Skin temperature after surgery as indication for wound infection in cows

Faculty of Veterinary Medicine
Department Farm animal health

Student veterinary medicine
Robbert van Drie

Supervisor: Dr. R. Jorritsma

Introduction

Ceasarean Section is the most frequently performed surgery in cattle and small ruminants {{109 Hoeben, Dagmar 1997;}}. In the Netherlands, it is commonly practised to use pre- and postoperative antibiotics, in order to prevent wound infection or to reduce the severity of the consequences. For this indication Penicillin's and Aminoglycosides are used most often (resp. 60% and 12%){{113 De Bruyne,N. 2014;}}.

Preventive antibiotic therapy was also routinely applied at the faculty of Veterinary Medicine at the University Utrecht in surgeries for educational purposes. Cows undergoing an exploratory laparotomy (LP) or a Caesarean section (CS) had surgery under optimal conditions when it comes to sterility. In human medicine some clinical trials have shown that prophylactic administration of antibiotics are effective in preventing surgical-wound infections {{116 Classen, David C 1992;}}. Within veterinary medicine less research is been done on prophylactic use of antibiotics before surgeries, which raises the question of whether prophylactic antibiotic therapy is necessary and effective. Additional the public opinion is recently critical on the use of especially (unnecessary) prophylactic administration of antibiotics.

The prophylactic use of antibiotics is aimed to prevent wound infection or to reduce the consequences of inflammation. The degree of wound infection should be objectively measurable to distinguish between different severity of wound inflammation. In order to apply appropriate therapy without unnecessary use of antibiotics.

A quick diagnosis can lead to early necessary therapy, which results in limitation of the damage cause by the disease or in this cases wound infection{{106 Dewulf, J 2003;}}. Parameters used for the

detection of a wound infection are redness, warmth, soreness, swelling, and possibly outflow. Also fever can be an indication of an inflammation of the wound area or even peritonitis.

The primary objective of this study is to measure local thermo activity around the incision after a surgical procedure. Warmth in the wound area can be detected by measuring the skin temperature by infrared thermography. The skin temperature is influenced by, among other things, (patho-) physiologic processes in the skin or in deeper tissue layers of the body. Could the skin temperature be a predictive value for the occurrence of wound inflammation or infection?

Study design

This study was performed from April 2014 until July 2015. During this period 23 cows were used for a caesarean section for educational purposes and a total of 27 multiparous cows underwent an exploratory laparotomy. Cows were housed in a tie-stall facility at the farm animal clinic of the faculty veterinary medicine. The surgery and measurements before, during- and after the operation were performed by students working in pairs, as part of the curriculum of the master veterinarian medicine at Utrecht University. The educational surgery and pre- and post-operative care were all performed under supervision of a veterinary clinician.

In this clinical trial every cow was randomized categorized in protocol A or B. Cows undergoing an exploratory laparotomy were categorized in treatment with (Protocol A) or without (protocol B) prophylactic antibiotic therapy (see Table 1). Cows undergoing caesarean section, categorized in protocol A and B, both groups received prophylactic antibiotics. Cows categorized in protocol A were also treated with antibiotics postoperatively (see Table 2).

Table 1 (Protocol A (pre- surgery ampicillin therapy) and protocol B (no antibiotic therapy) for the exploration laparotomy during this study, from April 2014 until July 2015. Both groups receive meloxicam perioperative and don't receive post-surgery antibiotics).

	Protocol A	Protocol B
Pre- surgery antibiotics	5 grams ampicillin (IV) ***max 15 minutes before incision***	None
Post- surgery antibiotics	None	None
perioperative analgesic	Single intravenous Metacam (meloxicam) 10 mg / 100 kg BW. On indication repeat after 48 hours.	Single intravenous Metacam (meloxicam) 10 mg / 100 kg BW. On indication repeat after 48 hours.

Table 2 (Protocol A (pre- and post- surgery ampicillin therapy) and Protocol B (pre-surgery ampicillin therapy) for the caesarean section for educational purposes during this study, from April 2014 until July 2015. Both groups receive meloxicam perioperative and post-surgery antibiotics).

	Protocol A	Protocol B
Pre- surgery antibiotics	5 gram ampicillin (IV) ***max 15 minutes before incision***	5 gram ampicillin (IV) ***max 15 minutes before incision***
Post- surgery antibiotics	Beginning on the day of surgery for 3 days 11 mg / kg of ampicillin (IM) (Norobrittin)	None
Peri-surgery analgesic	Single intravenous Metacam (meloxicam) 10 mg/ 100 kg BW. On indication repeat after 48 hours.	Single intravenous Metacam (meloxicam) 10 mg / 100 kg BW. On indication repeat after 48 hours.

Data collection

The skin temperature was measured by Infra-red thermography (IR) with a Pro-series non-contact infrared thermometer (accuracy is between 1,5 and 2% or 1°C). The principle of IR-thermometry is based on the detection of electromagnetic waves. These waves are emitted by the body because of the temperature difference between body and ambient temperature. The thermal radiation from the body is related to the difference between body temperature and ambient temperature (height of delta T), body mass and the ambient temperature (Boltzmann law). The photons released by this process are detected by IR-thermometry {{106 Dewulf, J 2003;}}. IR skin temperature measurements were taken of multiple body locations every hour from 1 hour before surgery to 21.00 h on the day of surgery (day 0), and again multiple times on day 1 and 2 post-surgery. IR measurements were taken on the left flank of the cow in cases of a caesarean section or right flank in cases of a exploratory laparotomy as shown in appendix 1 *(Measure locations of the skin temperature within and outside wound area).* All IR temperature measurements were taken +/- 20 cm from the skin surface, on each of the ten body measure locations.

Measure locations skin temperature
Outside wound area
1 (8th rib) (1/2 incision height)
2 (2 cm above incision)
3 (under tuber coxae) (1/2 incision height)
4 (2 cm under incision)
Within wound area
5 (2 cm cranial of incision) (1/4 dorsal of incision)
6 (on the incision) (1/4 dorsal of incision)
7 (2 cm caudal of incision) (1/4 dorsal of incision)
8 (2 cm cranial of incision) (1/4 ventral of incision)
9 (on the incision) (1/4 ventral of incision)
10 (2 cm caudal of incision) (1/4 ventral of incision)

Table 3 Skin temperature measure locations outside and within the wound area.

Every measure moment contained 6 skin temperature (ST) locations inside the wound area (table 3 and appendix 1). Three other variables were measured every measure moment: the skin temperature outside the wound area on 4 locations, the rectal temperature and the ambient temperature.

The ambient temperature is measured in this study to observe a possible effect of this variable on the skin temperature. In the farm animal clinic the climate control system measures and regulates the air temperature. This recorded measurement has been written down every measure moment and used as ambient temperature. The rectal temperature is measured just after the skin temperature measurement whit a digital rectal thermometer (Microlife VT 1831) with a accuracy of 0,1°C (between 34°C and 42°C).

Measure moments

The measure moments for both caesarean section and exploratory laparotomy were the same. One hour before the surgery starts the first set of measurements will be done as described before (10 skin temperature measurements, 1 rectal temperature and ambient temperature measurement). After the surgery area and measure locations outside the wound area are shaved, the second set of measurements are carried out. The third measure moment, after local- (in case of a caesarean section) or paravertebral- (in case of an exploratory laparotomy) anaesthesia, were carried out. Every hour after the surgery was finished a set of measurements was done until 21:00. Day 1 after surgery a set of measurements will be carried out at 8:00, 10:00, 12:00, 15:00, 18:00 and the last measure moment will be 22:00. On the second day (day 2), three measure moments take place at 8.00, 12.00 and 16.00 (Appendix 2 for a total overview of all measure moments). From day three after surgery until the sutures have been removed, cows in this study get a clinical health check every morning between 8 and 10 o'clock, including the measurement of the rectal temperature. The rectal temperature is measured up to a maximum of 31 times from day 0 to 14 days after surgery.

Despite possible missing values we want to compare rectal temperature and skin temperature differences between cows in this study. To obviated this problem the term "increased temperature" is used when the mean rectal temperature over all rectal temperature measurements is above 39 °C or two (or more) single rectal temperature measurements are above the 39.5 °C. When there are missing rectal temperature measurements the cow can still be included in this study.

Data processing

DeWulf (2003)reported that the skin temperature of a pig is composed by several variables: the ambient temperature, humidity, location of the measurement, the weight and metabolic state of the animal. The blood circulation is differently on every part of the body {{106 Dewulf, J 2003;}}.

The skin temperature is determined and influenced by many variables. In order to measure only the influence of local inflammation on the skin temperature in the wound area, most of the other variables should be excluded. The entire body surface is exposed to the same external influences (air humidity, ambient temperature and even body metabolism). The difference between the skin temperature outside the wound area and within the wound area could be an indication of the blood flow and inflammation reaction or changes in the wound area. This value will be referred to in this study as Delta ST (Skin temperature within the wound area minus the skin temperature outside the wound area). The influence of the wound reaction on the thermo activity on different measuring locations is unclear. It is possible that measure locations can be excluded from the calculation of Delta ST.

Wound score

The skin sutures are removed 10 to 14 days after surgery. The aspect of wound is then rated on warmth, swelling, tenderness, attachments of the wound edges and possible inflammatory exudate. The wound response is expressed as a score of 1; 1,5; 2 or 3. Classification shall be **Wound score 1**. No or minor wound infection (possibly with emphysema). **Wound score 1,5.** Sings of wound infection reported until the sutures are been removed, no or minor wound infection on day 14 (possibly with emphysema). **Wound score 2.** Excessive wound infection (possibly with emphysema). **Wound score 3**. Severe wound infection (possibly with emphysema).

During the clinical health check, until day 10 to 14 post surgery, the wound area is checked for the presence of wound inflammation. When there are signs of excessive or severe wound infection during this period and no or minor wound infection is seen at the moment the sutures are removed, this cow reserves a wound score 1,5. In this study will be referenced to the term “with wound infection” and “without wound infection”. Cows with wound scores above 1 are categorized in the group with wound infection, animals with wound score 1 form the group without wound infection.

Statistics

Ordinal regression will be done using SPSS (IBM statics data editor: version 22), with the wound score (ordinal distribution) as dependent factor and protocol A or B as independent variable or factor. This regression is both performed for exploratory laparotomy and caesarean section for educational use. The efficacy of prophylactic antibiotic use is tested with this regression.

The correlation between elevated rectal temperature and higher wound score will be tested by a binary logistic regression using SPSS where the increased rectal temperature (fever) functioned as a dependent variable and the treatment protocol (A or B) and the degree of wound reaction (wound score) is tested as a predictive value.

By using the function Mixed Models in SPSS the correlation between skin temperature and the rectal temperature has been measured. In the same equation has been examined whether the skin temperature can be an indication for the degree of wound infection (wound score).

Results

Wound score

Caesarean section: 23 cows completed a caesarean section, 11 animals were treated according to protocol A (ampicillin prior and after surgery) and 12 animals according to protocol B (only Ampi-Dry® prior to surgery). 7 animals were given a wound score 2 (2 animals protocol A and 5 animals protocol B) and in 3 cows were categorized in wound score 3, the surgery incision was severely infected at the time of the sutures removal (one animal from protocol B, and two animals from protocol A) (see Table 4).

The difference in wound response between the two protocols (protocol A and protocol B) after a caesarea section was found not to be significant. The average wound score in group A (CS) was 1.55 and the average wound score in group B (CS) was 1.58.

(Table 4) Wound score of cows undergoing a Caesarea section in this study (total of 23 animals), cows divided in protocol A (pre- and post-surgery ampicillin therapy) and protocol B (pre-surgery ampicillin therapy). Wound score 1: No or minor wound infection. Wound score 2: Excessive wound infection. Wound score 3: Severe wound infection.

Total 23 animals	**Wound score** (day 10 to 14 post-surgery)		
Protocol	1	2	3
A (11 cows)	*7*	*2*	*2*
B (12 cows)	*6*	*5*	*1*

Exploratory laparotomy: A exploratory laparotomy was performed on 27 cows in this study, 14 cows treated with ampicillin pre-surgery (protocol A) and 13 cows received no antibiotic treatment (protocol B) (see Table 5).

2 cows showed minimal excessive signs of inflammation of the incision area, the ventral wound edges were slightly separated for a few millimetres. 5 out of the 24 animals (given a wound score of 1,5) had some inflammatory response during the post-surgery period. The inflammatory response in the cows which did received ampicillin IV prior to surgery appears to be less than the non-treated group (protocol B). The average wound score of Protocol A is 1.04 and Protocol B is 1.31.The difference in wound score between protocol A and B is not significant in both CS and LP surgery.

(Table 5) Wound score of cows undergoing an exploration Laparotomy in this study (total of 27 animals), cows divided in protocol A (pre-surgery ampicillin therapy) and protocol B (no antibiotic therapy). Wound score 1: No or minor wound infection. Wound score 1,5: Sings of wound infection reported until the sutures are been removed, no or minor wound infection on day 14. Wound score 2: Excessive wound infection.

Total 27 animals	**Wound score** (day 10 to 14 post-surgery)		
Protocol	1	1,5	2
A (14 cows)	*13*	*1*	
B (13 cows)	*7*	*4*	*2*

Rectal temperature as indication of wound inflammation

Caesarean section: The results in figure 1 indicated that the mean rectal temperature is higher, from the end of the day of caesarean section until the sutures were removed, in cows with wound reaction compared to cows without wound reaction. This is particularly evident around 7 to 10 days after surgery. Although the animals in the group with wound reaction had a higher rectal temperature before surgery.

Figure 1 Mean rectal temperature of all cows who underwent caesarean section (blue) and the average rectal temperature divided in animals with wound score 1 (without wound reaction: green) and cows with wound score 2 and 3 (with wound reaction: red) on different measure moments.

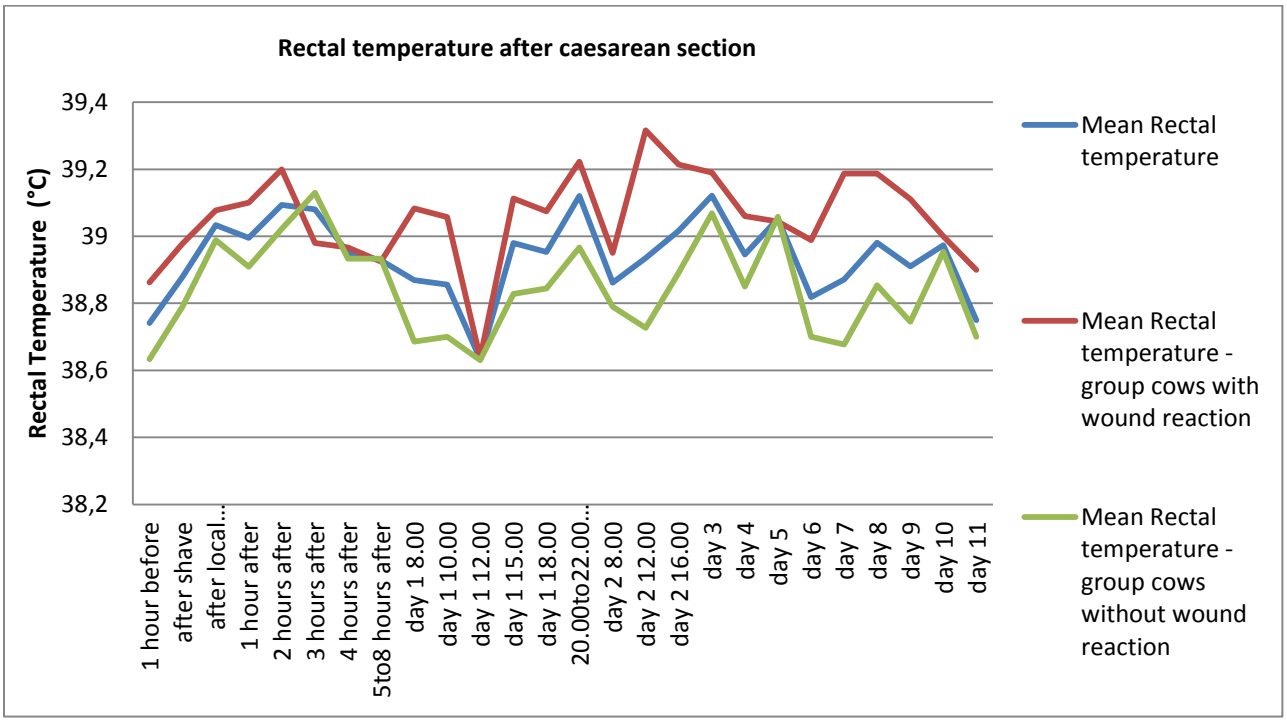
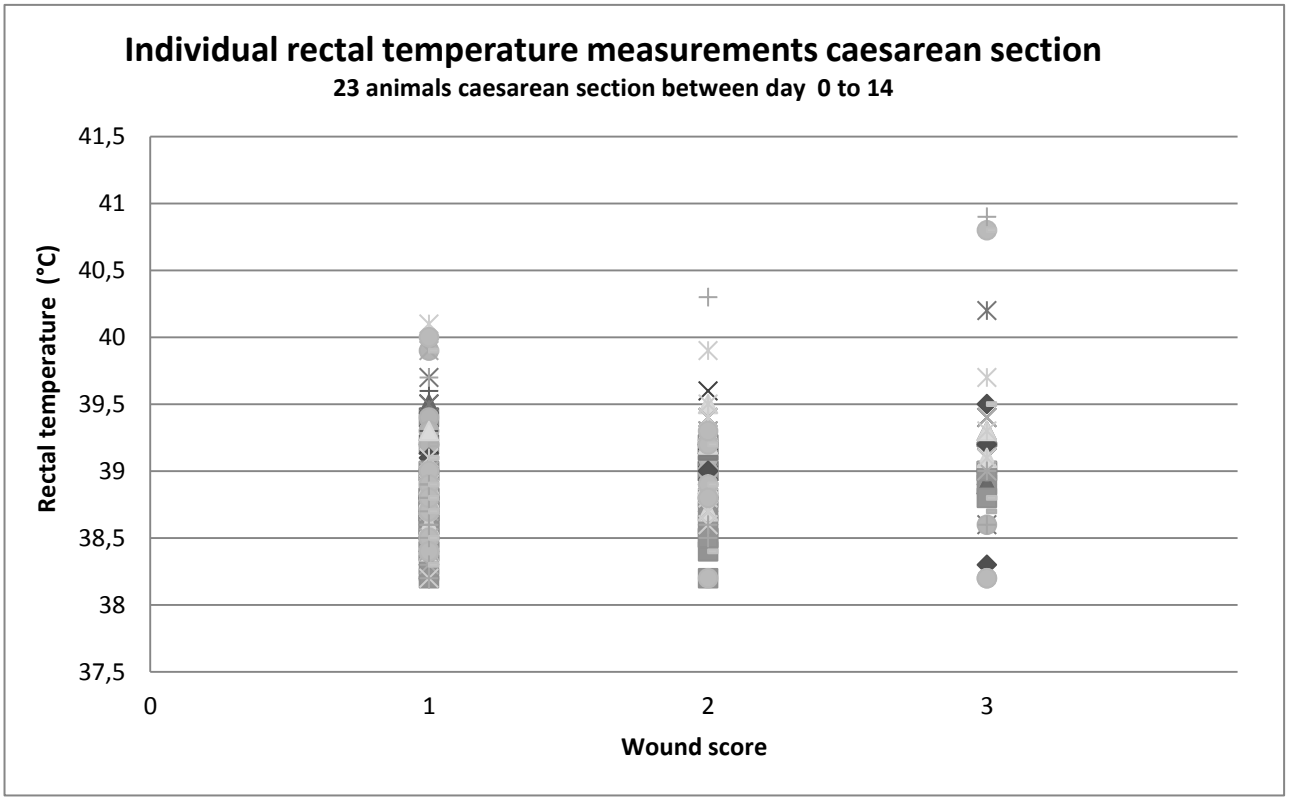
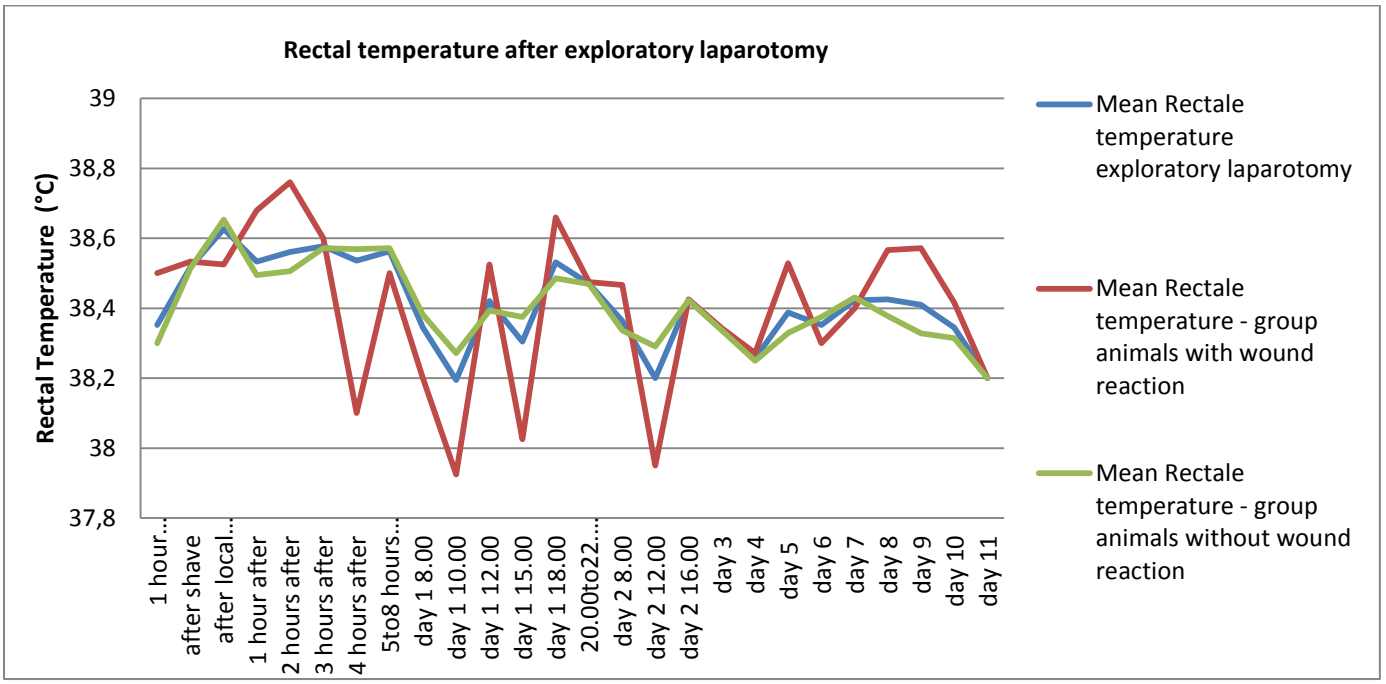


Figure 2 All individual rectal temperature measurements (group: caesarean section) of cows are classified on the basis of wound score. Data from 23 cows in 10 to 14 days of data collection. Wound score 1: No or minor wound infection. Wound score 2: Excessive wound infection. Wound score 3: Severe wound infection. Every single grey figure represent a cow.



The bottom of the variation in rectal temperature in all wound score groups are equal. The lowest measured rectal temperature in all three groups was 38.2°C. The average and maximum rectal temperature per group becomes higher with rising of the wound score. The mean rectal temperature of the cows with wound score 1 is 38.85 °C ± (+1.2°C and -0.7°C), the mean rectal temperature in cows with wound score 2 is 39.04°C ± (+1.4°C and -0.8°C) and in the group cows with wound score 3 the mean rectal temperature is 39.1°C ± (+1.8°C and -0.9°C).

Figure 3 Mean rectal temperature of all cows who underwent exploratory laparotomy and the average rectal temperature divided in animals with wound score 1 (without wound reaction) and cows with wound score 1,5 and 2 (with wound reaction) on different measure moments.



Exploratory laparotomy: Fluctuations of the rectal temperature over time are presented in figure 3. Generally, the lines in the graph of both exploratory laparotomy and caesarean section show an upward trend after the first measure moments. The elevated temperature in the group cows with wound reaction around day 8 to 11 was also observed in caesarean section.

The bottom of the variation in rectal temperature in all wound score groups was 37.5 °C after laparotomy. The average rectal temperature per group becomes lower with rising of the wound score. The mean rectal temperature after laparotomy of the cows with wound score 1 is 38.4°C ± (+0.9°C and -0.9°C), the mean rectal temperature in cows with wound score 1.5 is 38.39°C ± (+0.5°C and -0.9°C). Cows with excessive wound infection (wound score 2) had a mean rectal temperature of 38.32°C ± (+0.7°C and -0.8°C) (see figure 4 in appendix 3).

None of the cows which underwent an exploratory laparotomy had an elevated rectal temperature according to the earlier description of “elevated rectal temperature” in this study. The correlation between elevated rectal temperature and higher wound score could not be tested by a binary logistic regression using SPSS, in the absence of a dependent factor.

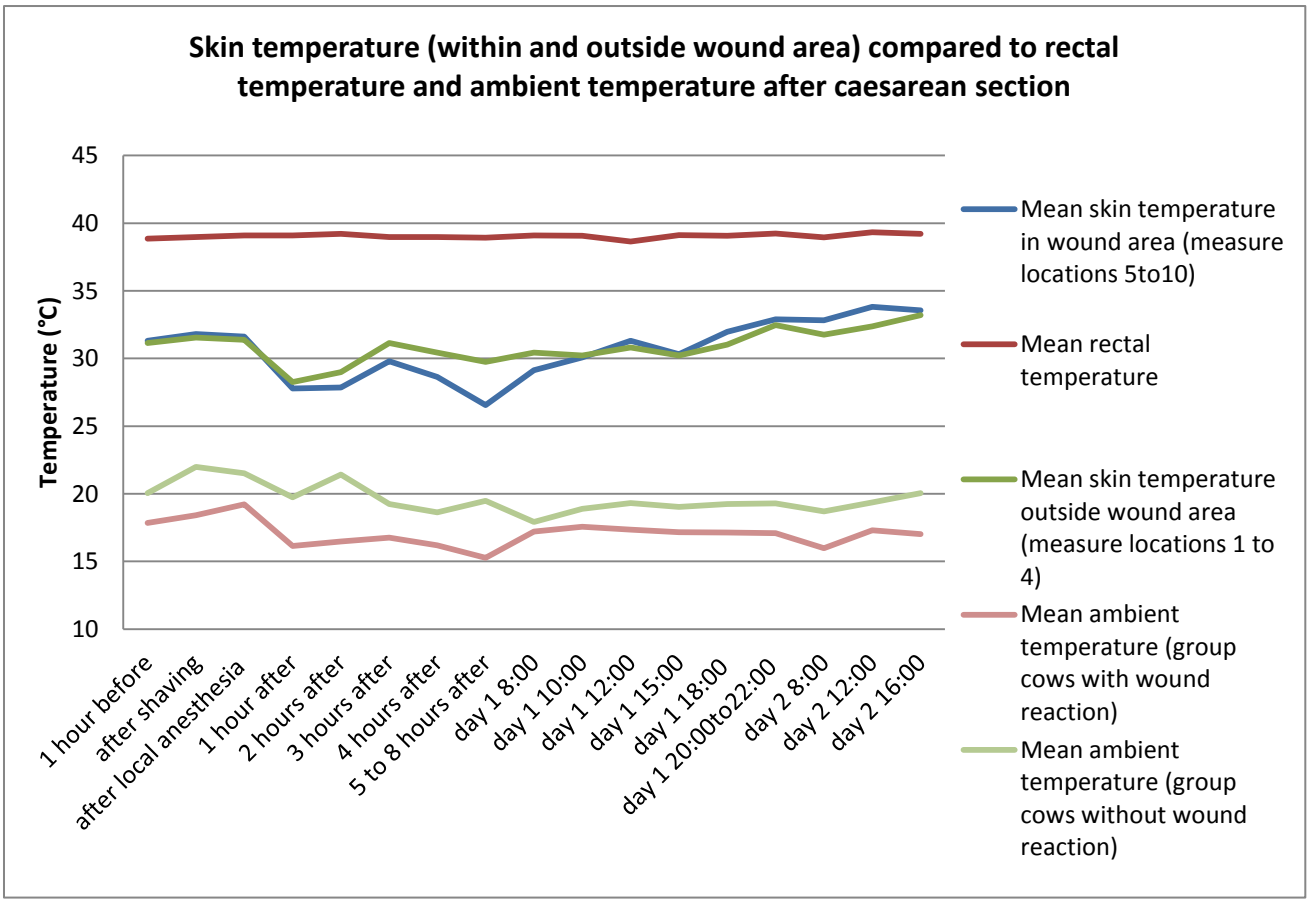
Caesarean section: A number of animals in the group of the caesarean section did show elevated rectal temperature (or fever). In total 12 of 23 cows had elevated rectal temperature after surgery. 5 animals out of the group with elevated rectal temperature had no wound reaction (wound score 1) when the sutures were removed. 5 cows had wound score 2 (extensive wound infection), the last 2 out of 12 cows had wound score 3 (severe wound infection). The binary logistic regression showed that there is no significant correlation between elevated rectal temperature and a wound score above 1 (0,164 sig. P-value).

9 out of 12 cows with elevated rectal temperature were treated according to Protocol A (pre- and post-surgery antibiotics). The correlation between protocol and elevated rectal temperature was not significant but a clear trend (0,056 sig. P-value).

Skin temperature as predictive value for wound infection

Caesarean section: An increase of approximately 6 degrees Celsius in skin temperature (within and outside the wound area) can be seen just after surgery until the end of day 2 post surgery. The maximum skin temperature after surgery is higher than the skin temperature before surgery, approximately 2 degrees Celsius (see figure 5). Figure 5 also shows that the average skin temperature outside the wound area is higher compared to the skin temperature within the wound area, from end of surgery until the start of measuring at day 1.

Figure 5 mean skin temperature within and outside the wound area compared to rectal- and ambient- temperature. 23 cows in the group caesarean section - total of seventeen skin temperature measure moments on ten locations.



Exploratory laparotomy: An increase of approximately 3 degrees Celsius in skin temperature can be seen just after surgery until the end of day 2. The maximum skin temperature after surgery is higher than the skin temperature before surgery, approximately 2 degrees Celsius (see figure 6). Unlike the skin temperature measurements after caesarean section: The skin temperature outside the wound area is not higher than the average skin temperature inside the wound area on any measure moment. Figure 6 also shows the variation between the skin temperature on different locations within the wound area. What should be notified, is the decrease of skin temperature after laparotomy on both measure locations 6 and 9 up to approximately 4°C.

Figure 6 skin temperature within the wound area on all 6 measure locations separated and the mean skin temperature outside the wound area. 27 cows in the group exploratory laparotomy - total of seventeen skin temperature measure moments on ten locations.

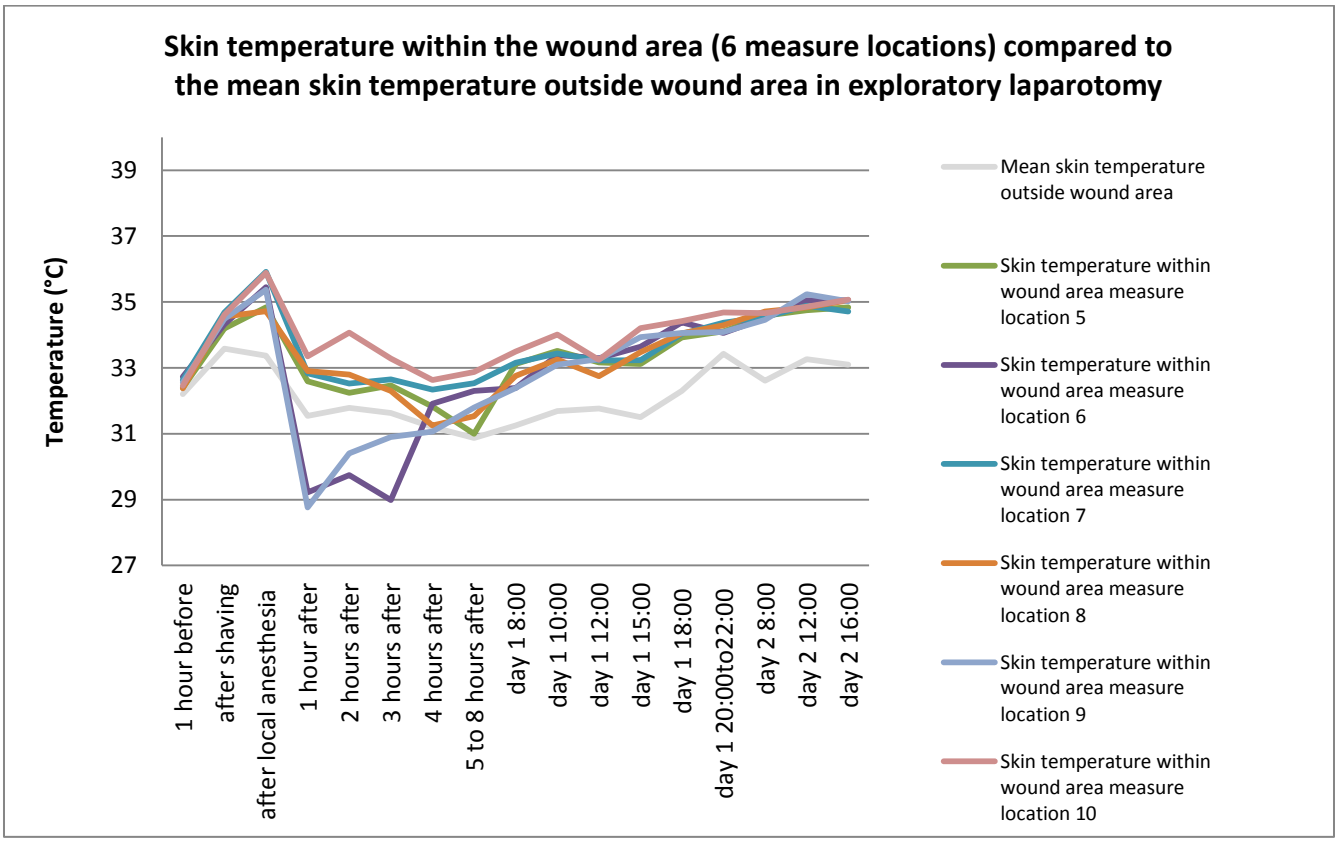


Figure 7 shows the skin temperature outside the wound area on all four measure locations. The skin temperature measured above and below the incision increases until the end of surgery to higher values compared to the other two measure locations outside the wound area (8th rib and under the Tuber coxae). From the start of measuring at day 1 after surgery the graph lines of all four go up.

Both figure 6 and 7 are skin temperature measurements before and after exploratory laparotomy. In the skin temperature data collected before and after caesarean section broadly the same appeared to happen with the skin temperature inside and outside the wound area. With the difference that the measurements at location 6 and 9 on the incision showed less decrease of skin temperature after surgery in cows which underwent a caesarean section.

Caesarean section: Figure 8 shows the variation in delta ST after caesarean section. ΔST = ST within wound area (location 5,7,8 and 10) – ST outside wound area (location 1 and 3). In order to perform the calculation of delta ST the skin temperature measure locations 2 and 4 outside the wound area are left out because it seemed that the skin temperature is affected by the surgical procedure. Skin temperature measure locations 6 and 9 are also not included in the calculation because the sharp decline of skin temperature after surgery (both caesarean section and exploratory laparotomy) are affected through the use of a wound dressing (this will be discussed in the discussion).

Figure 7 skin temperature outside the wound area all 4 measure locations separated and the mean skin temperature within the wound area. 27 cows in the group exploratory laparotomy - total of seventeen skin temperature measure moments on ten locations.

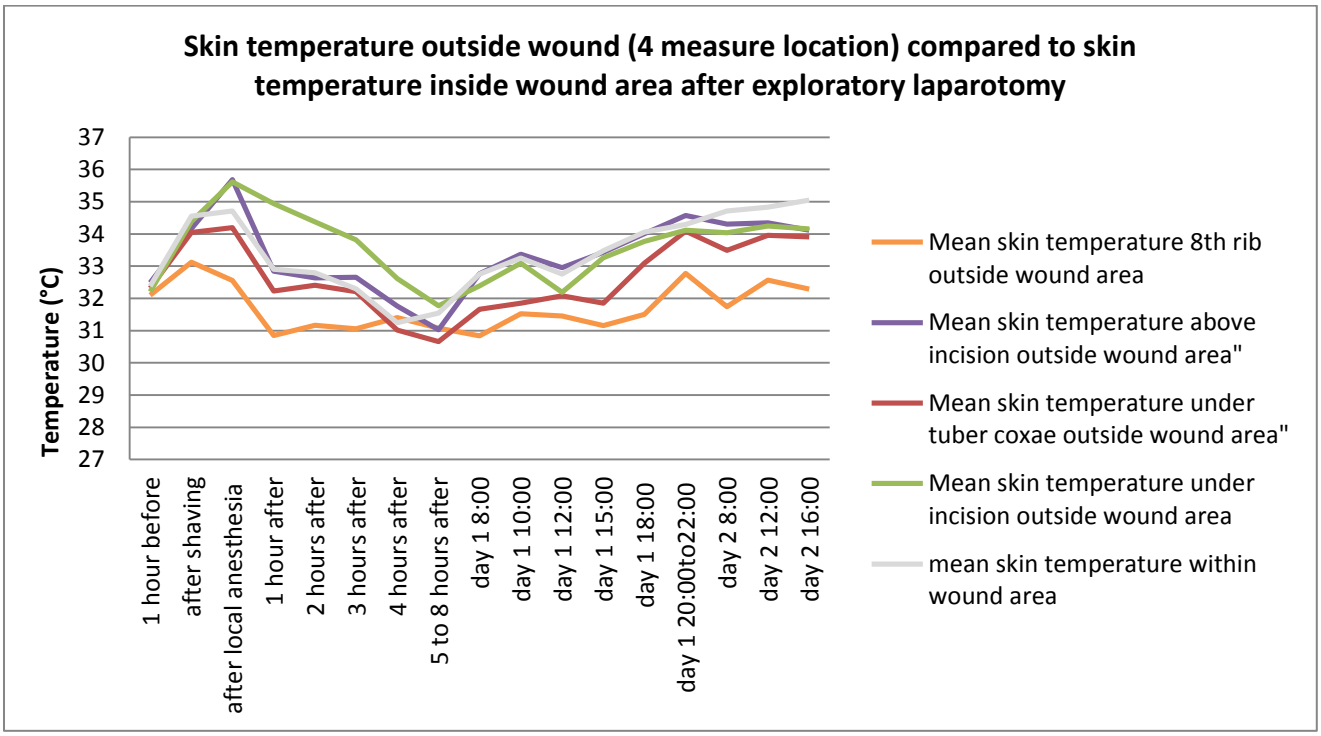
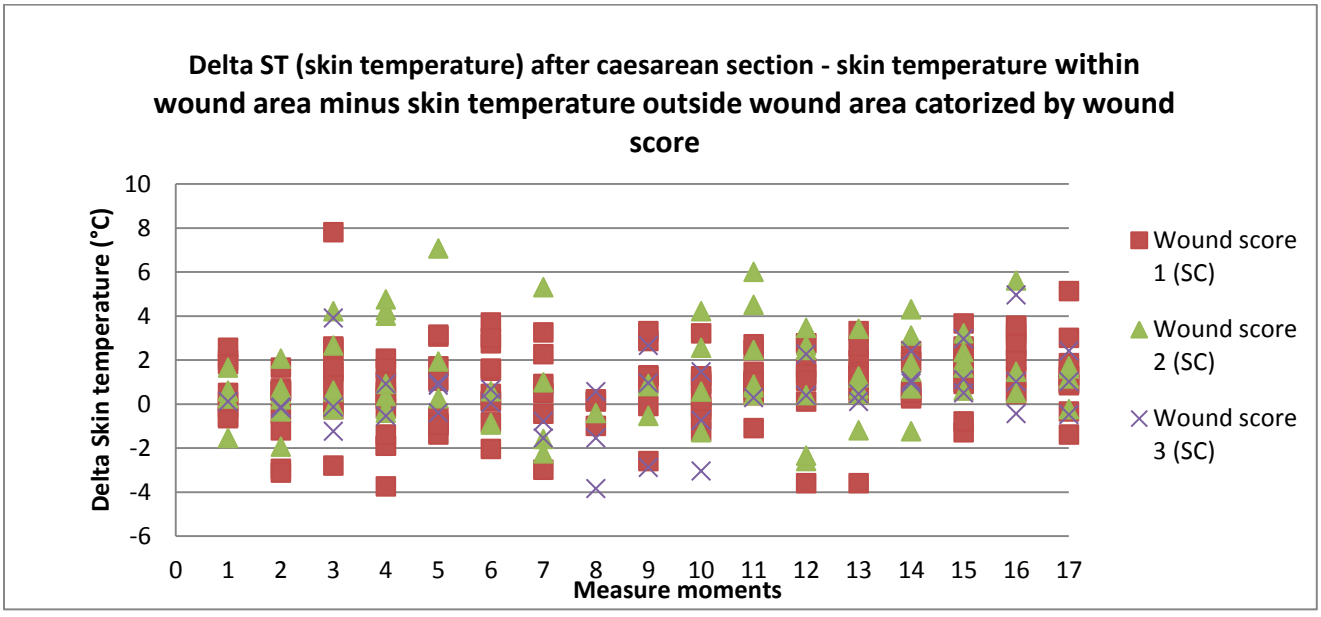


Figure 8 shows large variation of ΔST between measure moments of the same cows and within wound score groups. This variation can be as high as 11 degrees Celsius on the same measure moment within the same wound group. It was assumed that in increasing wound scores the ΔST would be higher. Because of the thermos activity of the wound infection on the skin within the wound area. Almost 40% of the cows with wound score 3 have a negative delta ST, more than cows with wound score 1 and 2.

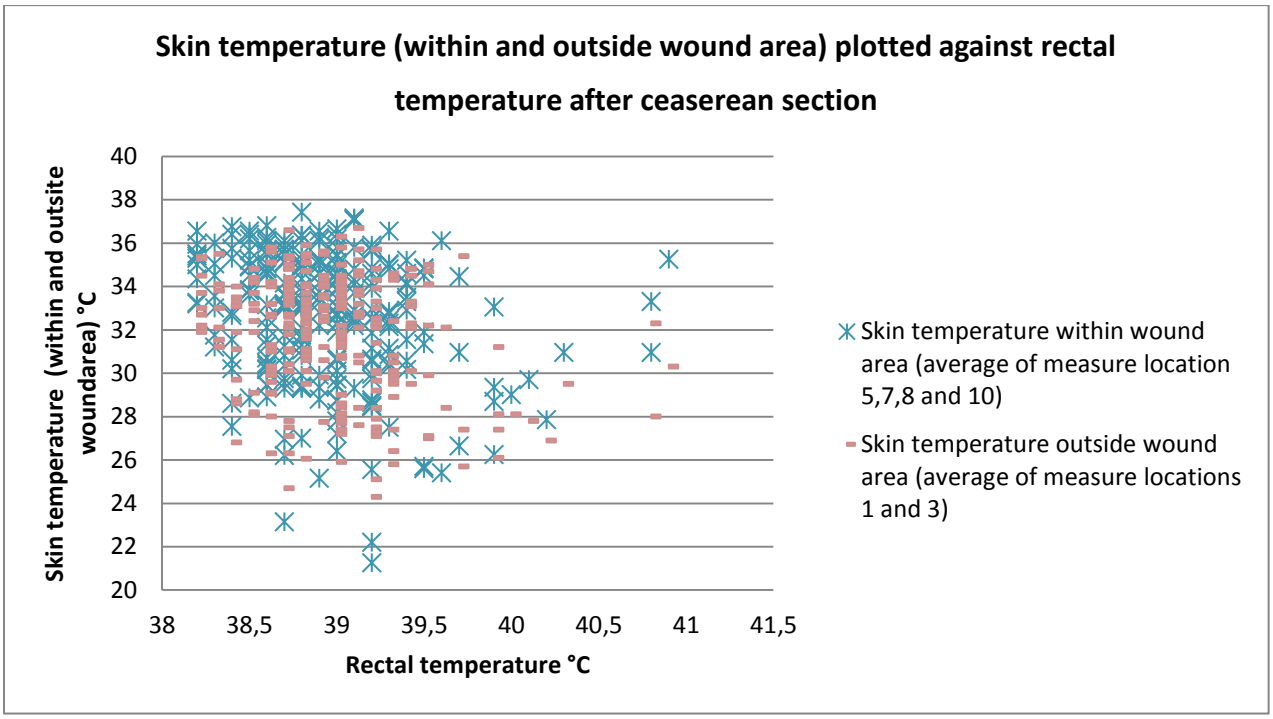
Figure 8 Delta skin temperature after caesarean section for all individual cows



Skin temperature as predictive value for rectal temperature

Caesarean section: The skin temperature measurements were always combined with rectal temperature measurements. Figure 9 shows all the skin temperatures measured on a specific rectal temperature measurement. There is a large variation, which can be up to 15 degrees Celsius, in skin temperature when the same rectal temperature was measured. The skin temperature within and outside the wound area have a similar distribution in the figure 9.

Figure 9 skin temperature outside the wound area average of 2 measure locations (1 and 3) and skin temperature within the wound area average of 4 measure location (5,7,8 and 10) plotted against the rectal temperature at those measure moments. 23 animals in the group caesarean section.



Exploratory laparotomy: figure 10 also shows a large variation in the measured skin temperature compared to the rectal temperature. The linear equation with a slight upward trend by the values of the skin temperature within the wound area seems not representative for the skin temperature within the wound area.

By using the function Mixed Models in SPSS the correlation between skin temperature and the rectal temperature was tested. Because there were several measurement points at one time in multiple locations SPSS mixed model didn't had any output. In the same mixed model the predictive value of the skin temperature for the degrees of wound infection was tested. Both these tested gave an error.

Figure 10 Skin temperature outside the wound area average of 2 measure locations (1 and 3) and skin temperature within the wound area average of 4 measure location (5,7,8 and 10) and the ambient temperature plotted against the rectal temperature at those measure moments. 27 animals in the group exploratory laparotomy.

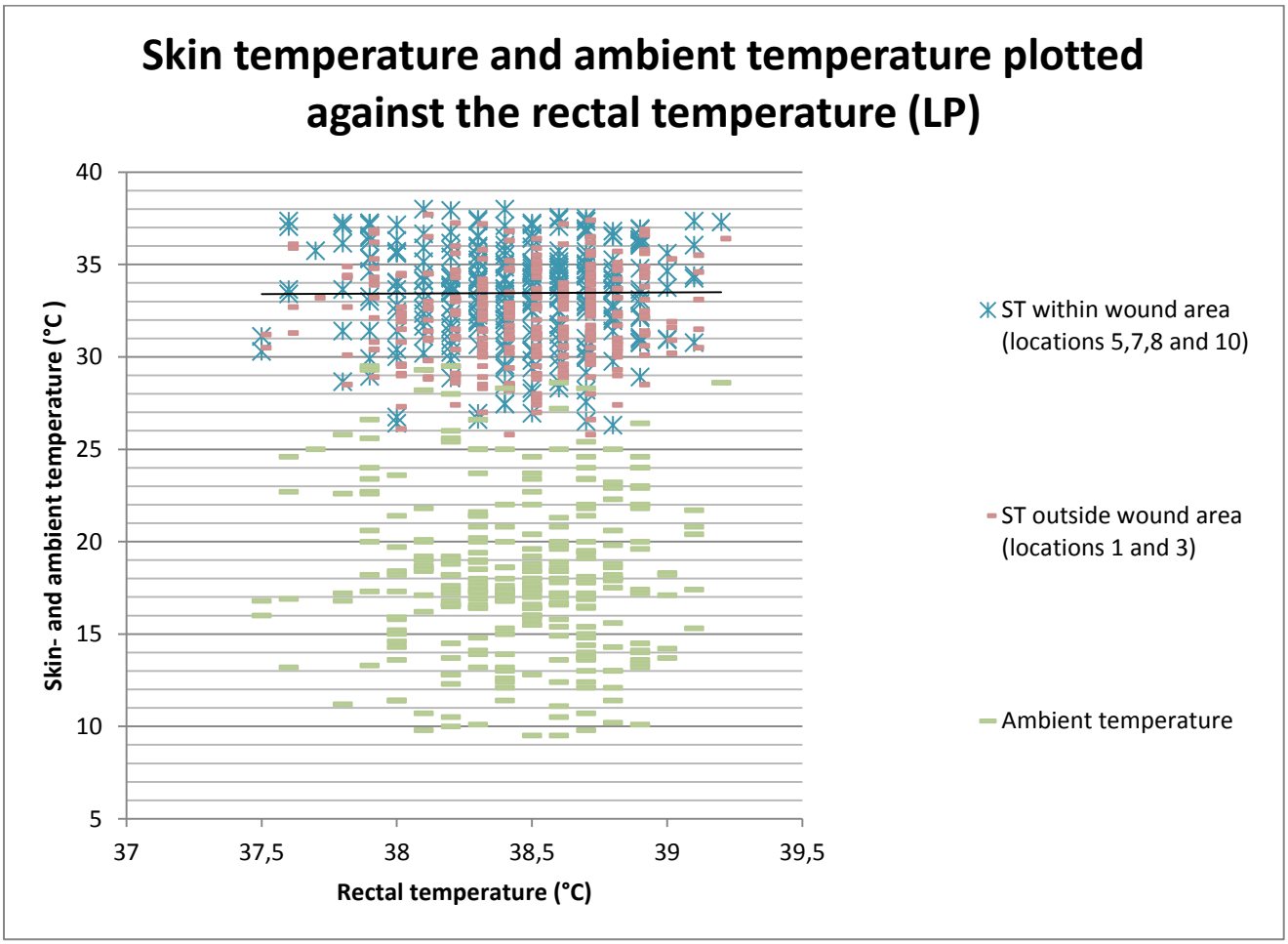


Figure 10 also shows the ambient temperature on every measure moment (first 3 day post-surgery) plotted against the rectal temperature of that particular measure moment. The ambient temperature fluctuated between 9 degrees Celsius (minimum) and 29 degrees Celsius (maximum). The average ambient temperature is 17,2 degrees Celsius.

Discussion

The objective of this research was to measure the skin temperature after surgery. And test the predictive value of the skin temperature on wound inflammation within this study. There should be any wound infection or reaction to be able to test this predictive value. The wound scores tended to be higher in both caesarean section and exploratory laparotomy in protocol B (tables 4 and 5), though there was no significant difference between protocol A and B. The assessment of the wound area 10 to 14 days after surgery (at least 7 days after last antibiotics gift) seemed not to be the most appropriated method to test efficiency of prophylactic antibiotic use.

The method most commonly used to identify sick dairy cows in the postpartum period is rectal temperature {{120 Smith, Billy I 2005;}}. Measuring rectal temperature for 5 to 10 d after calving has been incorporated into standard operating protocols for fresh cow management and disease intervention. A comparison between elevated rectal temperature and the occurrence of wound inflammation was not possible in the group animals which underwent a exploratory laparotomy, due to the absence of elevated rectal temperature in these cows. After caesarean section the elevated rectal temperature wasn´t significant correlated to wound infection. Animals with higher wound scores didn´t had elevated rectal temperature. That could indicate that wound infection doesn´t always result in a fever. Burfeind et al. 2000 concluded that a significant percentage of healthy cows occasionally have temperatures greater than 39.5 (26%) or 39.7°C (9%) in the first days postpartum {{119 Burfeind, O 2010;}}.

Earlier publication of Schaefer et al. (2004) who concluded that infrared thermography is a highly sensitive indicator for thermal changes of both rectal temperature and skin temperature, for example for the detection of BVD-virus infections. In this study the by IR thermography measured skin temperature shows a width. The reliability of its predictive value is questionable both for the occurrence of wound infection (figure 8) and rectal temperature (figure 9 and 10). Dewulf concluded that the way they recorded the skin temperature in piglets, with a point IR thermometer (just like the one we used in this study), on the same skin locations, the skin temperature could vary up to 9°C {{106 Dewulf, J 2003;}}.

The skin temperature is affected by many variables, which are difficult to be equalize between measurements and especially between patients. Moreover, it is well known that environmental temperature affects skin surface temperature {{118 Arp, SC 1983;}}. The ambient temperature, humidity, location of the measurement, weight and metabolic state of the animal. The blood circulation is different on every part of the body {{106 Dewulf, J 2003;}}. Bewley et al. (2008) reported that cows in early lactation had higher body temperature and metabolism compared to animals end lactation. Cows in early lactation also often suffer from infections like uterus and udder inflammation and these animals are most of the time in oestrus {{111 Bewley, JM 2008;}}. Cows from different breeds, age, production levels, body condition scores and immune status were used within this study. Which may increase the variation in skin temperature. None of this variable, except for the ambient temperature, was included in the analysis.

The data collection in this study was done by multiple students which increases the risk of errors in the collected data (wound score, rectal temperature and skin temperature). By working in pairs and doing control measurements, there has been tried to minimize this error. For example some students used a wound dressing after surgery to protect the incision for contamination. This may affect the

skin temperature measurements done whit the wound dressing still on. That's why measure location 6 and 9 weren´t included in the calculation of delta ST.

Conclusion

The variation between different skin temperature measurements in this study was too large to be a predictive value for both wound infection and rectal temperature. Environmental factors, the way of data collection and changes in cow metabolism may have an impact on the large variation of the skin temperature, rectal temperature and degree of wound infection.

Bibliography

1. Bewley, J., Einstein, M., Grott, M. & Schutz, M. Comparison of reticular and rectal core body temperatures in lactating dairy cows. *J. Dairy Sci.* **91**, 4661-4672 (2008).

2. Burfeind, O., Von Keyserlingk, M., Weary, D., Veira, D. & Heuwieser, W. Short communication: Repeatability of measures of rectal temperature in dairy cows. *J. Dairy Sci.* **93**, 624-627 (2010).

3. Classen, D. C. *et al*. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. *N. Engl. J. Med.* **326**, 281-286 (1992).

4. De Briyne, N., Atkinson, J., Pokludova, L. & Borriello, S. P. Antibiotics used most commonly to treat animals in Europe. *Vet. Rec.* **175**, 325 (2014).

5. de Greeff, S. & Mouton, J. Nethmap 2015: Consumption of antimicrobial agents and antimicrobial resistance among medically important bacteria in the Netherlands/Maran 2015: Monitoring of antimicrobial resistance and antibiotic usage in animals in the Netherlands in 2014. *RIVM rapport 2015-0113* (2015).

6. Dewulf, J., Koenen, F., Laevens, H. & de Kruif, A. Infraroodthermometrie is ongeschikt voor de detectie van koorts bij varkens. *Vlaams Diergen Tijds* **72**, 373-379 (2003).

7. Hoeben, D., Mijten, P. & de Kruif, A. Factors influencing complications during caesarean section on the standing cow. *Vet. Q.* **19**, 88-92 (1997).

8. Schaefer, A. *et al*. Early detection and prediction of infection using infrared thermography. *Canadian journal of animal science* **84**, 73-80 (2004).

9. Smaill, F. & Hofmeyr, G. Antibiotic prophylaxis for cesarean section (Review). (2007).

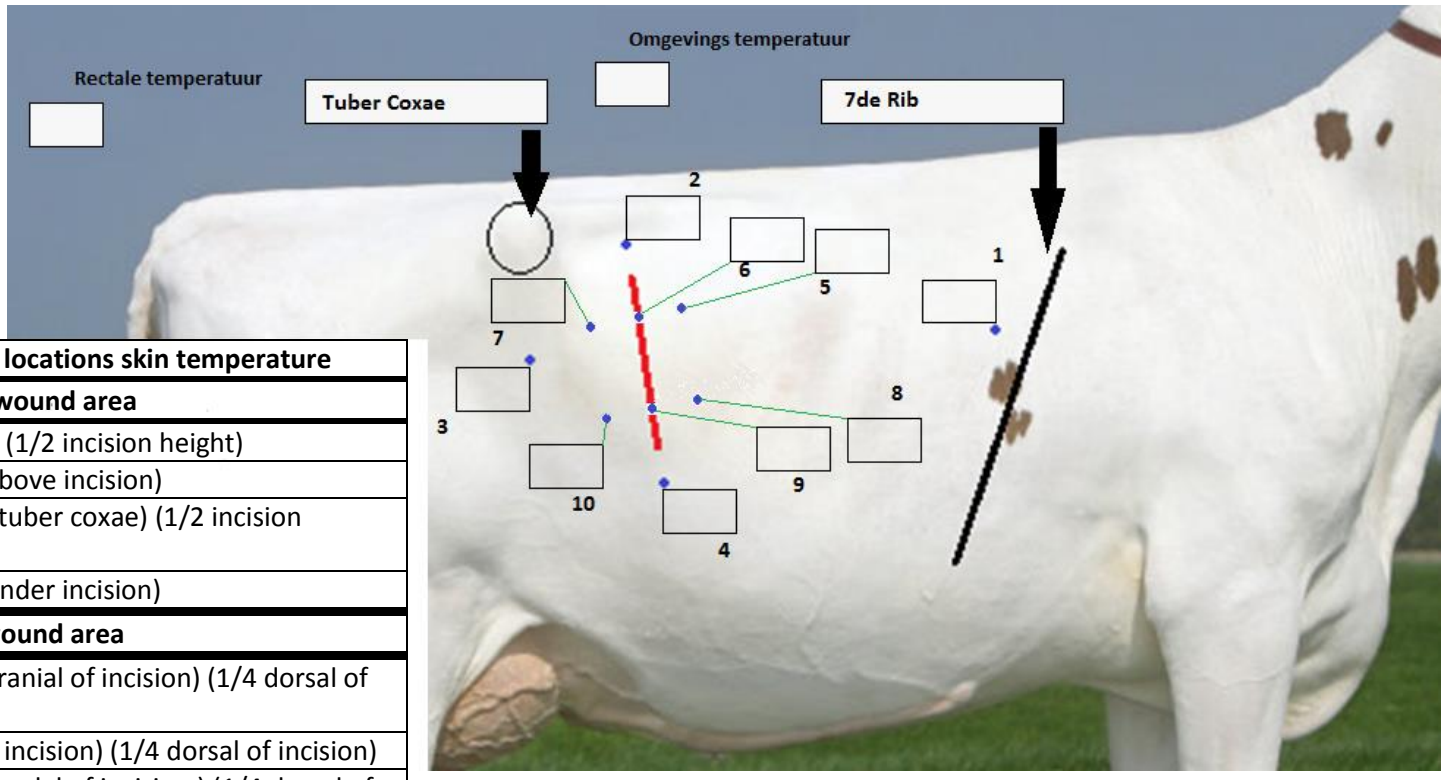
10. Smith, B. I. & Risco, C. A. Management of periparturient disorders in dairy cattle. *Veterinary Clinics of North America: Food Animal Practice* **21**, 503-521 (2005).

Appendix

Measure locations of the skin temperature within and outside wound area (appendix 1).

(Example measurement)

1) Measure locations 1 until 4 outside the wound area (write down after measuring) (Measure location 3: half hight incision, anterior to the Tuber coxae)
2) Measure locations 5 until 10, on top of the incision, 2 cm cranial and 2 cm caudal of the incision *(at one-quarter and three-quarter height of the estimated location of the incision)*
3) Skin temperature measuring by keeping the IR thermometer +/- 20 cm away from the skin. Press and hold the black button, write the skin temparture down after releasing the button (hold).
4) Measure the rectal temperature whit a normal (green) thermometer. The ambient temperature is read from the climatesystem in the clinic (write down the ambient temperature).



Measure locations skin temperature
Outside wound area
1 (8th rib) (1/2 incision height)
2 (2 cm above incision)
3 (under tuber coxae) (1/2 incision height)
4 (2 cm under incision)
Within wound area
5 (2 cm cranial of incision) (1/4 dorsal of incision)
6 (on the incision) (1/4 dorsal of incision)
7 (2 cm caudal of incision) (1/4 dorsal of incision)
8 (2 cm cranial of incision) (1/4 ventral of incision)
9 (on the incision) (1/4 ventral of incision)
10 (2 cm caudal of incision) (1/4 ventral of incision)

Measure moments (appendix 2)

Data (Day 0) *Dd – Mm – YYYY* ___-- ___ -- _____	**Time**	**Details**
1st measurement	1 hour before surgery	Presence of hair in woundarea
2nd measurement	After shaving	
3th measurement	After local anesthesia	
4th measurement	1 hour after surgery	
5th measurement	2 hours after surgery	
6th measurement	3 hours after surgery	Measurement is not performed when the procedure isn't completed before 18.00
7th measurement	4 hours after surgery	Measurement is not performed when the procedure isn't completed before 17.00
8th measurement	5 to 8 hours after surgery	Measurement is not performed when the procedure isn't completed before 16.00
Day 1 ___ -- ___ -- _____		
9th measurement at 8.00	Day 1 8.00	
10th measurement at 10.00	Day 1 10.00	
11th measurement at 12.00	Day 1 12.00	
12th measurement at 15.00	Day 1 15.00	
13th measurement at 18.00	Day 1 18.00	
14th measurement at 20.00-22.00	Day 1 20.00-22.00	
Day 2 __ -- __ -- ____		
15th measurement at 8.00	Day 2 8.00	
16th measurement at 12.00	Day 2 12.00	
17th measurement at 16.00	Day 2 16.00	

Figure 4: All individual rectal temperature measurements (group: exploratory laparotomy) cows are classified on the basis of wound score. Data from 27 cows in 10 to 14 days of data collection. (appendix 3)