Financial Effect of *Mycobacterium paratuberculosis* in a Dairy Herd: Influence on Mastitis, Milk Production and Cull Rate in Clinically Normal Cows

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Abstract

A 210 cow Holstein dairy herd contained approximately 45 cows that were *Mycobacterium paratuberculosis*-positive on the basis of fecal culture during a one year study. Farm management participated in the NY State Paratuberculosis Eradication Program. Paratuberculosis-positive cows were grouped separately from negative cows, but they were otherwise managed identically. During the year of the study, 180 paratuberculosis-negative cows and 113 clinically normal paratuberculosis-positive cows were identified. From paratuberculosis-negative cows, 6,100 quarter milk samples were aseptically collected for microbiologic culture of mastitis pathogens, and 3,129 quarter samples were obtained from paratuberculosis-positive cows. Dairy Herd Improvement Association (DHIA) records were kept for milk somatic cell count Linear Scores (LS), mature equivalent (ME) milk production new mastitis infections and chronic mastitis infections. Beginning in second lactation, and increasing with advancing parity, paratubculosis-positive cows had lower ME milk production than did negative herdmates. However, rates of new and chronic mastitis infections, as measured by DHIA LS were significantly ($P < 0.05$, $P = 0.05$, respectively) lower in cows with nonclinical paratuberculosis. Infected cows were culled from the herd at a faster rate than were negative herdmates. Overall, paratuberculosis was associated with economic benefit due to lower rates of mastitis in positive cows, but a net financial loss resulted because of reduced milk production and increased culling rates.

Introduction

Bovine paratuberculosis (Johne's disease) prevalence estimates range from 2 to 18% based upon slaughter surveys.[1,2] Only 5 to 10% of infected animals in a herd exhibit clinical signs of paratuberculosis, including diarrhea, progressive emaciation, and death. Nevertheless, costs of paratuberculosis include early culling of infected cattle, decreased slaughter value, and decrease milk production in dairy cows.[2-4] Evaluation of losses associated with subclinical paratuberculosis has been limited by insensitivity of tests (poor detection of true-positive animals), few herd testing programs, and culling of infected cattle from tested herds. Therefore, total cost of paratuberculosis is difficult to determine. Costs attributable to reduced slaughter value and reduced milk production were estimated in regional slaughter surveys at $52 million in Wisconsin, $5.6 million in Pennsylvania, and $15 million in New England.[1,2,5] More accurate estimates of the true losses associated with paratuberculosis will be possible with better quantification of effects on milk production, mastitis, reproduction, other diseases, and culling and lost genetic value in infected herds. This study tested differences in milk production, mastitis and culling rate among paratuberculosis-positive and negative herdmates in a single herd, and resultant financial effects.

Materials and Methods

A commercial Holstein dairy herd with mean lactating population of 210 cows was first diagnosed as having paratuberculosis in the herd in 1986. After joining the New York State Paratuberculosis Eradication Program in 1988, management changes were made. Calves were separated from paratuberculosis-positive dams after birth, and all known positive cows were segregated. No discard milk or colostrum from paratuberculosis-positive dams was fed to calves. Fecal culture for paratuberculosis was performed on all cows in the herd 5 times before the study began, and 3 more times during the period, from June 1990 to June 1991.

Northeast Dairy Herd Improvement Association (DHIA) Rolling Herd Average for this farm increased from 6909 kg (15,200 pounds) in December 1988 to 8955 kg (19,700 pounds) in June 1990.

Paratuberculosis culture-positive and -negative cows were separated within the same free stall barn and were fed the same ration. The only common use area for both groups was the holding pen outside the milking parlor. Fecal culture-positive cows were milked separately and last, using the same milking procedures for both groups. The herd was closed to purchased animals. Study population included all cows lactating for at least 1 month during the study period from June 1990 to June 1991.

Any cow developing clinical signs such as diarrhea and weight loss was culled soon afterward, as a standard practice. The farm operators had found through experience in the NY State Paratuberculosis Program that most culture-positive cattle leave the herd before ever having clinical signs of the disease and that culling all of the test positive animals would be prohibitively expense. Infected cows maintained in the herd were judged suitable for DHIA testing and were clinically normal without diarrhea and weight loss. All records of cows culled during the study were retained for all analyses.

Case definitions

Any cow that had ever been fecal culture-positive for *M paratuberculosis* was considered a paratuberculosis case. Classification of paratuberculosis status for all cows in the study was determined at the end of the study period. Any study cow that ever had been culture-positive as of June 1991 was considered paratuberculosis-positive and was assumed to have been infected with M paratuberculosis throughout her lifetime. Cattle are detected as positive by the fecal culture method if they shed at least 25 to 50 organisms/g of feces.[a]

Nonclinical mastitis was defined as DHIA individual cow somatic cell count Linear Score (LS) > 4.5 of any monthly test date during the 1 year study period. Nonclinical mastitis infections included new or chronic infections. New nonclinical infection (NI) was defined as LS > 4.5 when the preceding month's LS was < 4.5 or the cow was not lactating during the previous month. Chronic nonclinical infection (CHR) was defined as LS > 4.5 when the preceding month's LS was > 4.5.

Clinical mastitis (CM) was defined by abnormal appearance of milk or quarter detected by milking personnel and all CM quarter episodes were recorded. Subsequent episodes of CM in the same quarter during the same lactation were considered chronic clinical episodes and were not counted as cases. All treatments for CM were recorded. The categorical variable CM was positive or negative for each quarter of each cow each month.

Data collection

Milk samples were aseptically collected from all quarters of all cows at the beginning and end of the study period, in June 1990 and June 1991, and all nonclinical mastitis cows diagnosed by monthly DHIA LS were quarter sampled for culture each month, by Quality Milk Promotion Services personnel. All clinically mastitic quarters detected during the year were aseptically sampled by the herdsman. Microbiology was performed at the Quality Milk Promotion Services laboratory.

Values for age-, season-, and fat-corrected DHIA Mature Equivalent (ME) milk production, LS, NI, CHR, CM DHIA days in milk (DIM) and lactation number (LACT), and results of quarter milk microbiologic culture were recorded monthly for each cow. Fecal samples were collected for culture for *M. paratuberculosis* 3 times during the study.

Laboratory procedures

Standard microbiological culture was performed as described earlier.[6] Clinical mastitis milks were also incubated in trypticase soy broth at 37°C to improve sensitivity of detection of pathogens.

Fecal cultures were performed at the New York State College of Veterinary Medicine Diagnostic Laboratory using a double-incubation method used in the NY State Paratuberculosis Program.[7] Sensitivity of this method is estimated at about 40%. Detection of infected cows improves with multiple tests. Specificity is close to 100%.

Data and analysis

The variables ME, LS, NI, CHR, CM, DIM and LACT were recorded each month for all lactating cows. The variable paratuberculosis was calculated at the end of the study; each cow had one and only one value (positive or negative) for this variable.

For each cow, mean of monthly values was calculated for variables ME (MEAVE), LS (LSAVE), DIM (DIMAVE), and LACT (LACTAVE). To contrast mastitis cases among paratuberculosis status groups, NI, CHR, and CM were converted to rates of infection per cow per 305 days of lactation, and these rates were called NIR, CHRR, and CMR, respectively. For example, for all cows:

(246 clinical mastitis cases/292 cows)
x (305 days per lactation/164.9 mean DIM for all cows)
= 1.6 clinical cases/cow/305 days = CMR.

Differences in MEAVE, LSAVE, NIR, CHRR, CMR, DIMAVE, and LACTAVE among all paratuberculosis-positive and -negative cows were tested for significance using a t-test. Differences in culture-positive status of quarter milk samples were tested using chi-square. Differences in cull rates among paratuberculosis-positive and -negative cows were evaluated using chi-square.

Association between paratuberculosis status (positive or negative), other cow factors, and mastitis etiologic agents was reported earlier.[6]

For cows within each LACT, comparisons were made among paratuberculosis status groups for DIMAVE, MEAVE, and NIR using t-tests. All analyses were executed using a statistical analysis program.[8]

Economic loss was calculated from differences in performance among the paratuberculosis groups. Each nonclinical mastitis new infection was considered a loss of $210.00.[9]

Milk produced was valued at $13.00/cwt. Financial loss due to differences in milk production was calculated as (pounds lost) x ($.13/pound). For example, in fourth-plus lactation:

(1907 pounds) x ($.13/pound)
= $247.91 lost per cow per year.

Each culled cow was considered to represent a loss of $700.00. Cull rate losses were calculated based upon difference in overall herd culling from national average of 36%.[10]

Results

There were 293 cows on DHIA test for at least 1 month during the year: 106 cows remained for the entire year, 98 began the study and were culled, and 89 calved and began their first lactation. Paratuberculosis was detected in 113 clinically normal cows, and 180 herdmates were paratuberculosis-negative. The MEAVE milk production for all cows was 20,485 pounds, LSAVE was 3.1, NIR was 1.3 new mastitis infections/305 days, and CHRR was 1.3 chronic mastitis infections/305 days. The CMR was 1.6 clinical mastitis cases/305 days. Mean parity was 1.8 lactations, and mean DIM was 164.9 days (Table 1).

Mean monthly herd size was 208 cows, with 44 paratuberculosis-positive, a prevalence of 21%. A recent stratified sample of Wisconsin dairy herds estimated mean prevalence of paratuberculosis within positive herds at 20.3.[11]

Comparison of all paratuberculosis-positive and -negative cows revealed no differences in MEAVE, LSAVE, CMR, LACTAVE, or DIMAVE. However, nonclinical mastitis new and chronic infection rates were lower for paratuberculosis-positive cows than for negative cows (t-test, $P < 0.01$, $P = 0.05$, respectively, Table 1).

Financial effect of the reduced nonclinical mastitis among all paratuberculosis-positive cows was calculated as 0.6 less new cases/305 days x (210.00/case) = $126.00 economic benefit per cow per year (Table 1).

Mastitis effects of paratuberculosis differed by lactation. NIR for paratuberculosis-positive and -negative cows, respectively by LACT were: first lactation, 0.8, 1.1; second lactation, 1.1, 1.5; third lactation, 1.7, 1.6; fourth-plus lactation, 1.0, 2.7. Reduced new mastitis cases among paratuberculosis-positive cows was significant in first and fourth-plus lactations (t-test, $P < 0.05$, Table 2). Mastitis financial effects of paratuberculosis were $63.00 benefit in first lactation and $357.00 benefit in fourth-plus lactation (Table 2).

More paratuberculosis-positive cows were culled than were negative cows. The overall herd culling rate during the year of the study was 47% (98 culls/208 cows average monthly lactating herd size). Paratuberculosis-positive cows' cull rate was 139% (61 culls/44 positive cows on average in lactating herd), and cull rate was 23% (37/164 negative cows) for negative herdmates (chi-square, $P < 0.001$, Table 1, Table 5). Within each lactation, paratuberculosis-positive animals were culled at a greater rate than negative herdmates (Table 5).

The mean cull rate in dairy herds is 36%. With no differences caused by paratuberculosis, culling rates would be 75/208 (36%). In the study herd, actual cull rate was 98/208 (47%), an increase of 23 culls per year (11%). Culling losses attributable to paratuberculosis in the herd therefore were calculated as (23 additional culls) x ($700.00/cull) = $16,100.00 per year in a 208 cow-herd, or $77.40 per cow per year with a paratuberculosis prevalence of 21% (Table 1, Table 6). Results were similar in all lactations, with cull costs ranging from $72.92 to $93.33 per cow (Table 6).

Parity-matched comparisons among paratuberculosis-positive and -negative herdmates indicated that MEAVE was not significantly affected by paratuberculosis in heifers, although the trend was toward higher production in positive animals (Table 2). In the second lactation and thereafter, milk production was increasingly lower for paratuberculosis-positive cows than for herdmates (Table 2, t-test, $P < 0.05$).

Financial differences in milk production associated with paratuberculosis ranged from no significant effect in first lactation to a loss of $247.91 per cow per year in fourth-plus lactation (Table 2).

Mastitis pathogens were isolated from 5.9% of all quarter milk samples: 5.1% from paratuberculosis-positive cows and 6.3% of samples from paratuberculosis-negative cows were culture-positive. Using culture results from all clinical and nonclinical mastitis cases, mastitis infection rates per 305 days were 3.47 overall, 3.99 in paratuberculosis-negative cows, and 2.60 in paratuberculosis-positive herdmates (Table 3). This association of paratuberculosis with less mastitis was also significant (chi-square, $P < 0.05$).

Chi-square analysis indicated that paratuberculosis-positive cows contributed a higher proportion of cows in first and second lactations (41% in each) and a lower proportion of cows in third and fourth-plus

Table 1. Means for all cows and for paratuberculosis-positive and -negative cows

Variable	All Cows	n	Paratuberculosis-Negative	n	Paratuberculosis-Positive	n	Financial effects§
MEAVE(lb)	20,485	289	20,661	177	20,209	112	
LSAVE	3.1	289	3.2	177	3.0	112	
NIR	1.3	275	1.6†	173	1.0†	102	+$126.00‡
CHRR	1.3	275	1.7*	173	0.8*	102	
CMR	1.6	292	1.8	179	1.2	113	
LACTAVE	1.8	289	1.9	177	1.7	112	
DIMAVE	164.9	289	163.9	177	166.4	112	
CULLR	47%	208	23%**	164	139%**	44	-$77.40¶

† Statistically significant at P < 0.01, t-test
* Statistically significant at P = 0.05, t-test
** Statistically significant at P < 0.001, chi-square

§ Financial effect associated with paratuberculosis for all cows
‡ Difference in cases/305 days x $210.00 loss/case
¶ Difference in overall cull rate from U.S. average of 36% x $700.00 loss/cull

MEAVE = Mature Equivalent age, season, and fat adjusted milk production (mean of each cow's monthly values)
LSAVE = Linear Score of the somatic cell count (mean of each cow's monthly value)
NIR = nonclinical mastitis new infections per cow per 305 days of lactation
CHRR = nonclinical mastitis chronic infections per cow per 305 days of lactation
CMR = clinical mastitis cases per cow per 305 days
LACTAVE = lactation number (parity) (mean of each cow's monthly values)
DIMAVE = days in milk (mean of each cow's monthly values)
CULLR = annual cull rate

Table 2. Production and mastitis effects of paratuberculosis by lactation

LACT	PT	n	MEAVE	MILK COST	NIR	MAST COST
1	+	74	21,953	NSD†	0.8*	+$63.00§
	-	106	21,706		1.1*	
2	+	49	20,497*	-$ 82.81§	1.1	NSD
	-	72	21,134*		1.5	
3	+	12	18,298*	-$198.12	1.7	NSD
	-	39	19,821*		1.6	
4+	+	10	17,066*	-$247.91	1.0*	+$357.00
	-	27	18,973*		2.7*	

† No significant difference
* Statistically significant at P < 0.05, t-test
§ Positive number indicates economic beneift, negative number economic loss for paratuberculosis-positive cows

LACT = lactation number
PT = paratuberculosis status
MILK COST = milk production changes with paratuberculosis x $13.00/cwt
MAST COST = Difference in new mastitis cases/305 days with paratuberculosis x $210.00 loss/case
See Table 1 for key

Table 3. Milk culture results for all cows and for paratuberculosis-positive and -negative cows

Culture Results	All cows n=293	Paratuberculosis-Negative n=180	Paratuberculosis-Positive n=113
	Qtrs(%) Cows(%)/Rate§	Qtrs(%) Cows(%)/Rate	Qts(%) Cows(%)/Rate
Total	9,229(100.0) 293(100.0)/NA	6,100(100.0) 180(100.0)/NA	3,129(100.0)113(100.0)/NA
Negative	8,683(94.1) 145(49.5)/NA	5,714(93.7) 78(43.3)/NA	2,969(94.9) 67(59.3)/NA
Positive†	546(5.9) 148(50.5)/3.47	386(6.3) 102(56.7)/3.99*	160(5.1) 46(40.7)/2.60*

§ Rate = Case per cow per 305 days of lactation
† Positive = All quarters and cows with a mastitis pathogen isolated
* Statistically significant at P < 0.05, chi-square
Qtrs = quarters; NA = not applicable

Table 4 . Paratuberculosis status by parity

(Cows/mean cow-months on test/% of cows within each lactation)

Paratuberculosis Status*	Lactation number 1	2	3	4+	TOTALS
Negative	106 6.4 58.9	72 5.4 59.5	39 6.1 76.5	27 8.0 73.0	244 6.2 62.7
Positive	74 5.6 41.1	49 4.8 40.5	12 5.6 23.5	10 6.3 27.0	145 5.4 37.3
No. of cows	180	121	51	37	389
Months on test	6.1	5.2	6.0	7.6	5.9
% of all cows	46.3	31.1	13.1	9.5	100.0

* Paratuberculosis status = fecal culture results for *Mycobacterium paratuberculosis*

Chi-square = 190.4, df = 3, P < 0.001

Table 5. Culling effects of paratuberculosis by lactation

LACT	Paratuberculosis-positive Cull rate(%)	Paratuberculosis-negative Cull rate (%)
1	28†/23§ (122%)**	16/73 (22%)*
2	20/13 (154%)**	6/41 (15%)*
3	7/4(175%)*	8/26 (31%)
4+	6/4 (150%)*	7/24 (29%)
ALL	61/44 (139%)**	37/164 (23%)**

† Number of cows culled per year
§ Mean number of cows in that group during the study

* Statistically significant at P < 0.005, chi-square
** Statistically significant at P < 0.001, chi-square

Table 6. Financial effects of culling attributed to paratuberculosis by lactation*

LACT	Cull rate (%)	Difference from U. S. average (36%)	Cost/cow/year†
1	44/(46%)	10/96 (10%)	$72.92
2	26/54 (48%)	6/54 (11%)	$77.78
3	15/30 (50%)	4/30 (13%)	$93.33
4+	13/28 (46%)	3/28 (11%)	$75.00
ALL	98/208 (46%)	23/208 (11%)	$77.40

† Cost/cow/year = difference in cull rate from U.S. average of 36% x $700.00 loss/cull
* Paratuberculosis prevalence of 21% (44/208)
See Table 5 for key

lactations (24 and 27%, respectively; chi-square, $P < 0.001$), Table 4. All cells were significantly different from expected using cellular chi-square.

When all cows in all lactations were evaluated, total financial change associated with paratuberculosis was: ($126.00 gained by reduced nonclinical mastitis) + (-$77.40 lost due to increased culling) = $48.60 gained per cow per lactation (Table 1).

Differences in financial effects were evident by LACT. Milk loss, reduced mastits, and increased culling combined resulted in net annual cost per cow with paratuberculosis by parity group as follows: first, -$9.92; second, -$160.59; third,-plus, +$34.09.

Discussion

When all cows remaining in the herd were compared as two large groups, paratuberculosis did not appear to affect milk production. However, comparison of parity-matched cows with and without paratuberculosis indicated differences. Mature Equivalent milk production was unchanged in heifers with the disease, but beginning in second lactation and with advancing parity, milk production was lower in cows with paratuberculosis, with milk loss costs ranging from approximately $80.00 to $250.00 per lactation.

An earlier study reported a 16% decrease in ME in cows with subclinical paratuberculosis when the lactation during which they were culled was compared with the preceding lactation.[3] That study compared cows during the lactation that resulted in their being culled with their own past performance, rather than with performance of contemporary herdmates.

Clinical mastitis was not affected by paratuberculosis. However, paratuberculosis was surprisingly associated with less nonclinical mastitis, as much as 1.7 fewer new cases per lactation in older cows. This reduced the financial impact of the disease.

Paratuberculosis was most common in cows in first and second lactation. In the experience of the authors, newer methods of fecal culture reveal a higher prevalence of paratuberculosis in cows less than 3 or 4 years old than was previously reported. There may be decreased survival in dairy herds for cows with inapparent paratuberculosis, independent of culling practices. Infected cows are usually unknown to herd management for months to years, due to the long incubation period, time required for fecal culture to be completed, and relative insensitivity of diagnostic test. Therefore, selective more aggressive culling of paratuberculosis-positive cows based only on the knowledge that they are fecal culture-positive is unlikely.

Management on the study farm did not cull on the basis of paratuberculosis status. Despite no intentional difference in culling pressure among positive and negative cows, the culling rate was greater for paratuberculosis-positive cows during all lactations, with culling losses of approximately $75.00 per cow per year.

Results of this study suggest that inapparent (subclinical) infection with *M. paratuberculosis* begins causing milk production loss in second lactation. Paratuberculosis-positive cows did not remain in the herd for as long as uninfected herdmates. Because the disease was strongly associated with reduced subclinical mastitis, paratuberculosis did not appear to cost much money during first or fourth-plus lactations. Possibly paratuberculosis, being a chronic mycobacterial infection, provides some stimulation of the immune system for as long as cattle remain clinically normal. Study of this should be performed in more dairy herds.

Experience in this herd demonstrates that cows with subclinical paratuberculosis can perform as well as paratuberculosis-negative herdmates until second lactation. Dairy herd managers should be aware of whether paratuberculosis exists in their herds. If it does, control measures should be instituted with the aim of reducing transmission, especially to calves and young animals. However, in high-prevalence herds, culling based strictly on a positive fecal culture or other diagnostic test for paratuberculosis may be unwarranted and expensive.

Acknowledgments

Supported by a grant from the Cornell University Veterinary Alumni Funds.

The authors thank John Ackerman, Eric Hallstead, Brent Netherton, and Brenda Smith for technical assistance.

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