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Investigations on Milk Flow and Milk Yield from Teats with Milk Flow Disorders

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ABSTRACT

The objective of this study was to investigate peak milk flow, average milk flow, and milk yield in teats with milk flow disorders. A total of 100 hard milking teats were studied in 97 cows. Teats with milk flow disorders were examined endoscopically. Quarter milk flow and quarter milk yield were examined with four Lactocorders attached to a quarter milking machine. Peak milk flow, average milk flow, and milk yield were measured in all teats of the udder before treatment of the affected teat, as well as 1 and 6 mo later. Teats with milk flow disorders were compared to all other teats of the same udder. Before treatment, peak milk flow from affected teats was 20%, average milk flow 14%, and milk yield 53% of the control teats, adjusted for other significant explanatory variables. Milk flow and milk yield increased after surgical treatment of the affected teats. Six months after treatment peak milk flow was 79%, average milk flow 76%, milk yield was 71% compared with control teats. We conclude from these findings that teat endoscopy and measuring quarter milk flow and milk yield with Lactocorders are useful tools for examining teats with milk flow disorders.
(**Key words:** milk flow, teat, quarter, lactocorder)

INTRODUCTION

Teat injuries and other disorders often affect milk flow (Querengässer and Geishauser, 1999). Decreased machine milkability of single teats may impair milking the cow and the whole herd. Milk flow disorders cause economic losses because of increased labor, treatment costs (Querengässer et al., 1999), increased risks of mastitis (Tschäppät et al., 1976; Witzig et al., 1984; Agger and Hesselholdt, 1986; Zähner, 1989; Bigras-Poulin et al., 1990; Querengässer et al., 1999) and premature removal from the herd (Beaudeau et al., 1995; Bendixen et al., 1988; Dohoo and Martin, 1984; Duffield et al., 1999; Sol et al., 1984). New techniques have been developed for the treatment of milk flow disorders during recent years. These include teat endoscopy for diagnosis and treatment (Medl and Querengässer, 1994; Querengässer, 1998; Querengässer and Geishauser, 2001) and resting the affected teat by temporary cessation of milking (Heidrich and Gehring, 1958; Weigt et al., 1971; Kubicek, 1975; Rüsch et al., 1990; Weichselbaum et al., 1995).

The objective of this study was to investigate quarter milk flow and quarter milk yield in cows with milk flow disorders before and after treatment. Peak milk flow, average milk flow, and milk yield from teats with milk flow disorders will be lower than in the remaining teats of the udder (first research hypothesis). Milkability of teats with milk flow disorders is equal to unaffected teats 6 mo after treatment (second research hypothesis). When studying milk flow or milk yield, various factors may be considered. Milk flow may increase as milk yield (Blake and McDaniel, 1978; Bahr et al., 1995), lactation number (Göft et al., 1994), teat canal width (Wendt and Lüder, 1991; Bruckmaier et al., 1995), premilking stimulation (Rothenanger et al., 1995), and vaccum level (Ebendorf and Ziesack, 1991) are increased. Milk flow may decrease as DIM (Bahr et al., 1995; Bruckmaier et al., 1995), teat tip hyperkeratosis (Wendt and Lüder, 1991), and air vent in the claw (Bruckmaier et al., 1996) are increased. Hind quarters yielded more milk than front quarters (Rothenanger et al., 1995; Wellnitz et al., 1999).

MATERIALS AND METHODS

Animals

This study was performed on 97 dairy cows that had been referred to the Veterinary Clinic Babenhausen in Bavaria between May, 18 1999, and February 1, 2000, because of milk flow disorders. The outer skin of the

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Table 1. Case history of 97 cows.

Descriptive factor	%	Median
Brown Swiss (Braunvieh)	66	
Simmental (Fleckvieh)	19	
Holstein (Schwarzbunte)	11	
Other	4	
Tie stall	66	
Free stall	33	
Age (lactations)		
1	45	
2	30	
3	10	
4	7	
5	4	
6	2	
7	1	
8	1	
DIM When presented (days)		91
Duration of illness (days)		14
Pretreated	79	
Location of the affected teat		
Front left	12	
Front right	17	
Hind left	42	
Hind right	29	

affected teat was mainly intact. A total of 100 hard milking teats was investigated. Only one teat was affected in 94 cows; three cows had two affected teats. Three cows had one blind quarter. The cows originated from 78 herds. One cow was enrolled from 65 herds, two cows from eight herds, and three or more from five herds.

Procedures

On referral, case history (Table 1) was determined and a clinical examination (Table 2) was performed. Before examination of the teat, cows received xylazine (0.2 ml of a 2% solution per 100 kg body mass) and oxytocin (20 IU) intravenously. All udder examinations were performed at the quarter level. After thoroughly cleaning the teats, hand milkability was assessed (milkable by hand/not milkable by hand). The teat tip to floor distance (cm), and the teat length (cm) were measured, and the teat tip thickness (mm) was determined using spring-loaded calipers (Hamann et al., 1996; Hauptner, Solingen/Germany). After disinfection, milk samples were taken to determine SCC (1000 cells/ml), pathogens (type), inhibitor residues (present/not present), and antibiotic susceptibilty (susceptible/not susceptible) (DVG, 2000). Teat canal width (mm) was measured with a plug gauge (Johannson, 1957), and teat canal length (mm) with a thelometer (Querengässer and Geishauser, 1999; Eickemeyer, Tuttlingen, Germany).

Cows were milked with a quarter milking machine equipped with four Lactocorders (Wellnitz et al., 1999; WMB, Balgach, Switzerland). With this equipment, milk flow rates greater than 0.1 kg/min were recorded and graphed. The Lactocorders measured peak milk flow (kg/min) and milk yield (kg). Milking time was taken from the graphs, and average milk flow was calculated (milk yield/milking time). Upon initial examination, the affected teat was milked for only 1 min to prevent further injury. The remaining milk was drained with a milking tube and weighed. All unaffected quarters were milked out by machine.

To diagnose the cause of the milk flow disorder, we examined all affected teats by endoscopy (Medl et al., 1994; Querengässer, 1998, Eickemeyer, Tuttlingen, Germany). With the endoscopic findings, teats were classified into three groups as follows: 1) rupture of teat canal skin or muscle and connective tissue in the teat canal area without dislocation of tissue; 2) rupture in the teat canal area with dislocation of tissue (inversion or eversion), and 3) other. All milk flow disorders were treated surgically by removing dislocated tissue, dilating narrowed teat canals, or extracting free bodies from the teat cistern (Querengässer and Geishauser, 2001). After surgery, an antibiotic (600 mg of cefazolin; Merial, Halbergmoos, Germany) was administered into the teat cistern, either a silicone implant (SIMPL, profs-products.com, Germany) or a natural teat insert (NIT, profs-products.com, Germany) was inserted into the teat canal, the teat was bandaged and rested (not milked) for several days. Cows were reexamined 1 and 6 mo later in their herd of origin, and the teat was retreated if the herd manager reported low milk flow.

Statistics

The data were described as medians for continuous variables and as frequencies for categorical variables (descriptive statistics; Kreienbrock and Schach, 2000). Affected teats were compared to unaffected (control) teats. Then attempts were made to draw conclusions from the data (inductive statistics). Linear regression was used (Myers, 1990) to assess the effect of milk flow disorder (present/not present), and the effect of time relative to treatment (0 = before treatment, 1 = 1 mo later, 6 = 6 mo later) on peak milk flow, average milk flow, and milk yield (dependent variables). Because a square root-like course of the dependent variables was assumed after treatment in affected teats, an interaction term of milk flow disorder and the square root of the months after treatment were put into the model. The quarter milking time (s) and the time between milkings (min) were forced into the models to account for the differences during the initial examination. Other (explanatory) variables, known from the literature to affect the dependent variables, were offered to the

Table 2. Findings in teats affected or not affected with milk flow disorders; before treatment, as well as 1 or 6 mo after treatment.

	Examination before treatment				Reexamination 1 mo later				Reexamination 6 mo later			
	Affected quarter (n = 100)		Unaffected quarter (n = 297)		Affected quarter (n = 98)		Unaffected quarter (n = 291)		Affected quarter (n = 78)		Unaffected quarter (n = 233)	
Parameter	%	Median	%	Median	%	Median	%	Median	%	Median	%	Median
Days after initial examination						32		32		187		187
Teat tip to floor distance (cm)		46		47		48		48		47		47
Teat length (mm)		60		60		55		60		55		55
Teat tip thickness (mm)		14		13		14		13		13		12
Teat canal width (mm)		2		2		2		2		2		2.5
Teat canal length (mm)		10		9		9		9		10		9
SCC (1000 cells per ml)		2936		131		725		59		426		61
Pathogens detected	67		15		69		20		61		19	
Milkable by hand	76		100		100		100		97		100	
Milkable by machine	59		100		95		100		97		100	
Time between milkings (h.min)		7.30		7.30		11.45		11.30		11.00		11.30
Milked yield (kg)		0.11		1.33		1.38		2.30		1.66		2.30
Drained yield (kg)		1.38		0.00		0.00		0.00		0.00		0.00
Total yield (milked and drained) (kg)		1.50		1.39		1.55		2.30		1.66		2.30
Peak milk flow (kg/min)		0.14		0.63		0.44		0.63		0.49		0.63
Average milk flow (kg/min)		0.11		0.45		0.29		0.45		0.34		0.45
Milking time (min.s)		1.00		3.15		4.55		5.30		4.45		5.20

model and selected by a stepwise forward procedure. Effects of the individual cow (variable: cow) were adjusted for by using generalized estimation equations (Liang and Zeger 1986). The Statistical Analysis System (SAS, 1999) was used for computation. The P value was set at $P < 0.1$.

RESULTS

Descriptive Statistics

This study was performed predominantly on young brown Swiss cows, kept in tie-stall barns, and belonging to herds with a median herd size of 38 cows. Cows were at a median of 3 mo in milk and mostly pretreated. Predominantly hind teats were affected by an acute milk flow disorder (Table 1, Figure 1). In 96% of the affected teats, a rupture in the area of the teat canal was diagnosed (47% without tissue dislocation, 49% with tissue dislocation); in 4%, other causes were diagnosed such as papilloma and ruptures in the teat cistern area. Affected and unaffected teats seemed equal in teat tip to floor distance, teat length, teat thickness, teat canal length, and teat canal width (Table 2). Higher SCC were measured and pathogens were detected more frequently in milk samples from affected versus unaffected quarters. Upon initial examination, 59% of the affected teats were milkable by machine, peak milk flow was 22%, average milk flow 24%, milking time 33%, and milked yield was 8% compared with controls. However, the sum from milked and drained yield was 108% compared with controls. Upon reexamination 1 and 6 mo later, 95 and 99% of the affected teats were milkable by machine, respectively. Peak milk flow was 70 and 78%, average milk flow 64 and 76%, respectively, milking time 92% each time and the sum from milked and drained yield 67 and 72% compared with controls (Table 2).

Inductive Statistics

In the multivariable model, peak milk flow from teats with milk flow disorders was significantly decreased, with an average difference of 0.47 kg/min compared with control teats at the initial examination. Although peak milk flow increased after treatment, it may be an expected average of 0.14 kg/min lower than in control teats 6 mo later. Quarter peak milk flow was higher in free stalls than in tie stalls. It increased with lactation number, teat canal width, and time between milkings. It decreased with DIM, increasing teat canal length, and milking time. Quarters with high SCC showed lower peak milk flow (Table 3, Figure 2).

The average milk flow from affected teats was also significantly decreased with an average difference of 0.34 kg/min compared with control teats when examined initially. Again, although the average milk flow increased after treatment, it may be an exspected average of 0.11 kg/min lower than in control teats 6 mo later. Quarter average milk flow was higher in free stalls than in tie stalls, and increased with teat canal

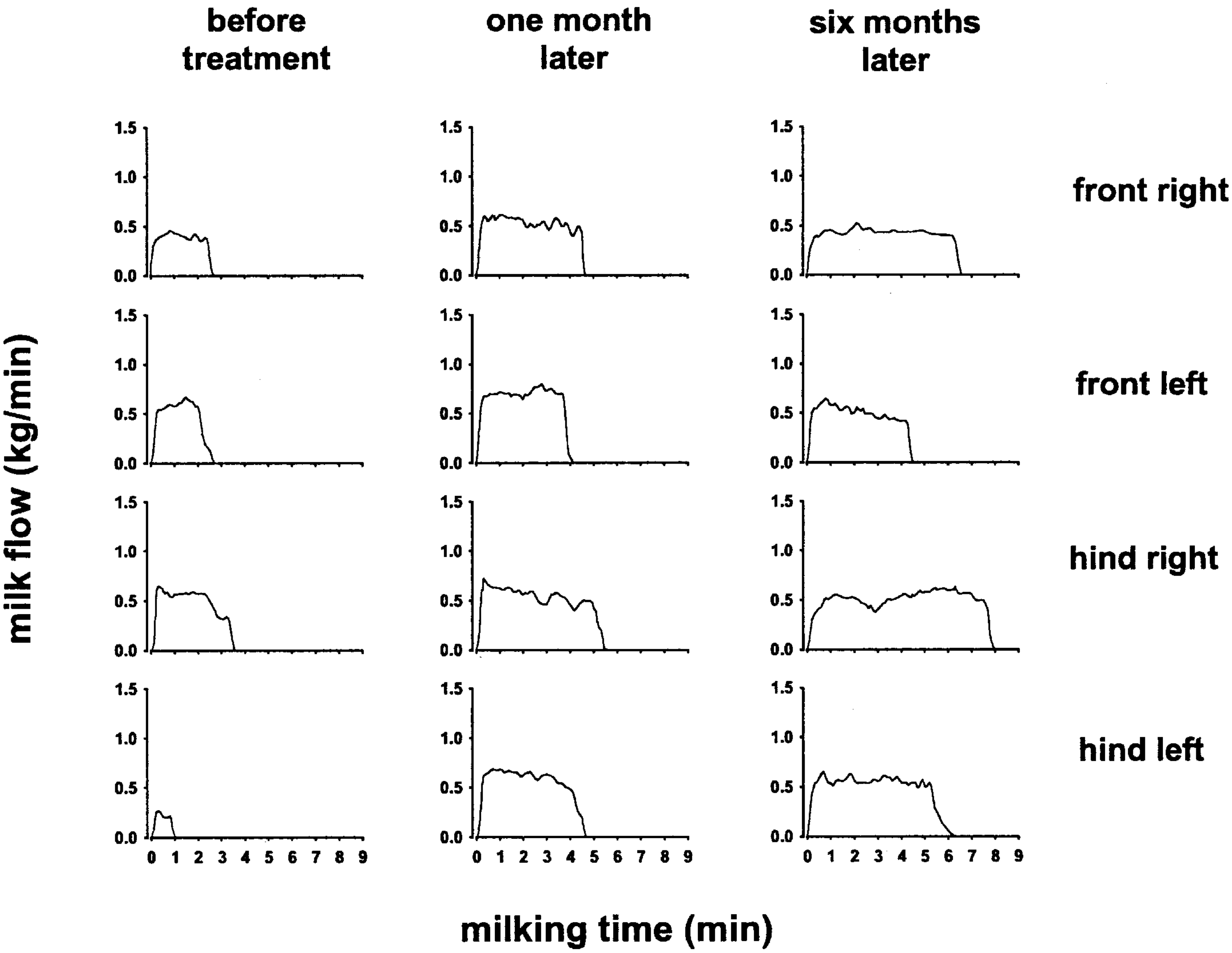

Figure 1. Milk flow curves of a Brown Swiss cow with a milk flow disorder in the hind left teat, before treatment, as well as 1 and 6 mo later. Note: Peak milk flow before treatment was 39% compared with the contralateral teat, and 98% 6 mo later.

Table 3. Model of the quarter peak milk flow (kg/min). Variables, estimates, standard errors (SE) and *P*-values are given.

Variable	Estimate	SE	*P*
Constant	0.562	0.046	0.00
Milk flow disorder (present vs not present)	–0.446	0.025	0.00
Month after treatment (n)	0.009	0.003	0.01
Milk flow disorder * month after treatment	–0.129	0.017	0.00
Milk flow disorder * square root of the month after treatment	0.453	0.044	0.00
Milking time (s)	–0.000	0.000	0.00
Time between milkings (min)	0.000	0.000	0.09
Free stall vs tie stall	0.077	0.012	0.00
Lactation (n)	0.016	0.004	0.02
Teat canal width (mm)	0.109	0.016	0.00
Days in milk (n)	–0.000	0.000	0.00
Teat canal length (mm)	–0.014	0.003	0.00
SCC (million cells per ml)	–0.011	0.002	0.01

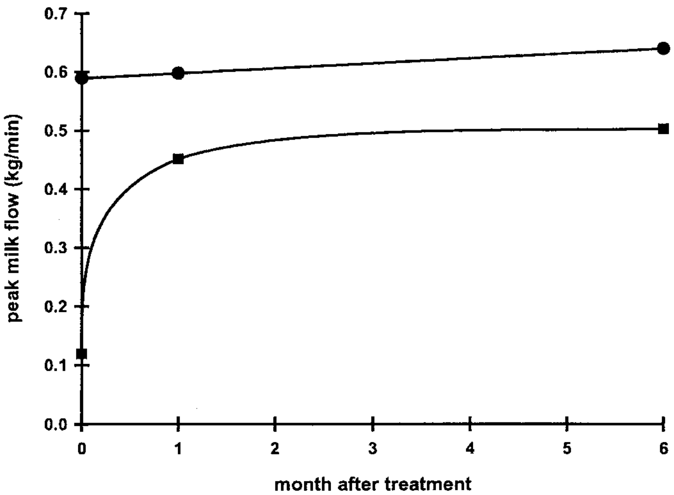

Figure 2. Peak milk flow from teats affected with a milk flow disorder (■) or from unaffected teats (●) before and after treatment. Calculated from the regression model for average cows kept in tie stalls.

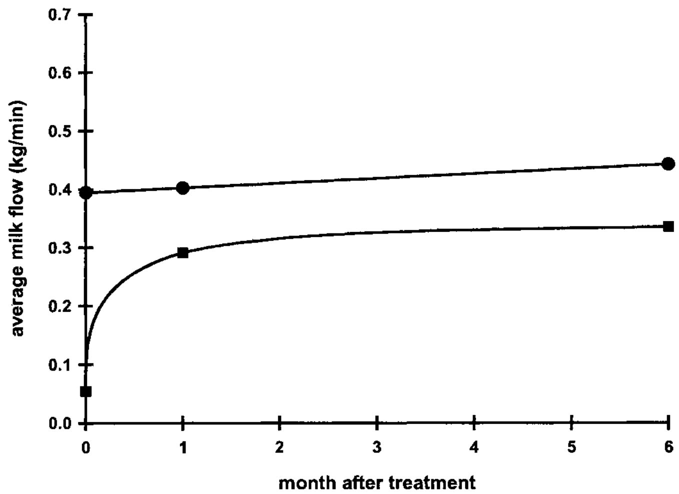

Figure 3. Average milk flow from teats affected with a milk flow disorder (■) or from unaffected teats (●) before and after treatment. Calculated from regression model for the hind teats of average cows kept in tie stalls.

width and with time between milkings. The average milk flow was lower from hind teats than from front teats, and decreased with DIM, and with increasing teat canal length and milking time. Quarters with high SCC showed lower average milk flow (Table 4, Figure 3).

Milk yield was significantly lower in quarters with milk flow disorders, with a predicted average difference of 0.76 kg compared with control quarters when initially examined. Had the affected quarter been milked as long as the unaffected quarters, then 0.85 kg may have been milked from the affected quarter, whereas unaffected quarters yielded on average 1.61 kg. During the whole study period, affected quarters yielded an estimated 227 kg less milk than unaffected quarters. It was to be expected that milk yield increased throughout the study period from affected as well as from unaffected quarters. However, 6 mo after treatment, the average milk yield from affected quarters is predicted to be 0.57 kg less than from unaffected quarters. Quarter milk yield was higher in free stalls than in tie stalls; it increased with lactation number, teat canal width, milking time, and time between milkings. Quarter milk yield was lower in Simmental than in other breeds, and decreased with DIM, increasing teat canal length, and SCC (Table 5, Figure 4).

DISCUSSION

The results of this study confirm the first research hypothesis in so far as peak milk flow and average milk flow from teats with milk flow disorders were lower than in unaffected teats when the cows were presented. This is in accordance with results of earler studies in which milkablility was measured with less precise

Table 4. Model of the quarter average milk flow (kg/min). Variables, estimates, standard errors (SE), and *P*-values are given.

Variable	Estimate	SE	*P*
Constant	0.520	0.037	0.00
Milk flow disorder (present vs not present)	–0.332	0.020	0.00
Month after treatment (n)	0.008	0.002	0.00
Milk flow disorder * month after treatment	–0.093	0.014	0.00
Milk flow disorder * square root of the month after treatment	0.322	0.035	0.00
Milking time (s)	–0.000	0.000	0.00
Time between milkings (min)	0.000	0.000	0.05
Free stall vs tie stall	0.056	0.009	0.00
Teat canal width (mm)	0.071	0.013	0.00
Hind quarter vs front quarter	–0.031	0.010	0.01
Days in milk (n)	–0.000	0.000	0.00
Teat canal length (mm)	–0.013	0.002	0.00
SCC (million cells per ml)	–0.010	0.002	0.00

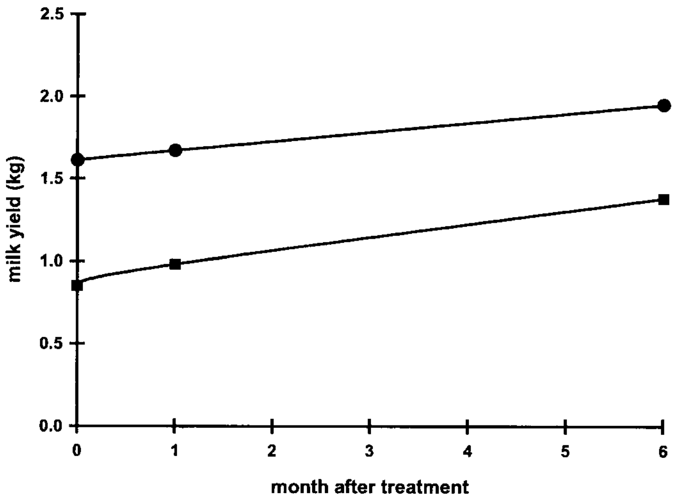

Figure 4. Milk yield from affected quarters (■) and unaffected quarters (●) before and after the treatment of a milk flow disorder. Calculated from the regression model for average Simmental cows kept in tie stalls. Note: Had the affected teat been milked as long as the unaffected teats, it would have given 0.85 kg.

methods (Querengässer and Geishauser, 1999). The predictions from the multivariable model may indicate that milk production in the affected quarters had decreased at the time cows were presented. A cause of the decreased milk production in the affected quarters may be that these quarters had not been milked out (Heidrich and Gehring, 1958; Burkhardt, 1985; Ebendorff et al., 1986) for 2 wk on average because of ruptures in the area of the teat canal. The nonaffected quarters may have compensated for some of the lower milk production in the affected quarter (Hamann and Reichmuth, 1990). However, this effect was difficult to assess in this study, because no data were available on quarter milk yields before the milk flow disorder had occurred. The causes of the milk flow disorders were easily and clearly diagnosed by endoscopy. The higher total milk yield (milked and drained) from the affected quarters on referral may indicate that milk had accumulated in the affected quarters, which may also be attributed to incomplete milk removal. Some (15%) of the affected quarters had not been milked at all on the morning before the cows were presented.

The second research hypothesis, however, was rejected because milk flow and milk yield from affected teats was still lower 6 mo after treatment than in unaffected teats. Milk flow returned closer to normal than milk yield. On average it may be expected that peak milk flow in affected teats will be 79%, and average milk flow 76% of unaffected teats 6 mo after treatment. Hence, half a year after treatment, peak milk flow may be 3.9 times higher than before treatment, and average milk flow 5.6 times higher. In accordance with other studies, milk flow was found to increase with age (Göft et al., 1994) and teat canal width (Grøhndahl, 1975; Wendt and Lüder, 1991; Bruckmaier et al., 1995) and decrease with DIM (Bruckmaier et al., 1995) and increasing teat canal length (Loppnow, 1959). However, in contrast to the results of this study, other studies reported that milk flow was higher from hind than from front quarters (Wellnitz et al., 1999), and increased with increasing SCC (Blake and McDaniel, 1978; Trede and Kalm, 1989; Göft et al., 1994; Bahr et al., 1995). The conflicting results may be explained by the fact that this study was performed on cows with impaired udder health, whereas others used cows with normal udder health. Further investigation is needed to determine why quarter milk flow is higher from cows in free stalls than in tie stalls.

It may also be expected that, half a year after treatment, quarters treated because of milk flow disorders will yield on average 29% less milk than unaffected quarters. This is in accordance with other reports that healthy quarters not milked for several days yielded 20 to 40% less milk than quarters milked without cessa-

Table 5. Model of the quarter milk yield (kg). Variables, estimates, standard errors (SE) and *P*-values are given.

Variable	Estimate	SE	*P*
Constant	0.272	0.174	0.25
Milk flow disorder (present vs not present)	–0.706	0.086	0.00
Month after treatment (n)	0.056	0.010	0.00
Milk flow disorder * square root of the month after treatment	0.078	0.052	0.10
Milking time (s)	0.004	0.000	0.00
Time between milkings (min)	0.001	0.000	0.00
Free stall vs tie stall	0.186	0.046	0.02
Lactation (n)	0.058	0.015	0.03
Teat canal width (mm)	0.300	0.062	0.00
Simmental vs other breeds	–0.159	0.056	0.07
Days in milk (n)	–0.002	0.000	0.00
Teat canal length (mm)	–0.031	0.011	0.03
SCC (million cells per ml)	–0.028	0.009	0.00

tion 3 wk after milking recommenced (Weichselbaum et al., 1995). This may indicate that the loss in milk yield from quarters affected with a milk flow disorder is due to incomplete milk removal. Other factors may also impact on quarter milk yield: In accordance with others, quarter milk yield was lower in Simmental than in other breeds (Göft et al., 1994), increased with age and decreased with days in milk (Grossman et al., 1999) and increasing SCC (Hortet and Seegers, 1998). Milk yield increasing with teat canal width and decreasing with teat canal length may be explained by the fact that wide and short canals favor milk flow. However, it is still unclear why cows in free stalls yield more milk than cows in tie stalls. The decreased milk volume from a quarter affected by a milk flow disorder may contribute an estimated economical loss of EUR 68 (= 227 kg × 0.3 EUR; 0.3 EUR/kg) in 6 mo, or EUR 11.4 (about 11 USD) per month. We conclude from these findings that teat endoscopy and measuring quarter milk flow and milk yield with Lactocorders are useful tools to examine teats with milk flow disorders.

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