Outbreak of Brucellosis at a United States Pork Packing Plant

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In 1992, the North Carolina Department of Environment, Health, and Natural Resources received 18 case reports of brucellosis from a county health department. All patients had potential exposure to the kill floor of one pork processing plant. A subsequent National Institute for Occupational Safety and Health health hazard evaluation surveyed 154 (99%) of 156 kill floor workers of this plant and found that 30 (19%) had evidence of recent (or persistent) brucellosis. These data show that significant exposure to Brucella *is occurring among packing plant workers in North Carolina and suggest that some of the approximately 38,000 production workers in pork processing plants in the United States are at risk of contracting swine brucellosis. Additional measures may need to be taken to prevent occupational exposure to* Brucella.

Brucellosis (also termed undulant, Mediterranean, or Malta fever) is caused by bacteria of the genus *Brucella. Brucella* species known to cause human disease (and their usual reservoir hosts) are *B. abortus* (cattle), *B. melitensis* (goats and sheep), *B. suis* (swine), and *B. canis* (dogs). In the United States, human brucellosis is a reportable disease in every state except Nevada. The number of reported brucellosis cases in the United States peaked in 1947 at over 6300 cases[1]; in 1992, 105 cases were reported.[2] It has been estimated, however, that only approximately 50% of cases are recognized and reported.[3] Currently, a large percentage of reported cases in the United States are associated with ingestion of unpasteurized dairy products; these are usually *B. melitensis* infections associated with ingestion of products from the Mediterranean countries and Mexico.[1] Occupational transmission of brucellosis occurs primarily among packing plant workers, veterinarians, livestock producers, and laboratory workers. In this report we describe an evaluation of an outbreak of brucellosis among employees of a pork slaughter and processing plant (packing plant).

Among packing plant workers, transmission of brucellosis may occur during slaughter from infected swine to workers through breaks in the workers' skin, inhalation of aerosols, conjunctival contact, and ingestion. Person-to-person transmission is extremely rare.[4] The symptoms of brucellosis are nonspecific and can include fever, chills, sweats, headaches, myalgia, arthralgia, anorexia,

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undue fatigue, and weight loss. The disease is treatable with antibiotics,* but even with treatment fatigability may persist for a month or more and be accompanied by pronounced disability. Relapsing illness occurs in approximately 2–10% of patients treated with recommended antibiotic regimens.[5] Persons who have fully recovered from brucellosis have resistance to reinfection; the protection provided by prior infection has been found to be approximately 90%.[6] Subclinical *Brucella* infection is known to occur; the ratio of subclinical to clinical infection has been reported to vary from 1:1 to 12:1.[7]

A definitive diagnosis of brucellosis is made by isolation of the causative organism in culture of blood or bone marrow, but brucellosis is more commonly diagnosed serologically using the standard tube agglutination test (STA), sometimes combined with the 2-mercaptoethanol (2-ME) test.[8–11] In a person with a clinical presentation compatible with brucellosis, a serologic diagnosis is made by a fourfold rise in STA titer (over a several-week period) or by the presence of a single serum titer of 160 or greater.[10,11] The 2-ME test can be used in addition to the STA as evidence of active (or recently treated) infection.[12,13]

Background

In 1991, the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR) received four case reports of brucellosis occurring among the employees of a swine packing plant. In 1992, NC DEHNR received 18 case reports of brucellosis among employees of the same plant. For these 18, onset of illness ranged from November 1991 to September 1992. All 18 patients had serologic tests and symptoms consistent with brucellosis, and 11 (61%) had *Brucella suis* isolated from blood at the time of illness. Two (11%) of the 18 patients were hospitalized for their illness, and many reported recurrent symptoms after receiving treatment. All patients worked on the kill floor of the plant. Through November 1993, an additional nine cases were reported. In the spring of 1993, the National Institute for Occupational Safety and Health (NIOSH) received requests from plant employees and from NC DEHNR for assistance in evaluating the occupational transmission of brucellosis at this plant.

Workplace Description

The plant has a work force of approximately 900 and is designed to process approximately 8000 "prime" hogs (4–5 months old, 180–280 pounds) per day; the plant does not purchase swine known to be brucellosis-exposed or brucellosis-infected. The plant is similar in size to another local swine packing plant, and the slaughter process is similar to that described in the literature.[15] The kill floor, where the swine are slaughtered and initial processing takes place, is staffed by employees of seven departments. Transfer of employees between departments is unusual. The kill floor is a 20,000-ft^2 area in a larger building that also includes the cut floor. The kill and cut floors are separated by a wall and have separate ventilation systems. They are directly connected only by a large freezer, and because of cross-contamination concerns, workers are discouraged from traveling between the two areas.

USDA Swine Brucellosis Program

In 1961, a unified national program to eradicate brucellosis from the nation's swine herds was begun. Under a cooperative United States Department of Agriculture (USDA)-state program,** in which all states participate, surveillance and procedures necessary for locating infected herds, controlling infected and exposed swine, and eliminating infected swine are established.[16] In addition, specific provisions exist to designate entire states or individual swine herds as brucellosis-free. As of December 31, 1993, 34 swine herds nationwide were under quarantine for brucellosis in seven states (FL, GA, HI, OK, SC, TN, TX). This means that these animals can only be moved to slaughter under permit issued by USDA. In general, packing plants that receive brucellosis-infected swine do not employ special precautions to prevent occupational exposure to the infected swine, potentially placing workers at risk of infection with *Brucella*.

Methods

Epidemiologic and Clinical Investigation

Our evaluation was conducted as part of the NIOSH health hazard evaluation program. Because all reported cases of brucellosis at the plant had occurred among kill floor employees, and because of the physical and operational separation of the kill floor from other areas of the plant, the medical evaluation was limited to kill floor workers. All kill floor workers were asked to participate, with informed consent, in a questionnaire and serologic survey. Additional case-finding was done by reviewing brucellosis cases reported to the Centers for Disease Control and Prevention National Electronic Telecommunication Surveillance System (CDC NETSS) between January 1991 and December 1993.

The questionnaire administered to employees included questions on medical and occupational history, including current work practices. Employee blood samples were drawn,

* The current World Health Organization recommendation for treatment of brucellosis is a 6-week course of doxycycline (100 mg every 12 hours orally) and rifampin (15 mg/kg per day [maximum of 600 mg] in a single morning dose).[14]

** Cooperative USDA Animal and Plant Health Inspection Service-State Animal Health Swine Brucellosis Eradication Program.

centrifuged, and split so that two identical samples were obtained from each employee. The first set of samples was analyzed by a commercial laboratory using the STA test. All samples with a titer of ≥40 were subsequently sent to a university-affiliated laboratory (Infectious Diseases Research and Teaching Institute of Houston, Houston, TX) under contract to NIOSH for this study for analysis by both STA and 2-ME methods. The STA was performed using saline diluent, and the 2-ME test was performed using saline diluent containing 0.05 M 2-ME.[12] All samples were routinely diluted to at least 1:640; the titer reported is the dilution of serum in the last tube showing at least 50% agglutination. In order to monitor the precision of the analysis both laboratories received triplicates of seven serum samples labeled as if from different workers.

Case Definition. For the purpose of this study, a case of brucellosis was defined by an STA titer of ≥160 and either (1) two or more symptoms consistent with brucellosis (fever, chills, sweats, headache, weakness, malaise, anorexia, weight loss, or myalgia/arthralgia), or (2) a positive 2-ME test (2-ME titer ≥20).

Industrial Hygiene Investigation

The industrial hygiene evaluation consisted of (1) observation of work practices including the use of personal protective equipment, (2) categorization of processing activities based on the potential for aerosol generation and employee contact to swine tissue and body fluids, (3) evaluation of the ventilation systems and air flow directions, (4) evaluation of plant sanitation activities, and (5) review of safety and health training efforts, including personal protective equipment policies.

Statistical Analysis

A multivariable logistic regression model was constructed to relate important predictor variables to the brucellosis case definition. The modeling strategy began with testing potential risk factors individually for a relationship with the case definition using univariate logistic regression. Only those risk factors showing an association with the brucellosis case definition were considered as candidates for the final model. A multivariable logistic regression model was fit using the candidate variables identified by the univariate analyses. The importance of each variable in the multivariable model was then verified. Variables found to be unimportant were removed sequentially from the model, weakest first, until an essential subset of risk factors remained. Interactions among variables in the essential set of risk factors were then checked individually for statistical significance.

TABLE 1
Characteristics of Kill Floor Employees, North Carolina Pork Packing Plant, 1993

	Cases (n = 30)	Non-Cases (n = 124)
Median age (years)	39.5	37.5
Median years employed	13.5	12.9
% Non-white*	83†	68
% Female	20	23

* Of the 154 employees tested, the racial make-up was as follows: 96 (62%) black; 45 (29%) white; 11 (7%) Hispanic; 2 (1%) Native American.
† P = .03.

Results

Epidemiologic Investigation

One hundred and fifty-four (99%) of 156 kill floor employees participated in the study (Table 1). Of the 154 participants, 95 had STA titers of ≥40 from the first laboratory (Laboratory A); these 95 samples were sent to the university-affiliated laboratory (Laboratory B) for 2-ME (and repeat STA) testing. Because of the poor reproducibility present in the results from Laboratory A, the results from Laboratory B were used in performing all data analyses. All 59 samples that were not analyzed at Laboratory B (samples with STA titer from Laboratory A of ≤20) were assigned STA and 2-ME results of <20 (negative) for all data analyses.

Table 2 presents the STA and 2-ME test results for all employees. One hundred five employees (68%) reported experiencing two or more symptoms consistent with brucellosis during the previous year. Thirty workers (19%) met our case definition for brucellosis. Sixteen (53%) of the 30 represented previously unrecognized cases. The head (33%), pet food (33%), and red offal (25%) departments had the highest percentage of employees identified as cases (Table 3). The racial make-up of the departments was similar among departments with the highest prevalence of brucellosis (Table 3). The most common symptoms among cases were chills, fever, headache, and myalgia/arthralgia (Table 4).

Evaluation of potential risk factors among study participants using multivariable logistic regression revealed that being non-white (odds ratio (OR) = 3.7; 95% confidence interval (CI) = 1.1–12), a history of ever being cut or scratched while working (OR = 14.4; CI = 1.2–177), and a history of not washing hands (with soap) prior to breaks (OR = 26.7; CI = 1.9–382) were all associated with meeting the case definition (Table 5). There was no statistically significant association in prevalence rates among employees by number of years employed at the plant or age. Other potential risk factors (a list of potential risk factors evaluated is presented in Table 6) and factors potentially causing false-positive STA tests (such as exposure to the causative organisms of cholera, tularemia, and yersiniosis) were not found to be associated with meeting the case definition.

A review of brucellosis cases reported to CDC from January 1, 1991, through December 31, 1993, revealed that 11 persons who had at one time worked on the kill floor of

TABLE 2
Serology Results* for Kill Floor Employees, North Carolina Pork Packing Plant, 1993

STA Titer	No. of Employees (%)	2-ME Titer	No. of Employees (%)†
≥640	10 (6)	≥640	8 (5)
320	12 (8)	320	5 (3)
160	8 (5)	160	7 (5)
80	6 (4)	80	7 (5)
40	5 (3)	40	5 (3)
20	1 (1)	20	1 (1)
<20	112 (73)	<20	121 (79)
Total	154		154

* 95 employees had STA titers of ≥40 on initial testing and were submitted for 2-ME and repeat STA testing. The 2-ME test results of the remaining 59 employees were presumed to be negative (<20).
† % of total 154 subjects, rounded to nearest whole number.

TABLE 4
Symptom Rates Among the 30 Employees Meeting Brucellosis Case Definition, North Carolina Pork Packing Plant, 1993

Symptom	No. of Employees (%*)
Chills	21 (70)
Fever	21 (70)
Headache	20 (67)
Myalgia/arthralgia	20 (67)
Weakness	18 (60)
Sweats	18 (60)
Malaise	18 (60)
Loss of appetite	16 (53)
Weight loss	15 (53)

* Number with symptoms (two or more)/ number of cases (30) ×100%.

TABLE 3
North Carolina Pork Packing Plant, 1993

Department	No. of Employees	% Non-white Employees	No. of Cases* (%†)
Head	21	71	7 (33)
Pet food	3	67	1 (33)
Red offal	16	75	4 (25)
Kill-mezzanine	37	70	7 (19)
White offal	32	78	6 (19)
Kill-other	11	82	2 (17)
Kill-scale	7	86	1 (14)
Maintenance	8	13	1 (13)
Kill-machine	12	75	1 (8)
Kill-bleed	4	100	0 (0)
Supervisors	3	33	0 (0)
Total	154	71	30

* Case is defined by STA ≥160 and either (1) two or more symptoms consistent with brucellosis or (2) a positive 2-ME test.
† Number of cases/number of employees × 100%.

the plant, but who were not employed at the plant during the week of our survey, had been reported as having brucellosis. In addition, six persons with brucellosis reported to CDC since 1991 were included in our evaluation but did not meet our case definition. These six cases were all reported in 1991 or 1992. For these six persons, STA titers at the time of our survey ranged from <20 to 80, 2-ME titers ranged from <20 to 80, and all reported two or more symptoms.

Industrial Hygiene Investigation

Employees in all areas of the kill floor had considerable potential for skin and conjunctival contact with fresh hog tissue or body fluids. Many of the employees performing eviscerating and trimming operations were in constant contact with hog tissue and body fluids. Although use of mandatory personal protective equipment—consisting of hardhats, metal mesh gloves (for workers using knives), hearing protection, arm guards, and safety shoes—was widespread, only a few workers were observed wearing the optional face shields and rubber gloves (face shields are required at a station where power saws are used).

Potential exposure to aerosols of tissue or body fluids was more limited. The primary area where aerosols may be generated is the "splitter" station, where power saws are used to split the carcasses in half. Two employees perform this task full-time, although other employees work in close proximity. The employee who performs the bleeding operation is potentially exposed to aerosolized blood, although skin (and possibly conjunctival) contact with blood occurs continuously. Evaluation of the ventilation system revealed that the kill floor was operating under negative pressure with respect to the outdoors and the cut division. The most likely pathway for air to be exhausted from much of the kill floor was via pass-throughs into the mezzanine roof ventilators.

Comment

To complete the evaluation at this plant, investigators distributed educational material concerning swine brucellosis to management and kill floor employees, notified participants of their individual results by mail, and held one-on-one meetings to supplement the mail notifications. Information about swine brucellosis was also sent to local physicians. Because identification and eradication of the disease in swine is considered the primary means of prevention,[15,16] it was recommended that

TABLE 5
Results of Multivariable Modeling for Case Definition, North Carolina Pork Packing Plant, 1993

Risk factor*	Odds Ratio	95% Confidence Interval	P
Non-white	3.7	(1.1, 12)	.03
Cut/scratched while working	14.4	(1.2, 177)	.04
Not washing hands (with soap) prior to breaks	26.7	(1.9, 382)	.02

* There was no evidence of interactions between these risk factors.

TABLE 6
Variables Evaluated as Potential Risk Factors for the Occupational Transmission of Brucellosis Among Packing Plant Employees, North Carolina Pork Packing Plant, 1993

Nonoccupational	Occupational
Gender	Cuts/scratches*
Age	Not wearing gloves
Race*	Not washing hands (with soap) prior to breaks*
Education	Not wearing eye/face cover
Hunting wild animals	Having fluid splash in face
Raise/handle swine	Working in head department
Raise/handle cattle	Working in kill-mezzanine department
	Length of time employed in department
	Length of time employed at plant

* Statistically significant.

the plant process only brucellosis-free swine. Recommendations were also provided to management and employees concerning periodic medical surveillance of employees, maintaining the kill floor under negative pressure with respect to the cut division, ongoing education of employees and management, and personal protective equipment use to reduce skin and conjunctival contact with potentially infectious tissue.

Although frequently recommended,[6,17–19] there is only limited evidence supporting the effectiveness of personal protective equipment in preventing the occupational transmission of brucellosis among packing plant workers.[20] Appropriate use of skin and eye protection should decrease employee exposure to potentially infectious tissue; however, further assessment of personal protective equipment use in packing plants is needed.

Airborne transmission of brucellosis in occupational settings has been demonstrated in several studies,[21–23] in part by comparing the case distributions within a plant with the workers' potential for inhalation of potentially infectious aerosols and potential for skin and conjunctival contact. In this outbreak, the workers in the kill-mezzanine department have the greatest potential for exposure to aerosols, both from production of aerosols by power saws, and from the design of the ventilation system (which appears to exhaust a portion of the kill floor air through the units in the roof of the mezzanine area). Comparison of the prevalence of cases among the mezzanine employees with that of the other employees (Table 3), however, does not support inhalation as the primary source of exposure. We found high rates of infection among workers who had a high level of contact with lymph tissue (head department) and liver (red offal department), both tissues in which *Brucella* organisms are known to concentrate. Therefore it appears that skin (and possibly conjunctival) contact with infectious tissue or body fluids has been the primary route of exposure in the outbreak occurring at this plant.

Our investigation did not detect all those who may have been infected with *Brucella* as a result of working at this pork packing plant. The one-time serologic testing we performed will not detect recently infected employees who had not yet mounted an immune response. In addition, employees who may have had brucellosis in the past, with subsequent serologic normalization or clinical recovery, would not necessarily be detected by our case definition.

Since 1991, there have been 17 cases of brucellosis reported to the CDC among workers exposed to the kill floor of this pork processing plant who were not included in our total of 30 cases. At the time of our study 11 of these persons were no longer employed at the plant and consequently were not evaluated by us; six were employed and included in our evaluation. The fact that these six did not meet our case definition is most likely due to falling titers after treatment.

The results of our evaluation suggest that brucellosis remains an underdiagnosed disease, even in a situation in which the index of suspicion was presumably high. Of the 30 employees who met our case definition for brucellosis, 16 (53%) represented newly identified cases. Our evaluation supports the conclusion that screening a population at risk of brucellosis increases the detection rate[9] and that ongoing surveillance of such populations is warranted.

Because of the relatively small number of cases upon which our statistical analyses are based, it is difficult to use the absolute numerical values of the odds ratio to "rank" potential risk factors in order of importance. Rather, our statistical analyses are useful to help differentiate characteristics, activities, or work practices that are potential risk factors for *Brucella* infection among packing plant workers. A history of being cut or scratched while working was identified as a risk factor for becoming infected. This agrees with other evidence suggesting that skin contact is a primary route of infection in this outbreak and is consistent with the notion that intact skin provides protection against infection.[1] We found that not washing hands prior to work breaks was related to an increased risk of infection. From our data we cannot tell whether it is the employees' use of soap that was important or rather just the act of washing. We also found that non-white employees were at a higher risk of infection than white employees. Race was evaluated as non-white versus white because one previous evaluation of a brucellosis outbreak had identified non-white employees as being at greater risk of brucellosis.[19] We evaluated whether race may have been acting as a surrogate for another potential risk factor (such as age, job titles or duties, or time on the job), and found that it was not. The reasons for the apparent race differences should be pursued further.

On March 17, 1994, the USDA Animal and Plant Health Inspection Service (APHIS) amended the brucellosis regulations (9 CFR, Parts 51 and 78) in order to provide for payment at fair market value for whole herds of swine depopulated because of brucellosis (regulations in effect prior to March 17, 1994 only allowed indemnity payments at set rates for breeding swine). When undertaking whole herd depopulation, herd owners, where it is possible, will be required to dispose of the swine through means other than slaughter (eg, through burial, incineration, rendering, etc). This action was necessary to eliminate in an expeditious manner all swine herds known to be affected with brucellosis and to eliminate the human health risk associated with swine brucellosis.

In addition, the new USDA APHIS regulation states that brucellosis-exposed swine from a herd known to be affected with brucellosis may be moved interstate from the herd only if such swine are individually identified with an ear tag. This identification will facilitate monitoring the movements of such swine and will alert packing plants to the arrival of such swine.

Based on the results of our evaluation, we are unable at this time to determine the specific swine or swine herd(s) that were the source of this outbreak. The USDA APHIS is currently conducting a traceback of the swine received at the packing plant from January 1, 1992, through April 1, 1993, to identify sources of infected swine. Although the incubation period of brucellosis is variable, the occurrence of multiple cases over a several-year time period suggests multiple sources of infection rather than a single source. No similar outbreaks of swine brucellosis at other processing plants have been reported to the CDC in this time period, and review of the CDC NETSS data did not reveal clusters potentially associated with packing plant exposures. It remains unclear why an outbreak would occur at only one plant and not at other pork processing plants.

In order to prevent brucellosis among pork packing plant employees in the future, hogs that are sent for processing must be free of *Brucella* infection. Until the time when brucellosis is eradicated from swine sent for processing, increased education among employees, supervisors, and health care providers, prompt medical evaluations for symptomatic employees, and use of appropriate personal protective equipment can lessen the impact of the disease. Further active surveillance for swine brucellosis among employees of pork processing plants in the United States is needed to help determine the extent of this problem nationally.

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Dumping on the Swedes

Air pollution, it is often assumed, was a modern invention, first practiced on a large scale by the dark satanic mills of the industrial revolution. But in this, as in so much else, Western civilization is indebted to the ancient Greeks and Romans. New evidence dredged from the depths of Swedish lakes suggests that while the Swedes were still thinking about making the switch to iron tools, their pristine lakes were being contaminated by lead wafting in on the wind from the smelters of southern Europe. The Romans were the prime culprits: they used lead to make water pipes and cooking utensils and, in some cases at least, to slowly poison themselves.

Environmental scientist Ingemar Renberg of the University of Umeå measured lead levels in sediment cores taken from 19 Swedish lakes. He found that the lead concentration had remained steady at about 10 parts per million for thousands of years after the lakes were first created by retreating glaciers about 10,000 years ago (the depth of the sediment layer in a core indicates its age and that of the lead that fell out of the atmosphere onto the lake). But around 2600 years ago the lead levels in the sediments began to rise slowly. That is when the Greeks began minting silver coins, which required them first to extract silver from ores that also contained lead. In the process they inevitably released some lead into the atmosphere. The contamination of Swedish lakes reached its ancient peak under the Romans, who were notorious for their use of lead piping. At the height of their empire they produced about 80,000 tons of lead per year from mines throughout south and central Europe. Some five percent of that lead would have been lost into the atmosphere during smelting, and some of that airborne lead apparently ended up in Sweden. Renberg found that the lead concentration in the Swedish sediments reached a peak of 20 to 30 parts per million—two to three times its pristine level—about 2000 years ago when Augustus was Caesar.

Although lead pollution caused health problems among Romans (as early as the first century B.C. the great architect Vitruvius warned that lead fumes destroyed the "vigor of the blood"), the amount reaching Sweden would not have been harmful. And as the empire declined, so did the contamination of Swedish lakes. By A.D. 1000, though, lead levels began to rise again. The Germans had started mining silver, and as Renberg notes, "there were a lot of wars. They needed a lot of lead." By 1800, at the dawn of the industrial revolution, the lead concentration in the Swedish lakes had reached 50 to 100 parts per million. By 1970 it was as high as 500 ppm in some lakes. Yet the remarkable thing to Renberg is that, on the whole, as much lead was dropped on Sweden before industrialization as after. "Air pollution isn't anything new, really," he says. "We've had it for a long time." We have, however, gotten better at it.

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