Short communication: Repeatability of measures of rectal temperature in dairy cows

O. Burfeind,*† M. A. G. von Keyserlingk,* D. M. Weary,* D. M. Veira,‡ and W. Heuwieser*†¹

*Animal Welfare Program, Faculty of Land and Food Systems, The University of British Columbia, 2357 Main Mall, Vancouver, BC, V6T 1Z4, Canada

†Clinic for Animal Reproduction, Faculty of Veterinary Medicine, Freie Universität Berlin, Koenigschweg 65, 14163 Berlin, Germany

‡Agriculture and Agri-Food Canada, Pacific Agriculture Research Station, Agassiz, British Columbia, Canada

ABSTRACT

Although taking body temperature by rectal thermometer is the method most commonly used to identify sick cows in the postpartum period, no data on the repeatability of this measure are available. The overall objective of this study was to evaluate variability of rectal temperatures in dairy cows considering different factors (intra- and interinvestigator repeatability, different thermometers, penetration depth into the rectum, and defecation). High coefficients of correlation ($r = 0.98$) and small differences between values of rectal temperatures (observer A = $39.3 \pm 1.0^\circ\text{C}$ and observer B = $39.4 \pm 1.0^\circ\text{C}$) provide evidence that rectal temperature was a repeatable measure in dairy cows. Testing was carried out using 4 different digital thermometers: GLA M750 (GLA Agricultural Electronics, San Luis Obispo, CA), MTI8101 (SES Scala Electronics, Stahnsdorf, Germany), MT1831 (Microlife AG, Widnau, Switzerland) and Domotherm TH1 (Uebe Medical GmbH, Wertheim, Germany). Thermometers were inserted into the rectum to a certain depth (GLA M750 and MTI8101 = 11.5 cm; MT1831 = 8.4 cm; Domotherm TH1 = 7.7 cm) and a measure was finished when a visual or acoustic signal was emitted by the thermometer. The measures could be influenced by the procedure itself (up to 0.5°C), type of thermometer (up to 0.3°C), and the penetration depth (11.5 cm or 6.0 cm in one of the experiments) into the rectum (up to 0.4°C difference between a penetration depth of 11.5 cm and 6.0 cm in one of the experiments). Differences in rectal temperature before and after defecation were minor ($<0.1^\circ\text{C}$). These results indicate that some care is required in generalizing rectal measures of body temperature.

Key words: dairy cow, rectal temperature, repeatability

The method most commonly used to identify sick dairy cows in the postpartum period is rectal temperature (Smith and Risco, 2005). Measuring rectal temperature for 5 to 10 d after calving has received attention in the past because of ease of implementation and low cost (Kristula et al., 2001) and has been incorporated into standard operating protocols for fresh cow management and disease intervention. Several studies demonstrating the efficacy of antibiotic treatment of postpartum metritis used rectal temperature thresholds as inclusion criteria (Drillich et al., 2001, 2006; Zhou et al., 2001). Among researchers, veterinarians, and producers, there is agreement that monitoring rectal temperatures during this critical period is a successful tool for the management of diseases (Smith and Risco, 2005).

Most authors define fever as a body temperature exceeding a predefined threshold and consider a single instance of a temperature above the threshold value an indication of illness. Threshold values of 39.4 and 39.7°C (Smith and Risco, 2005; Benzaquen et al., 2007; Wagner et al., 2007) distinguished between healthy cows and cows suffering from an infectious-related disease process.

Despite the common use of rectal temperatures, there is a lack of science-based information on the value or significance of measuring the rectal temperature as a diagnostic tool to identify infectious diseases in dairy cattle in the postpartum period (Benzaquen et al., 2007). Type I (fever when the animal is actually healthy) and type II (no fever when the animal is actually sick) errors were reported (Kristula et al., 2001; Sheldon et al., 2004; Wagner et al., 2007). A type I error can cause financial losses to the producer because a healthy animal is unnecessarily treated. A type II error leaves a beneficial treatment effect on health and performance unrealized and might constitute an animal welfare issue because a sick animal is not being treated.

No published study documents the repeatability of body temperature measured by rectal thermometer in dairy cattle. The objective of this study was to evaluate variability of rectal temperatures in dairy cows consid-

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¹Corresponding author: wolfgang.heuwieser@ubc.ca

ering different factors. Specifically, the objectives were 1) to determine intra- and interinvestigator variability of rectal temperature measurements; 2) to evaluate differences among 4 thermometers; and 3) to determine the effects of penetration depth into the rectum and defecation on measured body temperature.

Five experiments were conducted between January and April 2009 at the University of British Columbia Dairy Education and Research Centre (Agassiz, British Columbia, Canada). Cows were managed according to the guidelines set by the Canadian Council on Animal Care (1993) and were housed in postpartum group pens with sand-bedded freestalls. Cows were milked (approximately 0700 and 1700 h) and fed (approximately 0600 and 1600 h) twice daily. All measurements were performed between 0900 and 1100 h.

In experiment 1, rectal temperature was measured multiple times per cow by a single investigator using the same digital thermometer (GLA M750, GLA Agricultural Electronics, San Luis Obispo, CA) equipped with an angle probe (11.5 cm, 42°). The measurement was terminated when either a visual or acoustic signal was emitted by the digital thermometer, and the probe was retracted from the rectum. The thermometer was reset, the probe reinserted into the rectum, and the next measurement initiated. This general procedure of measuring rectal body temperature was the same in all 5 experiments. Any differences in protocol (e.g., penetration depth) are mentioned in the descriptions of the individual experiments. A total of 10 measures were completed within 5 ± 1 min/cow. For this experiment 33 cows were used, including 16 cows with a temperature above 39.4°C. For all measures the probe was inserted into the rectum such that the angle of the probe (located at 11.5 cm) had disappeared in the anus.

In experiment 2, the rectal temperature of 38 cows was measured by 2 investigators; 15 cows had temperatures above 39.4°C. The digital thermometer and the procedure used were identical to experiment 1. Both investigators measured the temperature twice and independently from each other. All 4 measurements were completed within 2 ± 0.5 min/cow.

Experiment 3 consisted of *in vitro* and *in vivo* phases to test the variation among different digital thermometers: GLA M750 (GLA Agricultural Electronics), MTI8101 (SES Scala Electronics, Stahnsdorf, Germany), Domotherm TH1 (Uebe Medical GmbH, Wertheim, Germany), and MT1831 (Microlife AG, Widnau, Switzerland). The *in vitro* phase used a water bath (GFL Gesellschaft für Labortechnik m.b.H., Burgwedel, Germany) filled with 16 L of water with a calibrated liquid-in-glass thermometer (validated by the Office of Legal Metrology of the State of Hessen, Germany; type E 0.1/0/50 DIN 12775; serial number 2253; verification

certificate 5–2253–81A) as a gold standard. The water bath was adjusted in 1.0°C increments from 35.0 to 42.0°C. This procedure was repeated 25 times per thermometer to provide 200 measurements per thermometer. The measurement was terminated and the values of the thermometers recorded when a visual or acoustic signal was emitted by the digital thermometer.

During the *in vivo* phase, a single investigator measured the rectal temperature of 37 dairy cows, including 10 with temperatures above 39.4°C. Rectal temperature was measured twice per cow with each of the 4 thermometers. The GLA M750 and the MTI8101 thermometers had an angle probe (42°). The distance from the tip of the sensor to the angle was 11.5 cm for both the GLA M750 and the MTI8101. The Domotherm TH1 and MT1831 were thermometers with straight probes. The distance from the tip of the sensor to the display was 7.7 and 8.4 cm for Domotherm TH1 and MT1831, respectively. The probe on the GLA M750 was made entirely of metal, whereas only the tip of the probe was metal on the MTI8101, Domotherm TH1, and MT1831 thermometers. All 4 thermometers were equipped with digital displays. The GLA M750 and the MTI8101 thermometers were made specifically for veterinary use, the MT1831 was recommended for use in both animals and humans, and the Domotherm TH1 was made for humans. For the measurements, the probe was inserted into the rectum such that the angle of the probe (located at 11.5 cm) disappeared into the anus (GLA M750, MTI8101) or up to the edge of the display (located at 8.4 cm for the MT1831 and at 7.7 cm for the Domotherm TH1). All 4 measurements were completed within 4 ± 1 min/cow.

In experiment 4, 1 investigator measured the rectal temperature of 33 cows (9 cows >39.4°C) with the MTI8101 thermometer, inserting the probe either 11.5 or 6.0 cm. Both measurements were conducted twice; all 4 measurements were taken within 2 ± 0.5 min/cow.

Experiment 5 tested the effect of defecation on rectal temperature. Temperature was measured twice before and twice after defecation in 20 cows using the GLA M750 thermometer. The temperature was measured first while the cows were lying. Cows were then gently encouraged to stand up. If cows defecated upon standing, the temperature was measured again. All 8 measurements were completed within 4 ± 1 min/cow.

All data were recorded in Excel (version 2003, Microsoft Office, Redmond, WA) and statistically analyzed with MedCalc software (version 10.1.3.0, MedCalc, Mariakerke, Belgium). Each rectal temperature was obtained by taking an initial measurement followed immediately by a second measurement. These 2 measures were averaged and the resulting mean used for further

Table 1. Correlation and differences of paired measurements between a calibrated liquid-in-glass thermometer and 4 digital thermometers using a water bath between 35.0 and 42.0°C¹

Thermometer ²	Coefficient of correlation		Difference of paired measurements		
	r	P-value	Mean $\pm$ SD (°C)	Paired <i>t</i>	P-value
GLA M750	0.99	<0.001	0.0 $\pm$ 0.1	5.39	<0.001
MTI8101	0.99	<0.001	0.0 $\pm$ 0.1	4.55	<0.001
MT1831	0.99	<0.001	0.0 $\pm$ 0.0	2.39	<0.05
Domotherm TH1	0.99	<0.001	0.1 $\pm$ 0.1	11.42	<0.001

¹The water bath was adjusted in 1.0°C increments from 35.0 to 42.0°C. This procedure was repeated 25 times per thermometer to provide 200 measurements per thermometer.

²Thermometer compared with a calibrated liquid-in-glass thermometer. GLA M750: GLA Agricultural Electronics, San Luis Obispo, CA; MTI8101: SES Scala Electronics, Stahnsdorf, Germany; MT1831: Microlife AG, Widnau, Switzerland; Domotherm TH1: Uebe Medical GmbH, Wertheim, Germany.

analysis. To determine intrainvestigator reliability, the minimum, maximum, differences, and coefficient of variance were calculated for each of the 33 cows. Pearson coefficient of correlation was calculated to determine the reliability between the 2 investigators. Relationships between the 4 thermometers and the influence of the 2 penetration depths into the rectum on temperature were evaluated by Pearson coefficients of correlation. Differences between investigators, thermometers, penetration depths, and temperatures before and after defecation were tested using paired *t*-tests.

Repeated measures by a single investigator (experiment 1) were consistent (mean $\pm$ SD = 39.5 $\pm$ 0.1°C; coefficient of variance = 0.2%), indicating a high repeatability. Within the 10 measurements on the same cow, the maximum difference varied between 0.1 and 0.5°C. The difference between lowest and highest rectal temperature was 0.5 and 0.4°C in 2 and 5 cows, respectively. For the remaining 26 cows, the difference between lowest and highest rectal temperature was 0.3°C or lower. Correlation between measures taken independently by 2 investigators (experiment 2) was high ($r = 0.98$; $P < 0.001$). The mean difference of the investigators was 0.1 $\pm$ 0.2°C (paired *t* = 2.77; $P < 0.01$). Overall, these data demonstrate a high repeatability of rectal temperature measurements within and between investigator(s). However, for some cows, the difference between lowest and highest rectal temperature was considerable (0.5°C in 2 cows and 0.4°C in 5 cows). The reason for these differences remains speculative. It was assumed that these differences were caused by the procedure of taking the temperature and not by a change of the body temperature of the animal.

Measures from all 4 digital thermometers were correlated to the calibrated liquid-in-glass thermometer (experiment 3 in vitro component; $r = 0.99$; $P < 0.001$) when measuring the temperatures of a water bath between 35 and 42°C. The mean differences between the liquid-in-glass thermometer and the 4 digital ther-

mometers were small (Table 1). The measures from the 4 different thermometers were highly correlated ($r = 0.94$ – 0.96 ; $P < 0.001$; Table 2) during the in vivo stage of experiment 3. The mean difference between thermometers varied from 0.1 to 0.3°C (Table 2; GLA M750 = 39.2 $\pm$ 0.7°C; MTI8101 = 39.3 $\pm$ 0.6°C; MT1831 = 39.0 $\pm$ 0.7°C; Domotherm TH1 = 38.9 $\pm$ 0.7°C). Agreement was high when both thermometers compared had either a short (MT1831 = 39.0 $\pm$ 0.7°C; Domotherm TH1 = 38.9 $\pm$ 0.7°C) or a long (GLA M750 = 39.2 $\pm$ 0.7°C; MTI8101 = 39.3 $\pm$ 0.6°C) probe (mean difference = 0.1°C). The effect of insertion depth was confirmed in experiment 4; measures taken at the 2 penetration depths were highly correlated (11.5 cm = 39.2 $\pm$ 0.8°C; 6.0 cm = 38.8 $\pm$ 0.7°C; $r = 0.95$; $P < 0.001$; $n = 33$), but the temperature was higher when the probe was inserted deeper into the rectum (0.4 $\pm$ 0.2°C; paired *t* = 10.33; $P < 0.001$).

Differences in rectal temperature before (38.6 $\pm$ 0.2°C) and after (38.5 $\pm$ 0.2°C) defecation were minor (i.e., experiment 5; 0.1 $\pm$ 0.2°C; paired *t* = 1.14; $P = 0.27$). In 2 cows the measured temperature was 0.3°C or higher before defecation, whereas in 3 cows it was 0.3°C or higher after defecation. In the remaining 15 cows, the difference before and after defecation was less than 0.3°C. The consistency of the manure was not systematically determined; however, all cows used had a normal manure.

The results indicated that rectal temperature can be measured repeatably in dairy cows. In some, albeit few, instances, the procedure itself can influence the result (up to 0.5°C). More importantly, the type of thermometer (up to 0.3°C) and the penetration depth into the rectum (up to 0.4°C) can bias the results. These factors may help explain why 1) a significant percentage of healthy cows occasionally have temperatures greater than 39.5 (26%) or 39.7°C (9%) in the first days postpartum (Smith and Risco, 2005; Benzaquen et al., 2007; Wagner et al., 2007), and 2) not all cows diagnosed

Table 2. Correlation and differences between paired measurements from 4 digital thermometers recorded on 37 dairy cows in experiment 2

Thermometer comparison ¹	Coefficient of correlation		Difference of paired measurements		
	r	P-value	Mean $\pm$ SD ($^{\circ}$ C)	Paired <i>t</i>	P-value
GLA M750 vs. MTI8101	0.96	<0.001	0.1 $\pm$ 0.2	2.44	<0.05
GLA M750 vs. MT1831	0.94	<0.001	0.2 $\pm$ 0.2	4.12	<0.001
GLA M750 vs. Domotherm TH1	0.96	<0.001	0.2 $\pm$ 0.2	7.45	<0.001
MTI8101 vs. MT1831	0.96	<0.001	0.2 $\pm$ 0.2	7.50	<0.001
MTI8101 vs. Domotherm TH1	0.96	<0.001	0.3 $\pm$ 0.2	10.84	<0.001
MT1831 vs. Domotherm TH1	0.96	<0.001	0.1 $\pm$ 0.2	2.48	<0.05

¹GLA M750: GLA Agricultural Electronics, San Luis Obispo, CA; MTI8101: SES Scala Electronics, Stahnsdorf, Germany; MT1831: Microlife AG, Widnau, Switzerland; Domotherm TH1: Uebe Medical GmbH, Wertheim, Germany.

with metritis have an instance of an elevated temperature when measured once per day (Benzaquen et al., 2007). Alternatively, endotoxins can be absorbed by the postpartum uterus in dairy cows (Peter et al., 1990). *Escherichia coli*, a common cause of metritis (Sheldon et al., 2008), might be a possible cause for endotoxemia, which can cause elevated rectal temperatures in dairy cows. Elevated rectal temperatures were not always observed in endotoxic cows (Andersen, 2003), thus providing a possible explanation as to why cows diagnosed with metritis failed to exhibit an elevated temperature when measured only once daily (Benzaquen et al., 2007). To develop individual-standard fresh-cow monitoring programs, treatment protocols at the herd level, and experimental protocols requiring body temperatures, veterinarians and dairy scientists should recommend measuring rectal temperature with the same thermometer and at the same penetration depth as part of the standard operating procedures. Furthermore, the results of this study confirm the necessity of additional, reliable indicators of illness besides a single temperature value above a certain threshold, as suggested by Kristula et al. (2001) and Sheldon et al. (2004). Further research should elucidate which combination of clinical signs, temperature threshold, and frequency of measurements per day can improve diagnostic performance in identifying sick cows postpartum.

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REFERENCES

- Andersen, P. H. 2003. Bovine endotoxemia: Some aspects of relevance to production diseases. *Acta Vet. Scand.* 98(Suppl.):141–155.
- Benzaquen, M. E., C. A. Risco, L. F. Archbald, P. Melendez, M.-J. Thatcher, and W. W. Thatcher. 2007. Rectal temperature, calving-related factors, and the incidence of puerperal metritis in postpartum dairy cows. *J. Dairy Sci.* 90:2804–2814.
- Canadian Council on Animal Care. 1993. Guide to the Care and Use of Experimental Animals. Vol. 1. E. D. Olfert, B. M. Cross, and A.A. McWilliam, ed. CCAC, Ottawa, Ontario, Canada.
- Drillich, M., O. Beetz, A. Pfutzner, M. Sabin, H. J. Sabin, P. Kutzer, H. Nattermann, and W. Heuwieser. 2001. Evaluation of a systemic antibiotic treatment of toxic puerperal metritis in dairy cows. *J. Dairy Sci.* 84:2010–2017.
- Drillich, M., M. Mahlstedt, U. Reichert, B. A. Tenhagen, and W. Heuwieser. 2006. Strategies to improve the therapy of retained fetal membranes in dairy cows. *J. Dairy Sci.* 89:627–635.
- Kristula, M., B. I. Smith, and A. Simeone. 2001. The use of daily postpartum rectal temperatures to select dairy cows for treatment with systemic antibiotics. *Bovine Pract.* 35:117–125.
- Peter, A. T., W. T. K. Bosu, and R. O. Gilbert. 1990. Absorption of endotoxin (lipopolysaccharide) from the uteri of postpartum dairy cows. *Theriogenology* 33:1011–1014.
- Sheldon, I. M., A. N. Rycroft, and C. Zhou. 2004. Association between postpartum pyrexia and uterine bacterial infection in dairy cattle. *Vet. Rec.* 154:289–293.
- Sheldon, I. M., E. J. Williams, A. N. A. Miller, D. M. Nash, and S. Herath. 2008. Uterine diseases in cattle after parturition. *Vet. J.* 176:115–121.
- Smith, B. I., and C. A. Risco. 2005. Management of periparturient disorders in dairy cattle. *Vet. Clin. North Am. Food Anim. Pract.* 21:503–521.
- Wagner, S. A., D. E. Schimeck, and F. C. Chend. 2007. Body temperature and white blood cell count in postpartum dairy cows. *Bovine Pract.* 42:18–26.
- Zhou, C., J. F. Boucher, K. J. Dame, M. Moreira, R. Graham, J. Nantel, S. Zuidhof, L. Arfi, R. Flores, G. Neubauer, and J. Olson. 2001. Multilocation trial of ceftiofur for treatment of postpartum cows with fever. *J. Am. Vet. Med. Assoc.* 219:805–808.