J. Dairy Sci. 89:2596–2602

The Effect of Digit Amputation or Arthrodesis Surgery on Culling and Milk Production in Holstein Dairy Cows

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ABSTRACT

The objectives of the study were to evaluate the effects of digit amputation and arthrodesis surgery performed in the field on culling and milk production during the early postsurgical period. Cows from 3 commercial dairy farms in New York State were recruited for the study. A total of 49 cows on which digit amputation (AMP) was performed were matched with 68 controls (MC-AMP), and 17 cows on which arthrodesis surgery (ARTHRO) was performed were matched with 20 controls (MC-ARTHRO) according to lactation, DIM, and lactation at the time of surgery. Performance was not directly comparable between the AMP and ARTHRO groups because cows were not randomly assigned to the 2 treatment groups. Therefore, each surgical group was evaluated relative to its respective matched control group. Cows with AMP had a significantly lower estimated median survival of 68 d (95% confidence interval; lower = 35 d, upper = 156 d) compared with 585 d (95% confidence interval; lower = 469 d, upper = 699 d) for the MC-AMP group. Total milk production for the first 60 d postsurgery was significantly lower for the AMP (1,533 ± SE = 101 kg) group compared with the MC-AMP (2,121 ± 101 kg) group and for the ARTHRO (1,883 ± 86 kg) group compared with the MC-ARTHRO (2,250 ± 88 kg) group. Septic arthritis of the distal interphalangeal joint was the most common condition treated by surgery, accounting for 70.5% of ARTHRO cases and 73.5% for AMP. Toe necrosis accounted for 14.3% of AMP cases, and retroarticular abscess made up the rest of the AMP (12.2%) cases and 29.5% of the ARTHRO cases. Results suggest that cows that had undergone ARTHRO had a lower culling rate and a faster return to production compared with those that had undergone AMP. Arthrodesis should be considered as a treatment option for deep sepsis of the bovine foot.

Key words: digit amputation, arthrodesis, culling, dairy cow

INTRODUCTION

Lameness in dairy cows is a serious welfare concern and causes significant economic losses to dairy farmers. Economic losses from lameness include decreased milk yield (Warnick et al., 2001; Green et al., 2002), impaired fertility (Hernandez et al., 2001; Melendez et al., 2003), and increased risk of culling (Esslemont and Kossaibati, 1997; Booth et al., 2004). The cause, severity, and time of lameness affect the degree of change in milk yield, fertility, and risk of culling (Warnick et al., 2001; Booth et al., 2004), with severe lameness causing the most significant losses. Common digit diseases such as sole ulcers, sole abscesses, foot rot, and white line disease may become complicated by extensive corium and laminae tissue necrosis leading to deep sepsis of the digit (Baxter et al., 1991). Nuss and Weaver (1991) reported septic arthritis of the distal interphalangeal (**DIP**) joint as constituting 3 to 10% of all hoof conditions. Deep infection of the digit causes severe lameness and, in herds with a high incidence of lameness, economic losses from this condition may be significant.

Digit amputation (**AMP**) and digit salvage techniques, such as arthrodesis surgery (**ARTHRO**), have been performed to successfully treat deep infections of the digit (Pesja et al., 1993; Desrochers et al., 1995). Nuss and Weaver (1991) reported the average survival times after AMP and ARTHRO as 13 and 18 mo, respectively. The authors suggested that cows undergoing AMP had faster returns to production than cows on which ARTHRO was performed. However, those studies had neither control cows with which to compare the survival time nor any data to support the claims that cows having AMP returned to production faster than cows having ARTHRO. The objective of this study was to evaluate the effect of AMP and ARTHRO on survival and milk production among cows with deep sepsis of the digit.

MATERIALS AND METHODS

Study Farms and Data Collection

Data were collected from 3 farms located near Ithaca, New York, from September 1, 2002, to April 15,

Received December 15, 2005.
Accepted February 15, 2006.
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2005. Farm A milked 2,500 cows, farm B milked 700 cows, and farm C milked 340 cows. The herds consisted of Holstein cows housed in free-stall barns with waste paper pulp bedding. Cows were milked 3 times daily in milking parlors. Lactating cows were fed a TMR consisting basically of 55% forage (corn silage, haylage, alfalfa hay, and wheat straw) and 45% concentrates (cornmeal, high-moisture corn, soybean meal, canola, cottonseed, citrus pulp, and brewer's grain).

Milk production data were obtained from electronic milk weighing in herd A, whereas DHIA records were used in herds B and C. Data were transferred to a dairy records database (Dairy Comp 305; Valley Agricultural Software, Tulare, CA). Lameness was diagnosed by farm personnel in all 3 herds based on visual gait abnormality. Farms A and B had trained farm personnel who performed scheduled corrective hoof trimming every week and also treated lame cows as they were diagnosed. A professional hoof trimmer visited farm C every 2 wk to perform scheduled hoof trimming and to treat lame cows. Maintenance trimmings were performed twice yearly in all 3 herds. Severely lame cows with a visual lameness score of 4 on a 1 to 4 scoring system (Sprecher et al., 1997) and chronically lame cows that had previously been treated but were still lame were presented to Cornell Ambulatory Clinic veterinarians for on-farm treatment. The farms were visited by the veterinarian at least once weekly. Deep sepsis of the foot was diagnosed by the veterinarian, and the affected cows were either treated with digit surgery or were culled. The digit surgeries performed were AMP and ARTHRO. The apparent cause of deep sepsis was noted for cows on which ARTHRO was performed. When amputation was performed, the digit was collected and a sagittal cut was made to split the digit. The digits were then photographed and lesions were identified and recorded.

Each cow having digit surgery was matched with 1 or 2 herdmates that served as controls. Control cows for both ARTHRO and AMP (**MC-ARTHRO** and **MC-AMP,** respectively) were matched as closely as possible for DIM, lactation number, being alive, and lactating at the time the case was treated. If more than 2 suitable control cows were identified, the first 2 cows on the list generated by Dairy Comp 305 were selected, and if only 1 suitable cow was identified, only 1 cow was used as a control. Days in milk were used to generate the list, and if no cows matched perfectly, the cow in the same lactation with the closest DIM was chosen. If no cows in the same lactation were found within 30 DIM but a close match for DIM was available in a cow 1 lactation younger, then that cow was chosen. If no control cows fit these criteria, the difference in DIM was expanded in the same or a lower lactation to find the closest match.

Case Definition and Exclusions

Conditions suitable for ARTHRO included septic arthritis and retroarticular abscess. Septic arthritis was defined as a septic process involving the DIP joint. Septic arthritis was diagnosed by physical examination findings of swelling over the coronary band, particularly over the caudal third of the abaxial side of the DIP joint. In some cows, bone was palpable through the fistulous tracts or through the sole ulcer. Confirmation of diagnosis was possible through visualization of pus and necrotic debris observed during surgery. Retroarticular abscess was defined as a septic process of the navicular bursa, the surrounding structures, or both but not involving the DIP joint. Definitive diagnosis was made intraoperatively. Conditions suitable for AMP were septic arthritis, retroarticular abscess, and toe necrosis. Toe necrosis was defined as necrotic osteomyelitis of the apex of the third phalanx. Toe necrosis cases were first diagnosed by the farm employees and brought to the veterinarian's attention. Definitive diagnosis was done after the amputated digit was split and necrotic osteomyelitis was observed in the apex of the distal phalanx.

Cows deemed unsuitable for surgical treatment included cows that had lesions on both claws of the same leg, recumbent cows, or cows that the farmer chose to cull for economic reasons. Cows on which surgery was performed less than 60 d before the end of data collection were excluded from all analyses. For milk yield analysis, only cows that remained in the herd at least 60 d after surgery were included. Cows that were not lactating at the time of the surgery or that were dried off within the first 60 d after surgery were excluded from the milk yield analysis.

Cows were not randomly assigned to surgical procedures for this study. Before January 2004, ARTHRO were not performed routinely and almost all cows that had septic arthritis, toe necrosis, or retroarticular abscess had AMP performed. Beginning in August 2004, the surgeon treated every cow with septic arthritis or retroarticular abscess with ARTHRO.

Surgical Technique Description

Following clipping and washing of the distal limb with diluted disinfectant solution, i.v. regional anesthesia was administered by applying an elastic tourniquet around the metatarsus and using a 19-gauge butterfly catheter to inject 35 mL of a 2% lidocaine solution, without epinephrine, into any accessible vein

distal to the tourniquet. For AMP, the affected digit was disarticulated at the pastern joint between the first and second phalanx using a sharp knife without removal of articular cartilage from the distal end of the first phalanx (Osman, 1970). The wound was packed with gauze and ichthammol with copper sulfate powder and was wrapped tightly using 10.16-cm Elastikon bandage (Johnson & Johnson Consumer Companies, Inc., Skillman, NJ). The bandage was removed after 3 d and the wound was left open to allow drainage. For ARTHRO, the approach and technique used was the same as described in Bicalho (accepted). A 4-cm horizontal incision was made just proximal to the plantar coronary band around the circumference of the heel. A wedge of tissue that included the deep digital flexor tendon was removed to allow visualization and removal of the navicular bone. Necrotic tissue and cartilage were removed before a hole was drilled from the plantar incision through the middle of the DIP joint and emerging on the dorsal surface proximal to the coronary band. Rubber tubing was placed from the plantar incision through the DIP joint to the hole created from the drill, and the ends of the tubing were tied together. When a fistula was present, rubber tubing was also placed through the plantar incision to the fistula. The wound was packed with antibiotic powder and the incision was sutured. The foot was bandaged for 3 d and the drains were removed after 2 wk. All cows in the study were treated with procaine Penicillin G, i.m. (Agri-Cillin, Agri Laboratories, Ltd., St. Joseph, MO), with a daily dose of 6,000,000 IU b.i.d. for 10 d. The cows were kept in the "sick cow" pen, which had bedded packs, and were fed the regular milking ration and milked twice daily at least until the end of the course of antibiotics.

Statistical Analyses

A retrospective case-control study design was used. Separate analyses were performed for each surgical procedure. Cumulative milk yield in the 60 d after the procedure was calculated by Dairy Comp 305 and compared with the same measurement of milk yield for matched healthy control cows. This was done using the PROC MIXED procedure of SAS, version 9.1 (SAS Institute, Cary, NC). The matching group was included in the model as a random effect with a variance components covariance structure. The model fit was assessed by plotting residuals against predicted values.

For cows with surgery, survival time was defined as the interval from the date of surgery until the cow was sold or had died. For control cows, survival time was defined as the interval from the date of surgery for the matched case until the cow was sold or had died. Cows still in the herd at the end of data collection were coded as censored observations. The survival of cows with surgery was compared with the survival of matched controls using Cox's proportional hazards model (SAS Institute). Two separate models were used for ARTHRO and AMP. The models were stratified on a matched group. Kaplan-Meier survival functions were plotted using Statistix (Analytical Software, Tallahassee, FL).

RESULTS

Disease Frequency and Distribution

Two cows on which ARTHRO was performed <60 d from the end of data collection were removed from all analyses. A total of 17 cows on which ARTHRO was performed and 49 cows on which AMP was performed were paired with 20 (MC-ARTHRO) and 68 (MC-AMP) matched control cows, respectively. Cows in the AMP group ranged from first to sixth lactation and from 1 to 623 DIM at the time of surgery. Cows in the ARTHRO group ranged from first to fourth lactation and from 1 to 535 DIM. Cows that had surgery late in lactation and cows in later lactations presented some problems in identifying suitable matched control cows. The differences in DIM and lactation between the AMP and MC-AMP cows are summarized in Table 1, and the differences in DIM and lactation between the ARTHRO and MC-ARTHRO cows are summarized in Table 2. The mean, median, and range of the difference in DIM and lactation shown in Tables 1 and 2 are for the imperfectly matched pairs.

Septic arthritis of the DIP joint was the most common deep infection of the digit observed, making up 73.5% of all AMP and 70.5% of all ARTHRO cases. The most common reason for the development of septic arthritis of the DIP joint was complications from a sole ulcer, accounting for 79.2% of that disease. The lateral digit of the hind limb was the most common digit affected and accounted for 81.6% of amputated digits and 88.2% of arthrodesed digits (Table 3).

Milk Production

Cows that survived a minimum of 60 d postsurgery were included in the analysis. Twenty-two cows in the AMP group, with 23 in the MC-AMP group, and 17 cows in the ARTHRO group, with 17 in the MC-ARTHRO group, were enrolled for milk production analysis. The median DIM for ARTHRO and MC-ARTHRO for this analysis was 78 d (min = 1 d, max = 535 d) and 76 d (min = 1 d, max = 535 d). The median DIM for AMP and MC-AMP was 127 d (min = 1 d,

Table 1. Matching closeness for pairs of cows that had undergone digit amputation surgery (AMP) and the matched control cows (MC–AMP)[1]

Selection criterion	AMP (n = 49)	MC-AMP (n = 68)	Imperfect match	Difference			*P*
				Mean	Median	Range	
DIM	172.96	169.17	36	10.5	5	–60, 30	0.90
Lactation	2.76	2.59	8	1	0	1, 0	0.45

[1]Imperfect match = number of pairs that were not matched perfectly; mean = average true difference for imperfectly matched pairs; median = median true difference for imperfectly matched pairs; *P* = probability of finding an exact match.

max = 491 d). Median lactation was 2 for the ARTHRO group (min = 1, max = 4) and 3 for the AMP group (min = 1, max = 6) for this analysis. Two cows in the AMP group that survived 60 d but that were dried off within the first 60 d postsurgery were excluded from the analysis. No cows in the ARTHRO group were dried off in the first 60 d postsurgery. A summary of survival is given in Table 4. The least squares mean for total milk production in the first 60 d postsurgery for the AMP group was 1,533 ± 101 kg, compared with 2,121 ± 101 kg in the MC-AMP group. The difference between the 2 groups was 587 ± 25 kg ($P < 0.001$, 95% confidence interval, 322, 853 kg). The least squares mean 60-d cumulative milk production for the ARTHRO group was 1,883 ± 86 kg, and total milk production for the same period for the MC-ARTHRO group was 2,250 ± 88 kg. The difference between these 2 groups was 367 ± 96 kg ($P = 0.013$, 95% confidence interval, 170, 564 kg). Milk production results are summarized in Figure 1.

Cow Survival

AMP. The analysis included 49 cows in the AMP group and 68 cows in the MC-AMP group. Survival time was censored at DIM on the end of data collection for 8 cows (16%) in the AMP group and 35 cows (53%) in the MC-AMP group because they were still alive at the end of data collection (Table 4). The median DIM for AMP at censoring was 355 d (min = 275 d, max = 541 d) and the median DIM for MC-AMP was 522 d (min = 233 d, max = 747 d). Cows with amputations had a higher rate of leaving the herd because of culling or death than the controls (hazard ratio = 5.5, $P < 0.001$). The Kaplan-Meier estimate for median survival time for cows with amputations was 68 d (95% confidence interval; lower = 35 d, upper = 156 d), compared with 585 d (95% confidence interval; lower = 469 d, upper = 699 d) for control cows (Figure 2).

ARTHRO. Seventeen cows in the ARTHRO group and 20 MC-ARTHRO cows were included in the analysis. Survival time was censored at DIM on the end of data collection for 13 cows (76%) in the ARTHRO group and 13 cows (65%) in the MC-ARTHRO group. The median DIM at censoring was 319 d (min = 27 d, max = 495 d) for the ARTHRO group and 286 d (min = 27 d, max = 527 d) for the MC-ARTHRO group. There was no effect of ARTHRO on survival; in fact, cows with ARTHRO tended ($P = 0.16$) to remain in the herd longer than matched controls (Figure 3).

DISCUSSION

Cows on which AMP was performed had a higher culling rate than their matched controls. However, the survival curve after 70 d was similar between the 2 groups. A survival analysis was used instead of the average survival time, which has been the measure most commonly published to describe survival after digit surgery. A survival analysis allows an animal that has not yet been culled to be used in the analysis, shows the rate of culling by time, and is generally accepted as the most appropriate method to analyze survival (Gröhn et al., 1998). The survival rate was

Table 2. Matching closeness for pairs of cows that had undergone arthrodesis surgery (ARTHRO) and the matched control cows (MC-ARTHRO)[1]

Selection criterion	ARTHRO (n = 17)	MC-ARTHRO (n = 20)	Imperfect match	Difference			*P*
				Mean	Median	Range	
DIM	139.76	8	7	9	3	–42, 8	0.96
Lactation	2.53	0	0	0	0	0, 0	1.00

[1]Imperfect match = number of pairs that were not matched perfectly; mean = average true difference for imperfectly matched pairs; median = median true difference for imperfectly matched pairs; *P* = probability of finding an exact match.

Table 3. Frequency and distribution of digit disease treated by digit surgery

Disease	Digit amputation	%	Arthrodesis	%
Septic arthritis				
Sole ulcer[1]	28	57.1	10	58.8
White line disease[2]	8	16.3	2	11.8
Toe necrosis	7	14.3	0	0.0
Retroarticular abscess	6	12.2	5	29.4
Total	49		17	
Affected digit				
Lateral hind digit	40	81.6	15	88.2
Medial hind digit	4	8.1	5	11.7
Medial front digit	5	10.2	0	0

[1]Sole ulcer = cows diagnosed with septic arthritis of the distal interphalangeal joint secondary to a complicated sole ulcer.

[2]White line disease = cows diagnosed with septic arthritis of the distal interphalangeal joint secondary to a complicated white line disease.

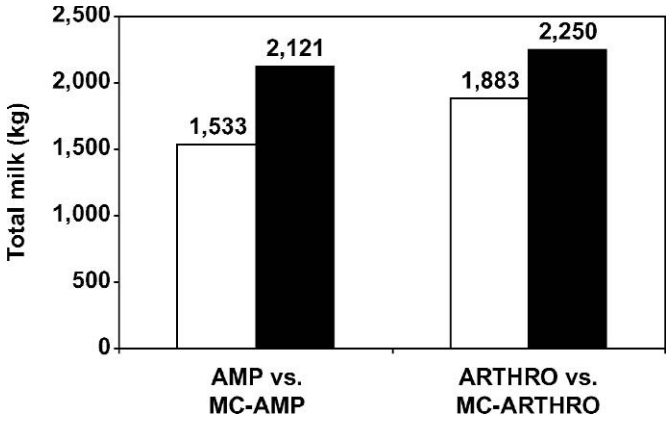

Figure 1. Least squares means for total milk production 60 d postsurgery. Digit amputation (AMP) and arthrodesis (ARTHRO) groups (white column) were significantly lower (AMP vs. MC-AMP, $P < 0.001$; ARTHRO vs. MC-ARTHRO, $P = 0.013$) than the matched control groups MC-AMP and MC-ARTHRO (black column).

similar between cows that underwent ARTHRO and the matched control cows. The 2 surgical treatments were not directly compared with each other because the cows were not randomized and the criteria for selection were different. However, results were suggestive that the cows undergoing ARTHRO had a more favorable prognosis compared with those undergoing AMP.

Reports on survival time after AMP vary among studies. In one study, 23 of 41 (56%) cows survived at least 1 yr after amputation (Pesja et al., 1993). In that study, a wide variety of patients were included, such as beef cattle, bulls, calves, and lactating dairy cows. Baxter et al. (1991) reported that in a series of AMP, 30 of 32 cattle were eliminated from the herd within 1 yr after the surgery. In our study, 56% of the cows on which AMP was performed were culled by the first 60 d, and over two-thirds of the cows were culled within 1 yr. The prognosis for AMP was worse when the lateral hind digit was the one operated on, or when the animal weighed >682 kg (Baxter et al., 1991; Pesja et al., 1993; Desrochers et al., 1995). Most of the affected digits in our study were lateral digits from one of the hind limbs (Table 1), and only Holstein cows in first lactation or greater were included. Therefore, the poor prognoses for AMP cows were expected.

Digit amputation might also be used to treat chronic necrosis of the apex of the distal phalanx, known as toe necrosis (Kofler, 1999). In the present study, 7 animals diagnosed with chronic necrosis of the distal phalanx were treated with AMP. The DIP joint was not affected in animals with toe necroses; therefore ARTHRO was not a treatment option for those animals. Although specific digit salvage techniques have been developed to treat animals with toe necroses (Kofler, 1999), it was not the objective of this study to evaluate the use of these techniques as an alternative to AMP.

For both surgical techniques, milk production during the first 60 d postsurgery was significantly lower compared with control cows. Previous researchers (Baxter et al., 1991; Nuss and Weaver, 1991) have found that cows on which AMP was performed returned to production faster than cows undergoing

Table 4. Survival summary by group and time of culling or death for the digit amputation group (AMP), arthrodesis group (ARTHRO), and their controls (MC-AMP and MC-ARTHRO)

	AMP		MC-AMP		ARTHRO		MC-ARTHRO	
Event[1]	n	%	n	%	n	%	n	%
Failure	22	44.9	3	4.4	0	0.0	0	0.0
Success	19	38.8	30	44.1	4	23.5	7	35.0
Censored	8	16.3	35	51.5	13	76.5	13	65.0
Total	49		68		17		20	

[1]Failure = cows that were culled or that died in the first 60 d postsurgery; success = cows that survived >60 d but that were culled or had died before the end of the study period; censored = cows that survived >60 d and that were still alive at the end of data collection.

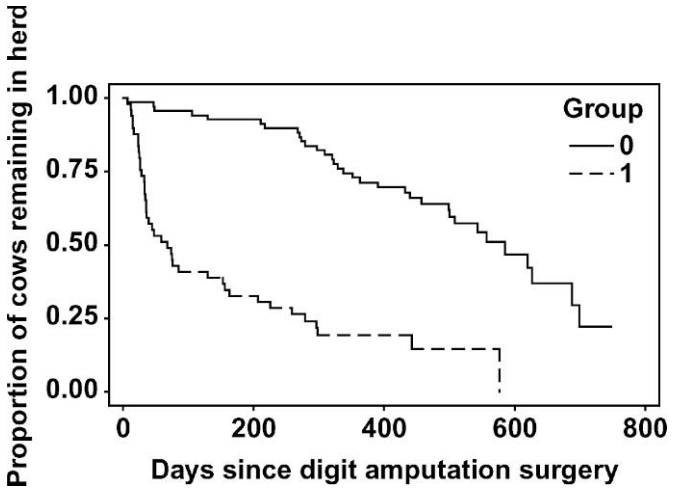

Figure 2. Proportion of cows remaining after digit amputation (thin dashed line; median = 68 d; 95% confidence interval; lower = 35 d, upper = 156 d) and of matched controls (thick line; median = 582 d; 95% confidence interval; lower = 469 d, upper = 699 d).

ARTHRO. The true difference in milk production was higher than reported in this analysis. Cows that did not survive at least 60 d after digit surgery were considered "failures" and were excluded from the milk production analysis to control for the difference in failure rates between the ARTHRO and AMP groups. The failure rate for AMP was 49%, compared with 0% for ARTHRO cows. Therefore, the analysis evaluated the difference in recovery of milk production only for successfully treated cows. Sixty days was chosen for the analysis to obtain sufficient data points through daily milk weight and DHIA records, and because the difference in culling rate was lower if the cows survived past that period.

The most common complication of surgery was ascending tendonitis and development of disease on the remaining digit. Milk production in these cows was severely affected, which increased the risk of culling. Deep sepsis of the digit causes severe lameness and may not be treatable, especially if both digits are affected, if the lesion extends proximal to the digit, or if the cow is systemically affected. Clinical judgment should be used to determine suitability of the surgical techniques.

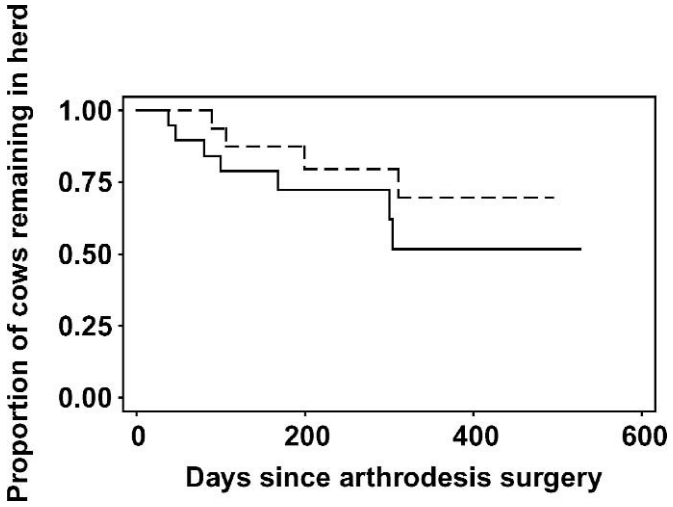

Figure 3. Proportion of cows remaining after arthrodesis surgery (thin dashed line; 90th percentile = 99 d; 95% confidence interval; lower = 27 d, upper = 311 d) and of matched control cows (thick line; 90th percentile = 45 d; 95% confidence interval; lower = 27 d, upper = 168 d).

CONCLUSIONS

Deep sepsis of the digit can result in significant economic losses for the farmer. Cows on which AMP was performed had a hazard ratio of 5.5 of being culled compared with matched controls, whereas ARTHRO did not increase the risk of culling compared with matched controls. Cows that underwent AMP produced 587 kg less milk than controls in the first 60 d, compared with a 367-kg deficit in 60-d milk production between ARTHRO cows and the controls. Although not compared simultaneously, our results suggest that ARTHRO was superior to AMP, with lower culling rates and higher total milk yields during the first 60 d postsurgery compared with matched control cows for each surgical procedure.

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