Tenosis of the teat canal, caused by self-inflicted trauma or chronic injury secondary to milking machine malfunction, is common in dairy cows. In most cases, the stenosis is caused by obstruction in the region of the proximal end of the teat canal (Fürstenberg rosette) or the teat canal. The condition hinders the flow of milk and makes milking difficult. Furthermore, the condition causes economic losses because of decreased milk yield, greater risk of mastitis, and premature culling. Blind resection is routinely used to treat teat canal stenosis caused by FRO or TCO. Obstructive conditions involving the teat canal may be amenable to blind resection. However, complete removal of injured mucosa or fibrous tissue in the region of the Fürstenberg rosette is impossible to assess, and the recurrence rate with blind resection is almost 100%. This is likely because the proximal part of the teat canal, including the Fürstenberg rosette region, is less accessible and wider, compared with the middle and distal parts of the teat canal. In these circumstances, it may be necessary to excise the obstructing tissue through a thelotomy or under theoscopic guidance. Therefore, an accurate diagnosis of the location and severity of stenosis is essential prior to the initiation of the appropriate management strategies.

Ultrasonography and theloscopy have been used to diagnose and treat teat canal stenosis; however, these techniques are limited in their ability to evaluate the severity of milk-flow impairment. To our knowledge, there is no precise and objective method of assessing the milk-flow characteristics of the teat canal and no information is available regarding the difference in milk-flow characteristics between teats with FRO and TCO.
The study reported here was designed to assess the usefulness and reliability of a milk-flow measurement technique and the values obtained in unobstructed teats and teats with teat canal stenosis in dairy cows.

Materials and Methods

Animals—All procedures were performed in accordance with the Guide for the Care and Use of Laboratory Animals of the School of Veterinary Medicine at Rakuno Gakuen University and the National Research Council (1996).  

Six lactating and 10 nonlactating Holstein cows with a mean ± SD body weight of 580.9 ± 60.5 kg were used. They ranged in age from 3 to 10 years, with a mean ± SD age of 4.6 ± 1.9 years. The inclusion criteria were generally good health and the presence of 1 or more unobstructed or partially obstructed teat canals. Teats from inflamed udders, those with positive results of a modified California mastitis test, and those with complete obstruction of the teat canal were excluded from the study. Teats from lactating cows were assessed via hand milking and classified as unobstructed and easy to milk by hand or partly obstructed and difficult to milk by hand. Teats from nonlactating cows were assessed by infusing saline (0.9% NaCl) solution into the teat cistern through the teat canal and milking by hand and classified as unobstructed, easy to fill the teat cistern with saline solution, and easy to milk by hand or as partially obstructed, easy or difficult to fill the teat cistern with saline solution, and hard to milk by hand. Partially obstructed teats were further categorized according to the anatomic location of the obstruction via ultrasonography into TCO and FRO. Ultrasonography of individual teats was performed on the basis of a described technique by use of a 7.5-MHz linear array transducer. Unobstructed teats were also examined ultrasonographically to confirm the absence of abnormal findings.

Milk-flow measurement procedure—Prior to conducting the study, the cows were properly restrained in a squeeze chute. The teats were cleansed thoroughly and prepared aseptically. Following the application of a rubber ring at the base of the teat, a ring block was performed immediately proximal to the rubber ring with 2 mL of 2% lidocaine hydrochloride solution. The pressure-measuring device (Figure 1) included 2 22-gauge, 1.25-inch intravascular cannulae, designated as cannula A and B, that were placed with the point directed toward the base of the teat, through the cranial and caudal wall of the teat, respectively. The proximal end of cannula A was connected to a disposable pressure transducer through which pressure variations were measured and simultaneously displayed and recorded in a pressure-recording system, whereas the proximal end of cannula B was connected to a syringe containing saline solution for infusion. The pressure transducer was zeroed at the level of the tip of cannula A after emptying the teat cistern by hand stripping immediately before each measurement. After proper placement of the cannula tips was confirmed via palpation, saline solution was manually infused through cannula B at a rate of 0.5 mL/s until a stream of saline solution was observed through the teat canal. This was described as the PSL. Once saline solution leakage was observed, infusion of saline solution was terminated and PCL was recorded. The reliability of the technique was assessed by comparing the PSL and PCL values of unobstructed and partially obstructed teats from 2 measurements within 1 session. Testing was performed by 1 examiner.

Statistical analysis—Data on PSL and PCL are presented as mean ± SD. Among unobstructed teats, significant differences in PSL and PCL among quarters in lactating and nonlactating cows were analyzed via 1-way ANOVA with a post hoc test (Tukey-Kramer multiple comparisons test). Significant differences in PSL and PCL between lactating and nonlactating cows were analyzed by use of an unpaired t test after an F test if no significant difference existed among quarters. To assess test-retest intrarater reliability, the intraclass correlation coefficient, 95% confidence intervals, and a paired Student t test were used. The mean PSL and PCL values among unobstructed, TCO, and FRO teats were analyzed via 1-way ANOVA with a post hoc test (Tukey-Kramer multiple comparisons test). Differences were considered significant at P < 0.05.

Results

Forty-three unobstructed, 10 partially obstructed, and 8 completely obstructed teats were determined by use of hand milkability assessment. Three teats were excluded because of mastitis. Ultrasonography revealed no abnormal findings in 43 unobstructed teats. Of the 10 partially obstructed teats, 6 had fibrotic proliferation around the Fürstenberg rosette, blocking the internal orifice of the teat canal and indicating FRO, whereas the other 4 had an irregular and thickened teat canal, suggesting TCO (Figure 2).

In lactating and nonlactating cows, the PSL and PCL values among unobstructed quarters were not signifi-

![Figure 1](https://via.placeholder.com/150)

Figure 1—Schematic illustration of a teat pressure-measuring apparatus used in dairy cows. Saline = Saline (0.9% NaCl) solution.
ly different. Similarly, there were no significant differences in the PSL and PCL values between lactating and nonlactating cows (Table 1).

Fifty-one teats were used to assess the reliability of the measurement. Two unobstructed teats were excluded because of dislodgement of the cannula after the first measurement. Mean PSL and PCL values between the test and retest were not significantly different. Significant correlations were detected for PSL (intraclass coefficient, 0.94; 95% confidence interval, 0.90 to 0.96) and PCL (intraclass coefficient, 0.92; 95% confidence interval, 0.86 to 0.95).

Teats with TCO and FRO had significantly higher PSL and PCL values, compared with unobstructed teats. Teats with FRO had significantly higher PSL but lower PCL than did teats with TCO (Table 2).

Discussion

The PSL and PCL values did not differ among quarters nor between lactating and nonlactating cows with unobstructed teats. These results suggest that measurement of PSL and PCL is feasible for assessing milk flow in lactating and nonlactating dairy cows. The high degree of test-retest correlation in both PSL and PCL suggests that the measurement process is stable and consistent. Hence, the present technique is a useful and reliable means of assessing the milk-flow characteristics of the teat canal. Results indicated that the milk-flow pattern varied between teats with TCO and FRO. Teats with FRO had a higher PSL but lower PCL, compared with TCO teats, indicating that the PSL and PCL might be valuable variables to discriminate between FRO and TCO. These results encourage the pursuit of future studies with larger numbers of cases.

The milk-flow variables PSL and PCL provided an excellent assessment of teat canal stenosis. By use of the present measurement technique, the teat canal is opened by applying sufficient intracisternal pressure to stretch the smooth muscle fibers surrounding the teat canal and is closed by the elastic fibers once the pressure is reduced. Early studies suggested that the teat canal is surrounded by a sphincter system intended to open and close the teat canal. Later, van der Merwe concluded that the concept of a sphincter system surrounding the teat canal should be substituted by the concept of a musculoelastic system that facilitates the closing and opening of the teat canal depending on the elastic fibers, smooth muscle fibers, and level of intracisternal milk pressure. According to Pounden and Grossman, the elastic tissues play an important role in maintaining closure of the teat canal. Consequently, the PSL reflects the extensibility of the muscles around the teat canal, whereas the PCL reflects the elasticity of the muscle. However, structural problems such as obstruction at the level of the Fürstenberg rosette or the teat canal may physically block the flow of milk, thereby affecting these milk-flow variables. Results of the present study provide evidence that teat obstruction can be readily detected as indicated by significantly higher PSL and PCL values in obstructed teats, compared with unobstructed teats.

Despite the general clinical awareness that teat canal stenosis is common, no efforts have been made to define this condition. The present technique was able to

Table 1—Mean ± SD PSL and PCL of unobstructed teats in 6 lactating and 10 nonlactating cows.

<table>
<thead>
<tr>
<th>Teat</th>
<th>Lactating</th>
<th>Nonlactating</th>
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<tbody>
<tr>
<td>A</td>
<td>57.2 ± 11.0</td>
<td>57.5 ± 19.6</td>
</tr>
<tr>
<td>B</td>
<td>74.5 ± 7.9</td>
<td>59.5 ± 16.6</td>
</tr>
<tr>
<td>C</td>
<td>64.1 ± 38.4</td>
<td>59.6 ± 20.4</td>
</tr>
<tr>
<td>D</td>
<td>80.1 ± 24.9</td>
<td>62.5 ± 21.5</td>
</tr>
<tr>
<td>Mean</td>
<td>68.9 ± 23.1</td>
<td>59.3 ± 18.2</td>
</tr>
</tbody>
</table>

Table 2—Mean ± SD PSL and PCL values of unobstructed teats and teats with FRO and TCO.

<table>
<thead>
<tr>
<th>Group</th>
<th>PSL (torr)</th>
<th>PCL (torr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unobstructed teat</td>
<td>63.4 ± 20.7</td>
<td>41.2 ± 17.0</td>
</tr>
<tr>
<td>TCO</td>
<td>136.0 ± 46.8*</td>
<td>105.6 ± 42.4*</td>
</tr>
<tr>
<td>FRO</td>
<td>184.0 ± 51.1*</td>
<td>69.5 ± 14.2*</td>
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*A significant \( P < 0.05 \) difference from unobstructed teats.
define the milk-flow characteristics of teat canal stenosis by measurement of the degree of milk-flow impairment in teats with FRO and TCO. Results indicated that teats with FRO had higher PSL than those with TCO, suggesting that stenosis of the teat canal from FRO may cause a more severe impairment of milk flow than will TCO. Aside from the muscle bundles and elastic fibers, the Fürstenberg rosette serves to block the teat canal between milkings. A slight fibrosis of a portion of this structure may greatly interfere with milking. The lower PCL values in teats with FRO, compared with TCO, could be attributed to the location of the obstruction in the teat canal. Considering that the distal and middle regions of the teat canal are narrower than the proximal region, the presence of an obstructive condition at the more distal part of the canal may lead to premature closure once the intracisternal pressure is reduced.

Teat canal stenosis has been diagnosed via ultrasonography and theloscopy; however, whether the problem is extensive enough to affect milk flow has not been investigated. Milk-flow measurement alone may fail to diagnose the location and extent of obstruction, but the use of ultrasonography greatly facilitated the diagnosis. Therefore, the milk-flow technique, if used in conjunction with ultrasonography, may give a more specific and accurate diagnosis and help determine appropriate treatment.

Several studies have been conducted by use of various methods to assess the milk-flow characteristics of the teat canal. Although previous studies have reported the amount of vacuum required to open the teat canal and assessed the positive pressure inside the teat during suckling, none have assessed the intracisternal pressure that needs to be applied when opening the teat canal. Williams and Meinhart have investigated the closing forces placed on the teat canal, but their method of canal dilation does not use the conventional means of opening the teat canal. The present technique overcomes the deficiencies of the previous methods of milk-flow assessment. Moreover, the ultimate objective of the present study, which was to develop a technique that may be used to objectively assess milk flow in teats with FRO and TCO, was different from those of previous studies.

The milk-flow pattern in teats with distal stenosis varies depending on the location of the obstruction. The technique of measuring intracisternal pressure is a useful and reliable means of assessing milk flow. In addition, this technique provides an excellent measure of the severity of teat canal stenosis and may provide an indicator of surgical success.

References