who had not had diarrhoea since 30 July. Only one person per household was included. Controls were identified by dialling three sequential digits from case-patient telephone numbers and were frequency-matched by age group (less than 5 years, 5–9 years, 10–14 years, 15–19 years, 20–39 years, and 40 years and above). The goal was to obtain two controls per case.

Household survey

To estimate the attack rate of illness among fair attendees, a household survey was done simultaneously with control selection for the case-control study. Households with at least one person who attended the fair were included and queried about history of diarrhoea and the number of fair visits among all household members. The proportion of persons with diarrhoea among potential controls was calculated as the attack rate. The total number of visits to the fair was determined by ticket sales. This was divided by the average number of fair visits per person to estimate the number of persons who visited the Medina County Fair. Thus, the total estimated number of ill persons was calculated as the product of the total number of visitors and the attack rate among potential controls.

Environmental investigation

The history and layout of the Medina County Fairgrounds' water supply was determined by discussion with municipal authorities and fairground staff. Concession stands were classified into zones based on the branch of the fairground water distribution system that supplied them. The location and repair of recent water pipe breaks was ascertained. Water samples were collected at various targeted sites around the fairground. Pressure and backflow studies were subsequently conducted as part of a comprehensive assessment of the water distribution system. Soil and surface samples were taken from areas implicated by the epidemiological investigation.

Investigation of agricultural fairs as risk factors for *E. coli* O157 infections

Northeast Ohio, 2000

Enhanced surveillance established for case finding during the outbreak provided an opportunity to investigate whether other agricultural fairs in Northeast Ohio were associated with *E. coli* O157 infections. Each patient with *E. coli* O157 infection was interviewed by a county health official and asked about the date of illness onset and whether they had attended an agricultural fair. Patients who became ill within 7 days of visiting an agricultural fair, and who were residents of the same county, were considered to have probable fair-associated infection. All others were considered to have non-fair-associated infections.

To calculate risk, data on fair-associated and non-associated illnesses were enumerated from the four counties that held fairs during the enhanced surveillance period. The number of well fair attendees in each county was calculated by dividing the fair ticket sales by the mean number of visits per person determined from a household survey conducted in Medina County. County populations were extrapolated from 1990 census data. To avoid weighting due to the Medina County Fair outbreak, risk was calculated both including and excluding Medina County data.

Ohio, 1999

To determine if agricultural fairs were associated with increased *E. coli* O157 infections in 1999, we conducted an ecological study to look for a significant increase in *E. coli* O157 cases by county during, and for 7 days following, an agricultural fair using the Public Health Laboratory Information System (PHLIS) data. PHLIS is a nationwide laboratory-based surveillance system. We linked positive *E. coli* O157 culture dates by county of residence in Ohio during 1999 with an index of fair exposure that was defined as the isolation of *E. coli* O157 from a patient's stool during, or for 7 days following, an agricultural fair in the same county. We obtained agricultural fair dates for 1999 by contacting the Ohio Department of Health and Ohio Department of Agriculture.

Statistical analysis

For the Medina County Fair case-control study, statistical analyses were conducted using Epi-Info version 6.04 (CDC, Stone Mountain, GA, USA, July 1996)

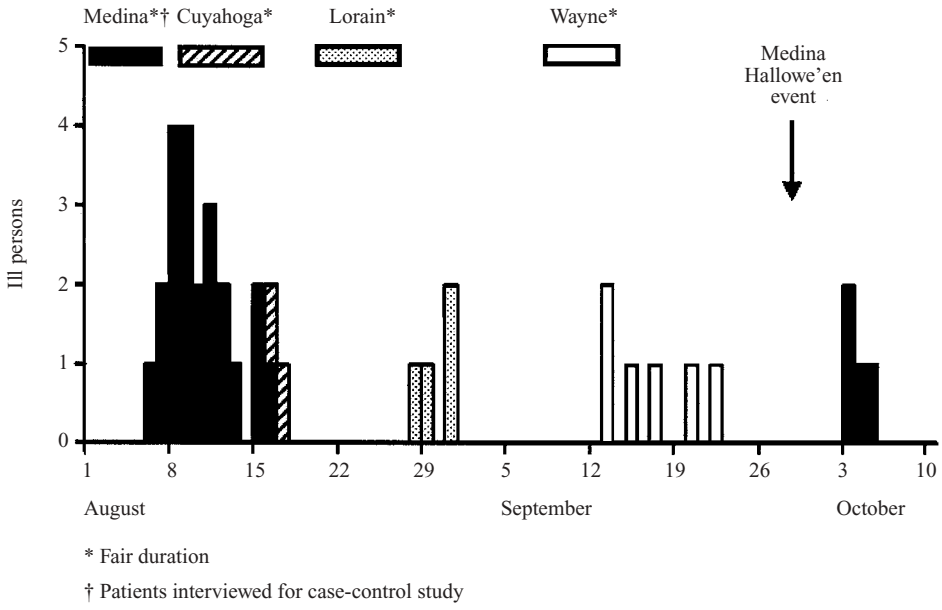

Fig. 1. *E. coli* O157 infections among attendees to four county agricultural fairs, Northeast Ohio, August to September, 2000.

and SAS software version 8.1 (SAS Institute, Cary, NC, USA). Initial analysis was stratified by age group.

Patients were excluded if they were believed to be secondary cases, either on the grounds of having a family member with an onset date of diarrhoea more than 1 day before that of the patient, or considered to be unrelated to the fair because their illness had an onset date more than 7 days after the end of the Medina County Fair. Exposure to concession stand food and beverages was analysed by concession and also by zone to assess risk associated with localized contamination of sections of the fairground water distribution system.

To evaluate a possible association between agricultural fairs and *E. coli* O157 infections in Ohio during 1999, we used a time-varying covariate proportional hazards model.

RESULTS

Case finding and enhanced surveillance

At the time of the case-control study, 44 culture-confirmed cases of *E. coli* O157 infection had been identified in the 15-county area. Of these, 22 (50%) occurred among Medina County Fair attendees from five counties in Northeast Ohio. Of note, an additional four patients with *E. coli* O157 infection were identified from attendees of a Hallowe'en event at the Medina County Fairgrounds 6 weeks after the Medina County Fair and after the case-control study was conducted.

Laboratory investigation

The majority of *E. coli* O157 isolates from patients who attended the Medina County Fair were negative for H7 antigen, but produced both Shiga toxins 1 and 2. PFGE of stool isolates showed that attendees at the Medina County Fair who developed *E. coli* O157 infection were more likely than non-fair attendees to have a particular molecular subtype of *E. coli* O157 (odds ratio undefined, $P<0{\cdot}001$). Of Medina County Fair attendee isolates, 22 of 22 (100%) tested were of the same PFGE pattern (outbreak pattern). Only 5 of 22 isolates from non-fair attendees had the outbreak pattern, and the remaining 17 isolates from non-fair attendees included 13 different PFGE patterns.

Case-control study

At the time of the case-control study, 22 patients met the case definition and all were interviewed. The median age of patients was 5 years (range 10 months to 72 years) and 10 (45%) were female. Dates of illness onset ranged from 6 to 16 August (Fig. 1). Symptoms included bloody diarrhoea (100%), fever (52%), and vomiting (35%). Ten (45%) patients were hospitalized and two (9%) patients developed haemolytic uraemic syndrome (HUS). Both individuals with HUS required dialysis. There were no deaths. Fifty-one frequency-matched controls were obtained. Six case-patients were excluded from subsequent analysis because they met the definition of secondary cases. The remaining 16 case-patients were more likely

than controls to have consumed food or beverage items from a geographically localized group of 11 vendors (Zone A) (OR 4·1, 95% CI 1·3–13·1, $P=0·017$) and specifically to have consumed products containing fairground water (summary: OR 5·3, 95% CI 1·6–18·2, $P=0·008$) within Zone A compared with all other areas. Furthermore, the exposure associated with illness could also be localized in time. Patients were more likely than controls to have attended the fair on 4 August (OR 10·4, 95% CI 2·9–37·6, $P=0·001$) or the final weekend of 4–6 August (OR undefined, 95% CI undefined, $P=0·006$). Many other exposures were examined but were found not to be associated with illness. These included hamburger consumption and exposure to various animal species and animal barns at the fair.

Household survey

In the process of obtaining controls, 1541 telephone calls were made to numbers in Medina County and surrounding counties in proportion to the contribution of cases. Of the calls, 392 resulted in a household being contacted; 113 (29%) reported that a household member had attended the Medina County Fair. Two (1·8%) reported that a household member who attended the fair had experienced diarrhoea since 30 July 2000. Household members attended the fair an average of 1·75 days. Daily ticket sales for the fair were 120 222. Therefore, ticket sales were estimated to represent attendance by 68 698 individuals. If the attack rate for diarrhoea was 1·8% among fair attendees, then it can be estimated that 1237 attendees developed diarrhoea.

Environmental investigation

Water to the Medina County Fairgrounds is supplied from a 12-inch main supply pipe of the Medina City municipal water system. A 6-inch feeding trunk runs into the fairground and to the fairground distribution system. The fairground has been in its present location for more than 100 years and has been supplied by the municipal water system since the 1930s. The distribution system within the fairgrounds was partially renovated in 1996.

Medina City municipal water records showed acceptable chlorine residual levels and negative coliform counts during the months of July and August 2000 in water from the main supply pipe located off the fairground site. A water sample was collected from one location within the fairgrounds near the site of a water burst on 15 August, 3 weeks after the burst and 1 week after the fair ended. The sample was negative for coliforms. Water collected from the storage tank of a recreational vehicle on 14 August 2000, was also negative for coliforms. This tank had been supplied by fair water during the fair period and had not been used since. Seven additional water samples were collected on 19 September, from spigots supplying concessions in Zone A. One of these was positive for coliforms, but negative for *E. coli*. Soil and surface samples collected from the Zone A environment and animal show arena were negative for *E. coli* O157. Several features of the water supply to Zone A were of interest. First, all concessions in Zone A were supplied by the same dead-end branch of the water system that terminated in an animal show arena building and cow-milking demonstration area. Secondly, one spigot in the show arena building supplied two concessions as well as a hose for general use and a ground level dust control sprinkler system for the show arena floor. Another spigot in the show arena building supplied hoses to a cow-milking demonstration area. These hoses were used for cleaning milking equipment and washing down the milking area.

Though this was originally considered to be an isolated contamination event at the agricultural fair, continued water contamination was associated with four cases of *E. coli* O157 infection among children and teenagers attending the Hallowe'en event 6 weeks after the agricultural fair. Four vendors at the Hallowe'en event used the same water line in Zone A. Isolates from four patients had the same PFGE pattern as the earlier agricultural fair outbreak strain, indicating an ongoing source of contamination.

These additional cases prompted an extensive reassessment of the fairground water system by the National Center for Environmental Health, CDC, including excavation to expose underground piping. This assessment revealed several problems with the system. First, hydrants were of a type designed to prevent freezing by allowing drainage of water after use through a riser drain port. Since contaminated water may enter the spigot riser through the riser drain port, such spigots are not suitable for 'potable' water systems. Secondly, during the fair the spigots in the animal barns and food vending areas were not fitted with back-flow prevention devices. Hoses that supplied animal holding areas were often connected to spigots that also supplied food and beverage vendors. This was true for concessions in Zone A,

Table 1. *Rates of* E. coli *O157 infection among agricultural fair attendees* vs. *non-attendees, Northeast Ohio, August and September 2000*

County	Rate among fair attendees* (Ill/fair attending population)	Rate among fair non-attendees* (Ill/non-fair attending population)	Risk ratio	95% CI	*P* value
Medina†, Cuyahoga, Lorain, Wayne	8·2 (25/306 085)	1·0 (19/1 912 139)	8·2	4·5–14·9	<0·001
Cuyahoga, Lorain, Wayne	5·6 (12/237 387)	0·9 (16/1 764 862)	5·6	2·6–11·8	<0·001

* Cases per 100 000.
† Including only Medina County residents.

where the animal show arena and milking demonstration area were also supplied. This may provide opportunities for entry of animal-contaminated water to concessions in low-pressure situations or when valves are incorrectly closed. Thirdly, the water distribution system is complex in layout and history and demonstrated numerous breaks. The supply to Zone A represented a dead end of a single branch, in which water could stand for long periods. It is difficult to maintain adequate free chlorine residual in dead-end sections of water distribution systems. This branch was subsequently found to have an occult underground leak at a water line connection that may have been present for a considerable time. The fairground water distribution system failed pressure tests in multiple places, and back siphoning was demonstrated. Many sites for possible contamination of water from the environment were identified.

Investigation of agricultural fairs as risk factors for *E. coli* O157 infections

Northeast Ohio, 2000

Fair-associated and non-fair-associated *E. coli* O157 infections during the enhanced surveillance period, which included fairs in four counties, are summarized in Table 1. Fair attendees were 8·2 times more likely to develop *E. coli* O157 infection than non-fair attendees if the Medina County population was included (95% CI 4·5–14·9, $P<0·001$). The association remained strong even when the Medina County population was excluded (relative risk 5·6, 95% CI 2·6–11·8, $P<0·001$) (Table 1). Figure 1 shows the dates of the agricultural fairs and associated *E. coli* O157 clusters for each county during the surveillance period. Infections associated with the Medina Hallowe'en event are also indicated.

Infections that occurred among attendees to other agricultural fairs were mostly caused by *E. coli* O157 with PFGE patterns different from that seen among Medina County Fair attendees. Further, these PFGE patterns were unique to the fair attended.

Ohio, 1999

The ecological study showed that throughout the state of Ohio in 1999, the year before the Medina County Fair outbreak, *E. coli* O157 reports significantly increased by county during, and in the 7 days following, a fair in that county (Fig. 2). Specifically, in a proportional hazards model, fair exposure, as a time-varying covariate, showed a significant association with the date of a case of *E. coli* O157 infection. The relative hazard rate for fair exposure was estimated to be 1·7 ($P=0·036$) with an approximate 95% CI of 1·0–2·8.

DISCUSSION

A large outbreak of *E. coli* O157 infections occurred among attendees to an agricultural fair in Ohio. Illness was associated with beverages made with water from a particular part of the fairground water distribution system. Persons who became ill were four times more likely than controls to have consumed food or beverages from one or more of 11 vendors within a geographically defined area of the fairgrounds. The same dead-end branch of the fairground water distribution system supplied the vendors in this area near the animal show arena and the milking demonstration area. This suggests that part of the fairground water system was at least transiently contaminated. Laboratory testing of the municipal water supply did not indicate general water contamination

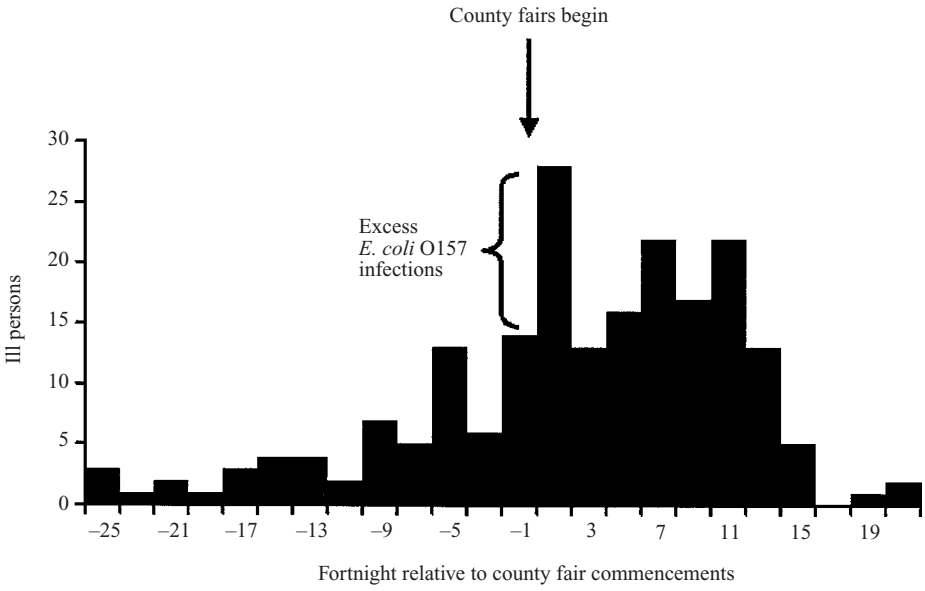

Fig. 2. *E. coli* O157 infections relative to county agricultural fair commencements, Ohio, 1999.

had occurred and testing water from the affected branch weeks later, yielded coliforms but not *E. coli*.

However, further illness among four children attending a Hallowe'en event held at the fairgrounds reinforced the epidemiological findings and led to an extensive assessment of the water distribution system. The system failed pressure tests, exhibited back-flow, and communicated with contaminated environments. These findings are compatible with intermittent contamination at times of use. Based on the findings, the entire water distribution system at the fairground was replaced. The second cluster of cases demonstrates that waterborne outbreaks can occur, even when routine tests for *E. coli* are negative or inconclusive, and that defects in water distribution systems are difficult to detect without intensive evaluation.

Clusters of *E. coli* O157 cases also followed other neighbouring agricultural fairs in 2000, indicating that the Medina County Fair outbreak was not an isolated event. Enhanced surveillance data revealed significantly higher rates of *E. coli* O157 infections in each county among fair attendees compared with non-attendees, confirming agricultural fair attendance as a general risk factor for *E. coli* O157 infection. Clusters were associated with unique PFGE patterns of *E. coli* O157 isolates, suggesting individual specific contamination occurrences at each fair. To address detection and reporting bias that may have occurred during 2000 due to the heightened public awareness of *E. coli* O157 infections associated with agricultural fairs in the region, we examined 1999 surveillance data for *E. coli* O157 using a time-varying covariate proportional hazards model. We found that agricultural fair exposure was significantly associated with the dates of *E. coli* O157 cases, supporting the pattern seen during 2000.

There are several possible explanations for the association between agricultural fairs and *E. coli* O157 transmission. First, agricultural fairs bring large numbers of children, a group at increased risk for severe disease [16], into close contact with the major animal reservoirs of *E. coli* O157 and other enteric pathogens. Direct transmission of *E. coli* O157 from live animals or their environment to humans is an increasingly recognized problem [4, 6, 8] and agricultural fairs provide ample opportunity for such contact. The risk is increased further where hand-washing facilities are of inadequate quality and capacity, as is often the case at agricultural fairs. Secondly, as temporary sites, water distribution systems at fairgrounds may be unregulated, old, and inadequately maintained and configured. The consequences of this are illustrated by the outbreak reported here, and by an outbreak at the Washington County Fair, New York, in 1999 [3]. Thirdly, large numbers of food and beverage vendors use fairground-supplied water and often food can be eaten in animal areas, promoting hand–mouth activity and enhancing transmission from animals and their environment [3].

We conclude that agricultural fairs are likely to represent a significant and previously underappreciated source of the burden of *E. coli* O157

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infections and contribute to the annual peak of cases of *E. coli* O157 infection in the United States during the summer months. Concentrating cattle, concession stands, and children in the presence of the inadequate water distribution systems results in a dangerous confluence of risk and susceptibility that is repeated nationwide every summer. Fairground managers should work with local public health officials to make agricultural fairs safer. Clinical suspicion for *E. coli* O157 infection should be heightened in patients who have recently attended an agricultural fair. Parents should ensure that children take good hygiene measures during such events, including eating or drinking apart from animal areas and after adequate hand washing [17].

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