Salad and Pseudoappendicitis: *Yersinia pseudotuberculosis* as a Foodborne Pathogen

Robert V. Tauxe
Foodborne and Diarrheal Diseases Branch, Division of Bacterial and Mycotic Diseases, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia

(See the article by Nuorti et al., on pages 766–74.)

The next time you take a fork-full of meat or rice or peas, ponder for a moment the environment with which you are about to become intimate.

D. Waltner-Toews, 1992 [1]

Another foodborne pathogen appears on the scene. A report by Nuorti et al. at the Finnish National Public Health Institute, in this issue of *The Journal of Infectious Diseases*, provides solid documentation that *Yersinia pseudotuberculosis* can be transmitted through food [2]. Although this rare and enigmatic organism was first identified in 1883, its sources have remained obscure [3]. Clusters have been reported to occur without evidence of secondary spread among persons, indicating that an environmental source is likely. By virtue of its similarity to *Y. enterocolitica*, it has been presumed to be a possible foodborne pathogen, but the evidence for this assumption has been limited to a few suggestive clusters and to a large Canadian outbreak in 1998 that has been epidemiologically linked to pasteurized milk [4, 5]. In that outbreak, the origin of the presumed contamination was not clarified. The Finnish investigation is the first to link an outbreak of human illness to a likely environmental reservoir via contaminated food.

The outbreak was detected because routine surveillance was conducted for laboratory-diagnosed infections and because clinical isolates from a broad region were subtyped in a public health laboratory. Once the outbreak was recognized, the investigators used classic epidemiologic methods to link the large outbreak to locally grown lettuce. Although the harvest had been completed and lettuces were no longer available for culture, the investigators returned to the field the following year and succeeded in isolating several strains of *Y. pseudotuberculosis* from lettuce, soil, and irrigation water, indicating both the source and environmental persistence at the same time. An animal reservoir (hares or deer) was suspected, but this reservoir is, as yet, unconfirmed [6].

Such speculation is well justified. Though it is relatively rare in humans, infection with *Y. pseudotuberculosis* is a recurrent problem in animals. *Y. pseudotuberculosis* likely has several zoonotic reservoirs around the world. The organism causes a fatal plague-like illness in the guinea pig [7] and significant epidemic illness in the European brown hare [8]. It causes enteric illness in domesticated sheep [9] and has been problematic enough among farmed deer to lead to the development of a vaccine for those animals in New Zealand [10]. In addition, the organism has been isolated from the feces of healthy swine and from a variety of other mammals and birds in Eurasia [11, 12]. Thus, it would not be unexpected to find this organism in the deer or hares that inhabit the areas near the fields where the implicated lettuce was grown.

This natural history may provide a glimpse into the evolutionary origins of another major pathogen, *Y. pestis*, which is exceedingly close to *Y. pseudotuberculosis* genetically. The 2 pathogens are so closely related that Achtman et al. [13] recently proposed that *Y. pestis* diverged clonally from a progenitor *Y. pseudotuberculosis* strain within only the last 20,000 years, basing this hypothesis on multilocus sequence typing. Acquisition of 2 plasmids by *Y. pseudotuberculosis* may have permitted the new variant to circulate via the flea, as well as via the fecal-oral route [3].

This outbreak also illustrates the im-
portance of transmission via fresh produce, a route that is becoming part of the dynamics of transmission of a growing variety of pathogens. In general, fresh produce is increasingly recognized as a source of foodborne infections [14]. Produce can be contaminated at many points from the field to the kitchen, but some of the largest outbreaks have occurred as a result of contamination that occurred early in the production process. In the early 1990s, outbreaks of salmonellosis in the Midwest were associated with tomatoes from South Carolina that may have been contaminated during a washing step immediately after harvest [15]. Outbreaks of Escherichia coli O157:H7 infections on the East Coast and in the Midwest were associated with lettuce grown in California that may have been contaminated while in the field or during harvest [16]. In 1996 and 1997, outbreaks of cyclosporiasis across North America were associated with imported raspberries that were probably contaminated while they were still in the field [17]. In 1998, 8 outbreaks of shigellosis and E. coli infection were traced to parsley from 1 farm in Mexico that used nonpotable water to wash and chill the produce [18]. In northern Europe, imported lettuce has caused large multistate outbreaks of shigellosis [19] and salmonellosis [20].

As the mechanisms of contamination of lettuce are explored, it is important to remember that the relationship between produce and pathogen can be more complex than mere surface contamination. Under some circumstances, pathogens can invade the fruit or leaves of plants, where they cannot be washed off. Lettuce plants irrigated with water contaminated with E. coli O157:H7 can take up the bacteria through their roots, and the bacteria can subsequently appear throughout the plant, including within the edible leaves [21]. Salmonellae can be similarly taken up by tomato plants [22]. E. coli O157:H7 can easily invade the core of apples through the calyx if they are immersed in contaminated water [23]. Salmonellae can enter warm tomatoes that are plunged into cold, contaminated water [24]. These observations suggest that some simple experiments with lettuce and Yersinia species could better define the potential for deep-tissue contamination with that pathogen-food combination. We should not be surprised at the idea that bacteria we know as human pathogens have a secret life in plants. After all, Burkholderia cepacia was first described as a pathogen of young onions [25], and Serratia marcescens has recently been established as the cause of yellow vine disease, an invasive infection of melons and squash [26].

The consumer can do little to prevent fresh produce–associated infections. Fresh produce is often eaten without having been cooked, so there is no final protective step to kill the pathogen in the kitchen. Washing dirt from the surface is prudent, but even washing with soap or using chlorine dips reduces the level of surface contamination by only 1–2 logs at best [27]. Prevention lies in reducing the likelihood of contamination from the field onward and in disinfection technologies, such as irradiation. In the case of the lettuce implicated in the Finnish study, it will be helpful to study the behavior of Y. pseudotuberculosis in the lettuce plant and to define whether deer, rabbits, or other animals are the specific reservoir. Prevention may ultimately involve fenc诸侯 and animal population control or vaccination, as well as the use of disinfected water in washing or processing. This outbreak reminds us how far the sources of illness extend beyond the clinic and hospital. The microbial world links the immediate illness in a patient to events over the horizon. To prevent such infections, we must first understand the pathogen's transmission, as well as their natural history, well enough to prevent it.

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