

ORIGINAL ARTICLE

Multistate Outbreak of Listeriosis Associated with Cantaloupe

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ABSTRACT

BACKGROUND

Although new pathogen–vehicle combinations are increasingly being identified in produce-related disease outbreaks, fresh produce is a rarely recognized vehicle for listeriosis. We investigated a nationwide listeriosis outbreak that occurred in the United States during 2011.

METHODS

We defined an outbreak-related case as a laboratory-confirmed infection with any of five outbreak-related subtypes of *Listeria monocytogenes* isolated during the period from August 1 through October 31, 2011. Multistate epidemiologic, trace-back, and environmental investigations were conducted, and outbreak-related cases were compared with sporadic cases reported previously to the Listeria Initiative, an enhanced surveillance system that routinely collects detailed information about U.S. cases of listeriosis.

RESULTS

We identified 147 outbreak-related cases in 28 states. The majority of patients (127 of 147, 86%) were 60 years of age or older. Seven infections among pregnant women and newborns and one related miscarriage were reported. Of 145 patients for whom information about hospitalization was available, 143 (99%) were hospitalized. Thirty-three of the 147 patients (22%) died. Patients with outbreak-related illness were significantly more likely to have eaten cantaloupe than were patients 60 years of age or older with sporadic illness (odds ratio, 8.5; 95% confidence interval, 1.3 to ∞). Cantaloupe and environmental samples collected during the investigation yielded isolates matching all five outbreak-related subtypes, confirming that whole cantaloupe produced by a single Colorado farm was the outbreak source. Unsanitary conditions identified in the processing facility operated by the farm probably resulted in contamination of cantaloupes with *L. monocytogenes*.

CONCLUSIONS

Raw produce, including cantaloupe, can serve as a vehicle for listeriosis. This outbreak highlights the importance of preventing produce contamination within farm and processing environments.

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LISTERIA MONOCYTOGENES IS AN INFREQUENT cause of bacterial foodborne illness but a leading cause of fatal foodborne infections in the United States, with an overall case fatality rate of 17% among patients with laboratory-confirmed infections.¹⁻³ Older adults, immunocompromised persons, pregnant women, and newborn infants have an increased risk of invasive listeriosis, characterized by bacteremia, meningitis, fetal loss, and death.^{4,5} On average, two or three listeriosis outbreaks are reported to the Centers for Disease Control and Prevention (CDC) annually; reported outbreaks are often associated with unpasteurized dairy products or processed, ready-to-eat meats.⁶ Although fresh produce is an uncommon cause of listeriosis outbreaks, several such outbreaks have been reported, including a multistate outbreak linked to sprouts in 2008 that caused 20 illnesses in seven states.⁷ *L. monocytogenes* typically has a longer incubation period (average, 1 to 3 weeks; range, 3 to 70 days) than other common foodborne pathogens, often complicating patient recall of consumed foods during outbreak investigations.

On September 2, 2011, the Colorado Department of Public Health and Environment (CDPHE) notified the CDC of a listeriosis outbreak first detected on August 29, with seven cases reported during the period from August 29 through August 31; two cases are typically reported each August in Colorado. Pulsed-field gel electrophoresis (PFGE) molecular subtyping revealed three distinct PFGE pattern combinations among the seven isolates obtained from patients. PulseNet, the national molecular subtyping network for foodborne disease surveillance and outbreak detection, identified additional isolates, with indistinguishable PFGE patterns, from patients residing in other states.^{8,9} Further illnesses, attributed to isolates with two additional distinct PFGE patterns, were subsequently linked to the outbreak through food and environmental testing. Isolates displaying any of these five distinct PFGE patterns were grouped to define the *L. monocytogenes* outbreak-related subtypes. In this article, we describe the rapid nationwide investigation that ensued to determine the outbreak source.

METHODS

CASE DEFINITIONS

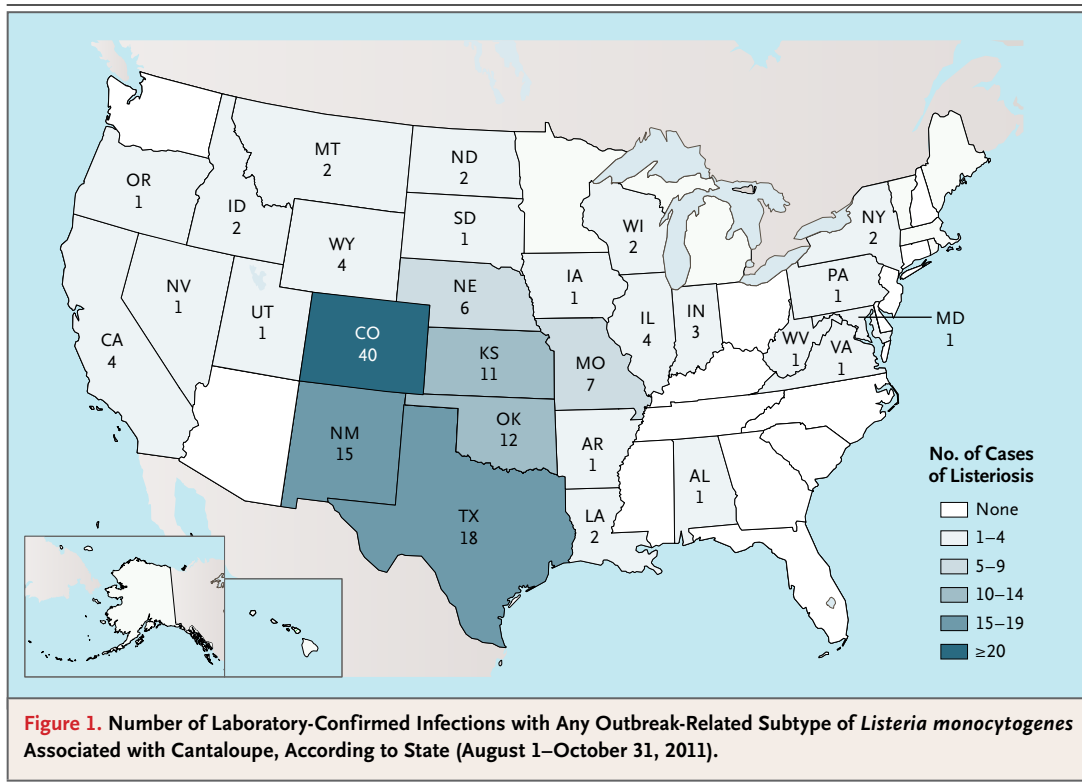
We defined an outbreak-related case as a laboratory-confirmed infection with any outbreak-related

subtype of *L. monocytogenes* cultured from a normally sterile site (e.g., blood or cerebrospinal fluid) during the period from August 1 through October 31, 2011. A pregnancy-associated case was defined as an outbreak-related infection in a pregnant woman or in a newborn (≤ 28 days old at the time of specimen collection). We included all newborns with outbreak-related illness who were born to an infected mother, regardless of the infant's specimen-collection date. State and local public health officials reviewed death certificates and other sources to determine whether deaths among patients with outbreak-related illness were attributable to listeriosis. *L. monocytogenes* isolates from ill patients were forwarded to public health laboratories for two-enzyme PFGE subtyping with the use of a standardized PulseNet protocol.¹⁰

EPIDEMIOLOGIC CASE INVESTIGATION

During this investigation, we used the Listeria Initiative, an enhanced surveillance system that routinely collects detailed information about patients with listeriosis in the United States. The CDC established the Listeria Initiative in 2004 to facilitate rapid generation of hypotheses about food vehicles in investigations of listeriosis clusters and outbreaks.^{11,12} Using the standardized Listeria Initiative questionnaire, we asked patients with suspected outbreak-related illness about their consumption of processed delicatessen-style meats, ready-to-eat salads, seafood, fruit, milk, cheeses, and other dairy products during the month before the onset of illness. Questionnaire data were reviewed to identify common food exposures among patients and to generate hypotheses regarding the likely food vehicle in the outbreak. Because the majority of patients initially interviewed reported having eaten cantaloupe and other types of melons, a supplemental questionnaire was administered to gather details about melon purchases. Underlying medical conditions were ascertained through interviews with patients or chart review with the use of a standardized data-collection form. Data were collected in response to a public health emergency; all interviewed patients or their proxy provided oral consent.

The Listeria Initiative links patient-specific information (e.g., demographic, clinical, and food exposures) to PulseNet molecular subtyping data to facilitate rapid hypothesis testing through



case–case comparison of outbreak-related and sporadic cases.¹² Because of the availability of Listeria Initiative data, we elected to conduct case–case comparisons in lieu of traditional case–control comparisons, which often require resource-intensive and time-intensive efforts to locate suitable controls. Because the majority of outbreak-related illnesses occurred in older adults, we compared the food exposures of patients with outbreak-related illness with those of patients 60 years of age or older with sporadic illness reported to the Listeria Initiative during the period from 2004 through 2010 (i.e., case–case analysis). As interview data became available from patients with newly identified outbreak-related infections, we repeated case–case analyses to reassess associations between foods and outbreak-related illness. For seasonal foods (e.g., fruits), we limited comparisons to sporadic cases reported to the Listeria Initiative with specimens collected during the month of August. We used SAS, version 9.1 (SAS Institute), to calculate odds ratios and 95% confidence intervals.

TRACE-BACK AND ENVIRONMENTAL INVESTIGATIONS
State and local health and regulatory agencies and the Food and Drug Administration (FDA)

conducted trace-back investigations of distribution pathways for retail cantaloupes consumed by patients with outbreak-related infections. FDA and Colorado officials conducted joint inspections of the implicated cantaloupe farm in Colorado to assess harvesting and processing operations. Cantaloupe samples were collected from patients' homes, retail stores, and the growing fields and processing facility operated by the farm for culture-based testing, serotyping, and PFGE subtyping of *L. monocytogenes* isolates; environmental samples were also collected from the fields and processing facility for testing.¹³

RESULTS

OUTBREAK DESCRIPTION

We identified 147 outbreak-related cases in 28 states (Fig. 1). Of the 145 patients for whom hospitalization information was available, 143 (99%) were hospitalized (Table 1); 33 (22%) of the 147 patients with outbreak-related illness died. The majority of patients (127 of 147, 86%) were 60 years of age or older. The median age of adults was 77 years (range, 21 to 96); the median age of those who died was 81 years (range, 48 to 96). Seven pregnancy-associated infections were re-

ported among four pregnant women and three neonates, including coincident infection in one mother–neonate pair with a neonatal specimen collected in early November. One miscarriage was reported. Of the patients reporting race or ethnic group, 89% (119 of 134) were white, and 15% (19 of 129) were Hispanic. Eighty-five patients (58%) were female. The majority of illnesses (96 of 147, 65%) occurred in five adjoining states: Colorado (40 illnesses), Texas (18), New Mexico (15), Oklahoma (12), and Kansas (11). Dates of illness onset ranged from July 31 through October 27, 2011 (Fig. 2).

EPIDEMIOLOGIC CASE INVESTIGATION

Patients with outbreak-related illness who were interviewed early in the investigation frequently reported having consumed cantaloupe, ice cream, delicatessen-style ham, and watermelon during the month preceding illness. To evaluate the significance of these food exposures, on September 9, a case–case comparison was performed with 11 outbreak-related cases and sporadic listeriosis cases previously reported to the Listeria Initiative (Table 2). Patients with outbreak-related illness were significantly more likely to have eaten cantaloupe than were patients 60 years of age or older with sporadic listeriosis (odds ratio, 8.5; 95% confidence interval, 1.3 to ∞). Subsequent comparisons using interview data collected later in the investigation further supported the association between outbreak-related illness and cantaloupe consumption; associations with ham and watermelon consumption were not significant. Because patients reported having eaten different types and brands of ice cream, it was deemed an unlikely outbreak source, and a comparison for ice cream consumption was not performed. Of the patients with outbreak-related illness for whom data were available, 93% (134 of 144) reported having consumed cantaloupe during the month before illness onset; ice cream, ham, and watermelon consumption was reported by 64% (73 of 114 patients), 46% (58 of 127), and 68% (86 of 126), respectively.

Of 118 patients who described their melon purchases, 113 (96%) reported having purchased cantaloupe primarily from major grocery-store chains; 86 of these patients (76%) had purchased whole, uncut cantaloupe. Of 20 patients who recalled the cantaloupe brand, 16 (80%) reported consuming regionally branded cantaloupe varieties grown exclusively in Colorado, here-

Table 1. Demographic and Laboratory Characteristics of 147 Patients with Outbreak-Related *Listeria monocytogenes* Infections Associated with Cantaloupe.*

Characteristic	Value
Median age (range) — yr	
All patients	77 (<1–96)
Pregnant women	29 (21–38)
Men and nonpregnant women	78 (40–96)
Race — no./total no. (%)†	
White	119/134 (89)
Black	8/134 (6)
Asian	3/134 (2)
Other	4/134 (3)
Hispanic ethnic background — no./total no. (%)†	19/129 (15)
Pregnancy-associated cases — no. (%)‡	
Total	7 (5)
Pregnant women	4 (3)
Newborns	3 (2)
Mother–neonate pair	1
Miscarriage — no.	1
Female sex — no. (%)	85 (58)
Hospitalization — no./total no. (%)	143/145 (99)
Died — no. (%)§	33 (22)
Age group at death — no. (%)	
<60 yr	2 (1)
60–69 yr	4 (3)
70–79 yr	7 (5)
80–89 yr	14 (10)
≥90 yr	6 (4)
Median age at death (range) — yr	81 (48–96)
Residence in long-term care facility — no./total no. (%)¶	8/127 (6)
<i>L. monocytogenes</i> culture site — no. (%)	
Blood	124 (84)
Cerebrospinal fluid	7 (5)
Amniotic fluid	1 (<1)
Ocular fluid	1 (<1)
Pericardial fluid	1 (<1)
Pleural fluid	1 (<1)
Synovial fluid	1 (<1)
>1 site	9 (6)
Site not specified	2 (1)

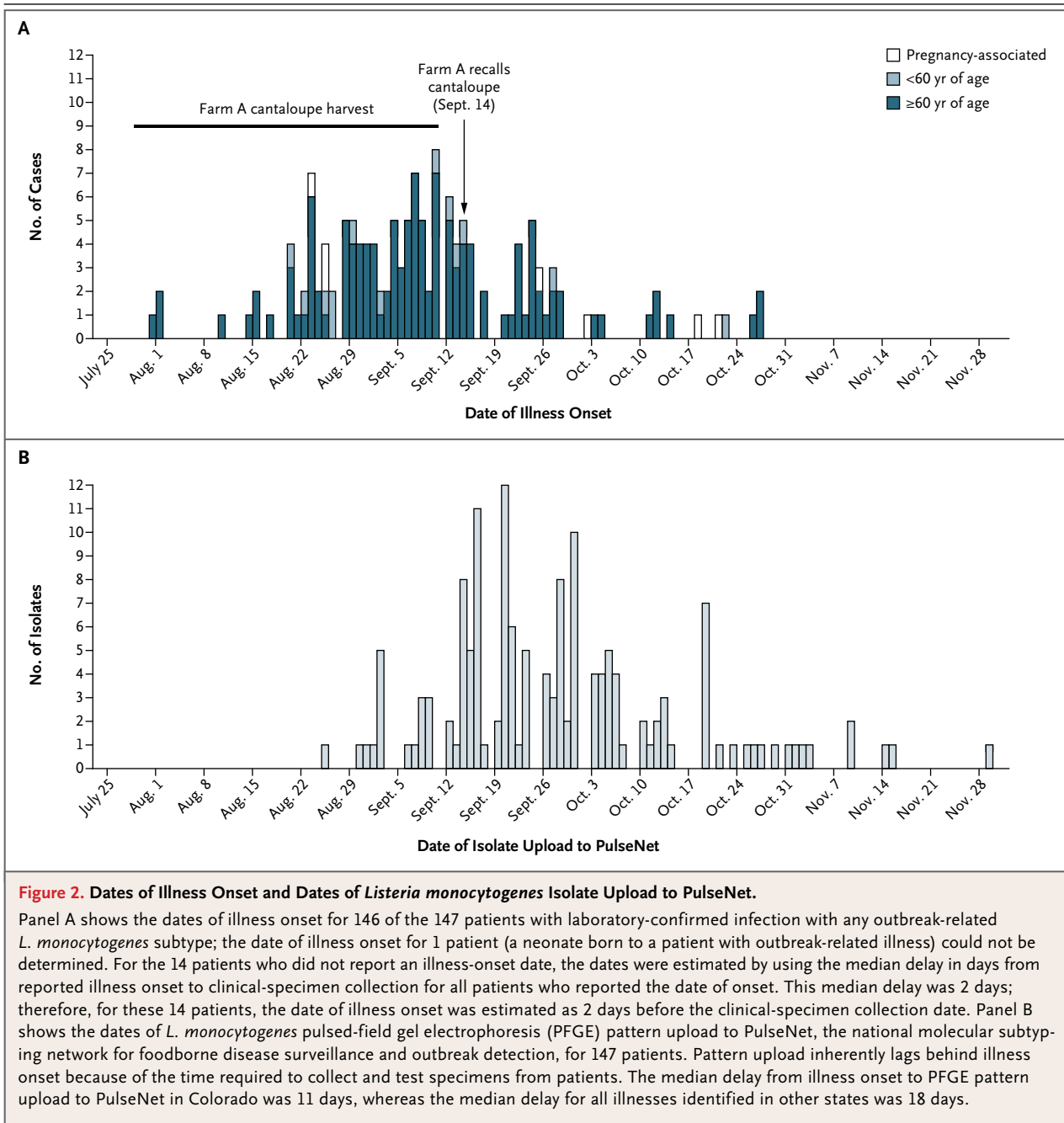
* The completeness of questionnaire responses varied among patients; therefore, the total number of respondents varies among the characteristics assessed.

† Race and ethnic background were self-reported.

‡ A pregnancy-associated case was defined as illness in a pregnant woman or in a newborn (≤28 days of age).

§ State and local public health officials reviewed death certificates and other sources to determine whether deaths among patients with outbreak-related illness were attributable to listeriosis. The single miscarriage is not included as an outbreak-related death.

¶ Residence in a long-term care facility was defined as residence in a nursing home or other long-term care facility during the 4 weeks preceding illness.



after referred to as Region A cantaloupe. The majority of patients reported multiple cantaloupe exposures or could not recall actual dates of cantaloupe consumption, which precluded calculation of incubation periods.

Among the 123 patients for whom information on underlying medical conditions was available, hypertension was the most common condition, followed by heart disease, cancer, diabetes, and kidney disease; 108 patients (88%) had one

or more potentially immunosuppressive conditions or were receiving immunosuppressive therapy (Table S1 in the Supplementary Appendix, available with the full text of this article at NEJM.org).

TRACE-BACK AND ENVIRONMENTAL INVESTIGATIONS

The trace-back investigation to determine the origin of cantaloupes purchased by Colorado patients was impeded by the considerable number

Table 2. Consumption of Specific Foods among Patients with Outbreak-Related Listeriosis as Compared with Patients with Sporadic Listeriosis Previously Reported to the Listeria Initiative.*

Food Consumed	Outbreak Cases <i>no. exposed/total no. (%)</i>	Sporadic Cases† <i>no. exposed/total no. (%)</i>	Odds Ratio (95% CI)
Sept. 9			
Delicatessen-style ham	7/11 (64)	360/774 (47)	2.0 (0.5–9.4)
Watermelon	5/10 (50)	49/82 (60)	0.7 (0.1–3.2)
Cantaloupe	11/11 (100)	54/85 (64)	8.5 (1.3–∞)
Sept. 12			
Cantaloupe	13/13 (100)	54/85 (64)	10.1 (1.6–∞)
Sept. 14			
Cantaloupe	19/19 (100)	54/85 (64)	14.9 (2.4–∞)

* Because the fourth and fifth pulsed-field gel electrophoresis (PFGE) patterns were not linked to the outbreak until after September 14, 2011, analyses were limited to patients infected with *Listeria monocytogenes* outbreak-related subtypes indistinguishable from PFGE patterns 1, 2, and 3. Since the Centers for Disease Control and Prevention established the Listeria Initiative in 2004, the proportion of U.S. jurisdictions participating in and reporting to it has increased each year. In 2011, a total of 621 listeriosis cases were reported to the Listeria Initiative from 47 states, representing 67% of all U.S. listeriosis cases reported through the National Notifiable Disease Surveillance System, which collects and compiles reports of nationally notifiable infectious diseases, and 69% of all human clinical *L. monocytogenes* isolates reported to PulseNet, the national molecular subtyping network for foodborne disease surveillance and outbreak detection. CI denotes confidence interval.

† All sporadic cases used for comparison with outbreak-related cases occurred in nonpregnant patients 60 years of age or older and were reported to the Listeria Initiative during the 2004–2010 period. For comparisons of watermelon and cantaloupe consumption between the two groups of cases, we selected sporadic cases for which specimens had been collected in August, since consumption of these foods is predominantly seasonal. For comparisons of delicatessen-style ham, which is not a seasonal product, selection of sporadic cases was not limited to those with a specimen-collection date in August.

of stores where patients had shopped, multiple and sometimes uncertain purchase dates, and frequent lack of knowledge of the brand of cantaloupe purchased. However, Region A cantaloupes are common in Colorado markets during the yearly harvest (July through September), and trace-back investigation confirmed Region A cantaloupe availability in all stores where initial Colorado patients reported having purchased cantaloupe. Collectively, the significant association between cantaloupe consumption and outbreak-related illness, patients' specific mention of Region A cantaloupe, preliminary trace-back information, and the availability of Region A cantaloupes in Colorado retail markets during the period when patients became ill led to an investigative focus on Colorado-grown cantaloupe as the outbreak source.

On September 10, 2011, the CDPHE and FDA conducted a joint inspection of Farm A, the only Colorado grower still engaged in seasonal harvest and packing operations for melons marketed as Region A cantaloupe. At the Farm A processing facility, whole cantaloupes were washed, sorted, boxed, and refrigerated before shipment.

In previous years, Farm A had used a recirculating, chlorinated, chilled-water wash to clean and precool cantaloupes. In 2011, the farm substituted a nonrecirculating wash method using municipal water, without supplemental chlorine, and a series of brush and felt rollers to mechanically clean and dry cantaloupes. To implement this process change, in July 2011, Farm A installed washing and drying equipment that had been used previously in a packing operation for another raw agricultural commodity.

Of 39 environmental swabs collected from food-contact or adjacent surfaces in the Farm A processing facility, 12 swabs (31%) yielded *L. monocytogenes* isolates with PFGE patterns that were indistinguishable from three outbreak-related subtypes, confirming the farm as the source of contaminated cantaloupes; all 12 swabs were collected from within or immediately downstream of the newly installed equipment (Table 3). Ten samples from market-ready whole cantaloupes were also collected from the Farm A coolers for testing; five (50%) yielded an outbreak-related subtype of *L. monocytogenes*. Of 18 Farm A cantaloupes collected from Colorado stores in

Table 3. Serotypes and Number of Illnesses, Deaths, Cantaloupe Samples, and Environmental Swabs Yielding Outbreak-Related *Listeria monocytogenes* Isolate Subtypes, According to PFGE Pattern.

PFGE Pattern No.	PulseNet Pattern Name*		Serotype	Illnesses (N=147)	Deaths (N=33)	Source of Cantaloupe Samples†			Environmental Swabs from Processing Facility‡
	Ascl Restriction Enzyme	Apal Restriction Enzyme				Farm A Cooler§	Retail Location	Patient's Home	
				no. (%)¶		no. of samples			no.
1	GX6A16.0029	GX6A12.0069	1/2a	48 (33)	12 (36)	0	3	2	0
2	GX6A16.0019	GX6A12.0227	1/2b	40 (27)	10 (30)	4	16	4	10
3	GX6A16.0099	GX6A12.0001	1/2a	28 (19)	3 (9)	0	2	1	1
4	GX6A16.0001	GX6A12.0001	1/2a	30 (20)	7 (21)	1	2	2	1
5	GX6A16.1471	GX6A12.2154	1/2b	1 (<1)	1 (3)	0	0	1	0

* In the United States, all *L. monocytogenes* isolates are routinely subtyped by means of PFGE with the use of *Ascl* and *Apal* restriction endonucleases, according to a standard protocol. The resulting PFGE patterns are then uploaded into PulseNet, the national molecular subtyping network for foodborne disease surveillance and outbreak detection, and assigned a PulseNet pattern name to facilitate identification of other, related patterns in the database.

† Data were available for a total of 31 cantaloupe samples tested for at least one outbreak-related subtype of *L. monocytogenes* by state health departments in Colorado and New Mexico, the Centers for Disease Control and Prevention, and the Food and Drug Administration. For some cantaloupe samples tested by state health departments in Colorado and New Mexico, multiple *L. monocytogenes* culture isolates were selected for PFGE subtyping. Two cantaloupe samples collected at retail locations and three samples collected from patients' homes yielded multiple isolates matching different outbreak patterns. All PFGE data from these samples are displayed. Thus, for cantaloupe samples with more than one outbreak-related subtype on PFGE, data have been entered in multiple table cells. Cantaloupe samples from some patients' homes lacked the product labeling necessary to confirm production by Farm A.

‡ A total of 13 of 39 environmental swabs (33%) taken from the cantaloupe-processing facility at Farm A yielded an isolate of *L. monocytogenes*; PFGE showed that 12 of these isolates matched outbreak-related subtypes. A single isolate yielded a PFGE pattern distinct from outbreak-related patterns 1 through 5; no illnesses attributable to isolates matching this PFGE pattern were reported in PulseNet, and this pattern was not included as part of the outbreak.

§ These samples were obtained from a storage cooler at the Farm A facility where processed, boxed cantaloupes were stored on pallets before shipment.

¶ A single *L. monocytogenes* culture isolate was selected for PFGE subtyping from specimens collected from each patient; therefore, coinfections with multiple *L. monocytogenes* outbreak-related subtypes, if present, were undetected.

early September, 17 (94%) yielded an outbreak-related subtype of *L. monocytogenes*. Whole and cut cantaloupes from the homes of several patients also yielded one or more *L. monocytogenes* outbreak-related subtypes. Cantaloupe samples from some patients' homes lacked the product labeling necessary for confirming production by Farm A. Cantaloupe samples collected from the farm's processing facility, retail stores, and patients' homes yielded isolates matching all five outbreak-related subtypes and included two serotypes, 1/2a and 1/2b.¹⁴ Farm A directly distributed cantaloupes to 24 states, including Colorado; there was no evidence of foreign distribution.

To investigate the source of cantaloupe contamination, FDA and Colorado officials conducted an environmental assessment at Farm A on September 22 and 23, 2011. No substantial deficiencies in growing practices were identified, and listeria was not detected in environmental or cantaloupe samples from production

fields. However, evaluation of processing operations identified possible contributors to *L. monocytogenes* contamination and amplification, including inadequate facility and equipment design, which precluded effective cleaning and sanitization of cantaloupe-contact and adjacent surfaces, and a lack of cantaloupe precooling.¹⁵ Possible routes for *L. monocytogenes* introduction were also identified, including a truck kept adjacent to the processing line and used to haul culled melons to a cattle operation, low-level contamination of incoming cantaloupe, and pre-existing contamination of the aforementioned equipment.

CONTROL MEASURES

On September 9, 2011, the CDPHE issued the first consumer warning, advising persons at increased risk for listeriosis not to eat cantaloupe.¹⁶ Additional health alerts subsequently issued by states, the CDC, and the FDA first warned con-

sumers at increased risk not to eat Region A cantaloupe and later advised all consumers to avoid Farm A cantaloupe specifically. On September 10, Farm A voluntarily halted cantaloupe harvesting and processing operations and ceased further cantaloupe distribution; the farm issued a voluntary recall of all whole cantaloupes on September 14.

DISCUSSION

This was a large U.S. listeriosis outbreak, with 147 illnesses and 33 deaths reported among residents of 28 states. Consumption of cantaloupe was significantly associated with illness; investigative findings confirmed that whole cantaloupe produced by a single Colorado farm was the outbreak source. Although severe listeriosis illnesses are likely to be confirmed by culture and reported, additional outbreak-related illnesses probably occurred but were unidentified.¹

Outbreaks of foodborne illness associated with fresh produce, including cantaloupe, are increasingly being reported, and new pathogen-vehicle combinations have been identified in contemporary produce-related outbreaks.¹⁷⁻¹⁹ It is notable that this listeriosis outbreak was associated with whole produce. Previous studies have linked sporadic listeriosis with consumption of precut melons at commercial establishments,²⁰ and a 2010 listeriosis outbreak in Australia was caused by contaminated honeydew and cantaloupe used in a commercially prepared fruit salad.²¹ Of 28 cantaloupe-related disease outbreaks reported to the CDC during the period from 1973 through 2003, a total of 21 (75%) were linked to commercially prepared, precut cantaloupe. Eleven of the 28 outbreaks (39%) were caused by salmonella, 7 (25%) by norovirus, and 1 each by *Campylobacter jejuni* and *Escherichia coli* O157:H7 (4%); none were caused by *L. monocytogenes*.¹⁸ Eight outbreaks (29%) had an undetermined cause.

Cantaloupe preparation (i.e., washing and cutting) affects the level and growth of rind bacterial contaminants. To reduce pathogen numbers, the FDA recommends that before melons are cut, they be scrubbed with a clean produce brush during washing and then dried with a clean cloth.²² However, these steps are unlikely to remove all pathogens that might be present on the rind, making primary contamination

prevention within farm and processing environments critical for consumer safety. When a cantaloupe is cut, pathogens contaminating the rind surface can be transferred to the pulp.²³ After inoculation, cantaloupe pulp is a suitable substrate for survival and growth of *L. monocytogenes*, even under refrigeration.²⁴

Some studies have shown greater bacterial contamination among melons that have been processed after harvesting than among field-fresh melons,^{25,26} and the findings of our investigation indicate that cantaloupe contamination most likely occurred during processing operations conducted by Farm A. The recent introduction of equipment to accommodate changes in cantaloupe washing and drying processes probably created environmental conditions that promoted cantaloupe contamination and the subsequent outbreak. This equipment was not designed for cantaloupe or for easy cleaning and sanitizing. These factors probably promoted pathogen colonization and growth on equipment components that were in contact with cantaloupes (e.g., brush and felt rollers), which may have inoculated the cantaloupes and spread *L. monocytogenes* to other food-contact surfaces. Results of environmental testing support this hypothesis; only samples obtained within or immediately beyond the newly installed equipment yielded *L. monocytogenes*. Niche sites for *L. monocytogenes* harborage, such as processing equipment, are recognized as primary contamination sources in food-processing settings and can result in dispersion of organisms onto foods and other surfaces within processing environments.^{27,28} The occurrence of polyclonal *L. monocytogenes* outbreak-related subtypes indicates multiple niche sites, extensive and multiple contamination sources, or repeated *L. monocytogenes* introductions within the processing facility that might have promoted progressive cantaloupe contamination. In addition, the failure to sanitize and precool cantaloupes, combined with residual rind moisture after washing and inadequate air circulation during cold storage, might have promoted amplification of the *L. monocytogenes* present on the rind surface. Laboratory data in this investigation support postprocessing *L. monocytogenes* amplification on cantaloupes during storage and distribution; nearly all Farm A cantaloupes collected at Colorado stores yielded *L. monocytogenes*, a proportion substantially

exceeding that among cantaloupes collected from the Farm A processing facility.

The proportion of pregnancy-associated cases reported in this outbreak (5%) was relatively low. Pregnancy-associated infections have accounted for a larger percentage of cases (12 to 66%) in other domestic listeriosis outbreaks,⁵ and 17% of cases reported to the Listeria Initiative have occurred among pregnant women and newborns.²⁹ Possible explanations for the low proportion of pregnancy-associated infections reported in this outbreak include differences in cantaloupe consumption and handling practices between pregnant and nonpregnant persons, differences in dose–response relationships between pregnant women and other groups at increased risk, and differences in maternal–fetal virulence among strains causing outbreaks. Although multiple *L. monocytogenes* lineage-specific and strain-specific characteristics affecting virulence have been recognized, the way in which these characteristics might influence virulence expression among persons with listeriosis remains unclear.^{30–32}

This investigation demonstrated the usefulness of the Listeria Initiative and the efficiency of the case–case approach for outbreak investigations. The Listeria Initiative facilitated rapid case–case comparisons, which quickly confirmed the association between the outbreak-related illnesses and cantaloupe consumption, prompting the initial farm visit and same-day halt of cantaloupe production 12 days after recognition of the outbreak in Colorado. Case–case analyses have been used successfully in previous listeriosis outbreak investigations.^{12,28,33} Although such analyses can be an efficient alternative to traditional case–control studies, the approach has limitations. Case–case analyses using historical data sources (e.g., the Listeria Initiative) rely on the scope of existing data-collection tools (e.g., questionnaires), which cannot detect new exposures. The case–case approach also precludes assessment of the general underlying risk of illness, because the study design inherently controls for underlying risk factors.³⁴ Despite these limitations, use of the Listeria Initiative data to perform case–case analyses, combined with the rapid outbreak investigation in Colorado, allowed for early public notice and prompt recall of cantaloupes.

This outbreak confirms the viability of raw produce, including cantaloupe, as a vehicle for listeriosis and highlights the importance of preventing produce contamination within farm and processing environments. To prevent similar outbreaks in the future, fresh-produce processors should consistently use good agricultural and manufacturing practices to minimize opportunities for foodborne-pathogen introduction and food-product contamination.^{35,36} Enhanced oversight of the growers and processors of cantaloupe and other produce, through either industry initiatives or traditional regulatory means, should also be considered as a means of forestalling future outbreaks. In addition, growers and processors of fresh produce should thoroughly evaluate existing processes, as well as proposed processing changes before implementation, to facilitate recognition and mitigation of potential contamination sources for foods. To aid future investigations of listeriosis and other foodborne illnesses, routine data-collection methods supporting enhanced surveillance for foodborne pathogens should be considered.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or institutions with which the authors are affiliated.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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