Radiotelemetry Systems for Measuring Body Temperature

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Radiotelemetry systems for measuring body temperature

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Introduction

Radio based signalling will play an important role in future generations for remote monitoring of humans and many other species. Ultimately it will be possible to sample vital signs, e.g. body temperature, heart-rate and ovulation rate from animals whatever their location, without they being aware of the procedure. The advent of radiotelemetric techniques to continuously monitor heart-rate and blood pressure in a totally non-invasive manner, without any disturbance to the animals, should facilitate the analytical approach of this complex and multifactorial condition.

Body temperature is a good indicator of stress in all species. In poultry, for example physiological data can act as an immediate indicator of stress (Hamrita et al 1997, Kettlewell et al 1997). It is important that some variables be measured without disturbing the natural behaviour of the animal. Many studies have been conducted using telemetry systems to measure body temperature in bovine animals (Hahn, 1999; Lefcourt and Adams, 1998; Bergen & Kennedy, 2000; Brown-Brandl et al., 2001). Hetzel et al. (1987) measured body temperature using subcutaneous transmitters and reported that temperatures from the transmitters were 0.2^{o}C higher than rectal. The overall correlation between implanted and rectal temperature was 0.96. Kort et al. (1998) had varying results using a subcutaneous transponder when compared with rectal temperature in mice. Differences between transponder transmitted and rectal temperatures were large ($P < 0.001$). Hahn et al. (1990), found that rectal and tympanic temperatures were very similar ($P > 0.05$), but tympanic was affected by ambient tempertures. Brown Brandl et al (2001) found significant differences ($P < 0.05$) between tympanic and rectal temperatures. A number of other studies, using heifers, observed that tympanic temperature was affected by ambient temperature (Lefcourt and Adams, 1998; Hahn et al., 1990).

Objectives

The objective of this study was to compare three methods of measuring body temperature in the bovine and examine their relationship with ambient temperature. The three methods used were (a) rumen bolus (b) tympanic logger and (c) rectal.

Materials and Methods

Cow Temp^{TM} rumen bolus (Figure 1) was used to monitor deep body temperature which is Innotek's patented bovine health monitoring system. It is designed to continuously monitor the animal's body temperature 24 hours a day. The bolus utilises an internal battery for power and contains electronic circuitry for a low-power, low-frequency receiver; a low-power, high-frequency transmitter; a temperature sensor; and a microprocessor to control all circuit functions and timing. The outside diameter of the bolus measures 25 mm, the length is 95 mm and it weighs 116 grams. The system is made up of a receiver unit, and software which runs a PC to perform data processing and create graphical displays.

The receiver unit has a keypad that enables the user to assign to an identification (ID) number each bolus. The user programs this ID number into the bolus using a modulated magnetic field generated by the handheld receiver unit. This programming technique also allows the user to program the time interval at which the bolus will automatically transmit. The bolus continuously transmits the animals ID number followed by temperature at the programmed time interval.

Figure 1. Cow Temp^{TM} rumen bolus

The system used to transmit tympanic temperature was developed by Teagasc and Silsoe Research Institute (U.K.). It comprises a sensor placed at the end of a probe which is placed near the tympanum in the ear. The sensor transmits to a remote unit which is placed in the outer ear. This ‘Remote Unit’, has a number of discrete subsystems; each having it’s own on-board microcomputer responsible for handling communications over the radio link power control, and configuration settings such as the calibration of the temperature circuit (Figure 2A). The units communicate via the radio link with a ‘Base Station’ unit, which is connected to a standard serial (‘COM’) port on a standard PC. Separate analogue signal conditioning circuits provide for the amplification and conditioning of the temperature sensor signal. The Radio Module performs the radio communication with the remote ‘Base Station’ (Figure 2B).

Custom software on the PC, written in Visual Basic, sends commands to the Base Station unit for onward transmission to the units, and receives data and status information from the remote unit via the same route.

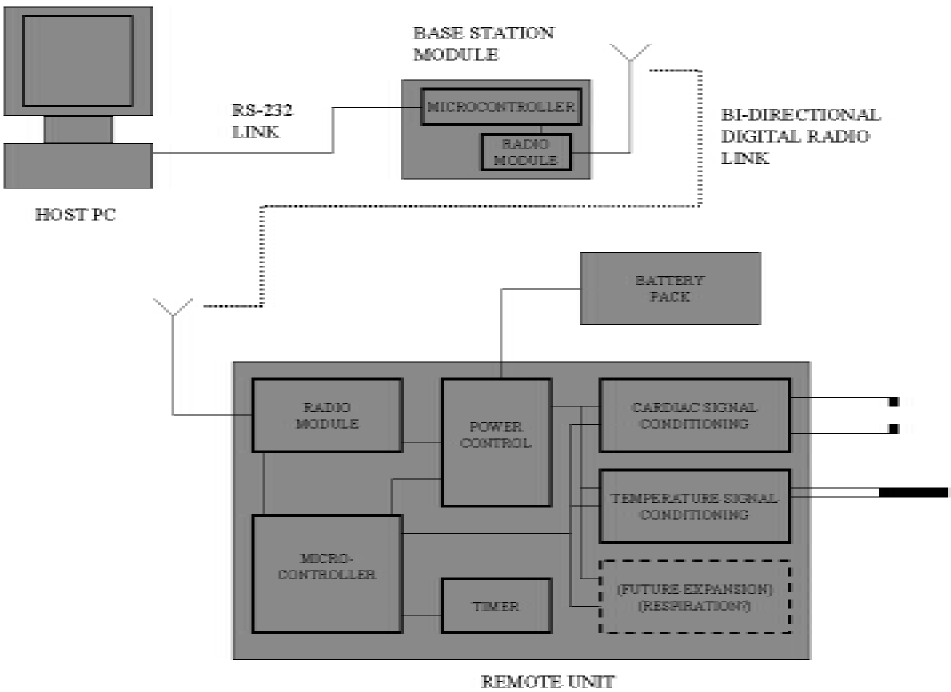
All units operate on a single common frequency, with bidirectional radio communications using digital modulation techniques. Instead of transmitting continuously, each unit listens for a request from the Base Station (each unit having it’s own unique address), and transmits it’s response on the common frequency only when requested. This single-frequency operation greatly simplifies the overall system design, and the ‘request and response’ protocol allows, in principle, any number of units to be used together. The digital modulation techniques allow any number of measured parameters, and complex status and command information, to be communicated with ease - the communication method is inherently extendable and ‘future-proof’.

Figure 2A

Figure 2B

Ear Tag Telemetry System - Outline Details

A block diagram of the telemetry system is shown below:



Experimental Treatments

Boluses (B) were inserted into the rumen in eight Charolais x steers weighing 500 kg. The animals were housed in a conventional slatted shed at a stocking density of 3 m^2, and were fed silage *ad libitum* and 6 kg of concentrates. The recording frequency was set at approximately 8 times every hour. Telemetry transmitters (T) were inserted into the left ear of the same eight steers. Temperatures were recorded every minute over the same period of five days. Rectal temperatures (R) were taken every hour over the same period using digital thermometers (Jorgen Kruuse A/S. Model VT-801BWC Lot No 0701). Animals were not removed from their pens during the 5 day period of temperature recording.

Results

On days 1, 4 and 5 the B temperature measurements were significantly higher than the R or T ($P \leq 0.05$) (Table 1). Over the five days the average temperatures recorded for B, R and T were 39.0, 38.4 and 38.2, respectively. There was no difference between R and T ($P > 0.05$).

Table 1. Mean temperature recorded by each method on days 1-5

Day	Bolus (B)	Rectal (R)	Tympanic (T)	LSD	SED
1	39.0^{a}	38.6^{b}	38.2^{b}	0.54	0.31
2	39.2^{a}	38.4^{ab}	38.3^{b}	0.78	0.37
3	39.1^{a}	38.5^{ab}	38.2^{b}	0.72	0.35
4	38.9^{a}	38.0^{b}	38.2^{b}	0.51	0.24
5	38.9^{a}	38.4^{b}	38.3^{b}	0.42	0.20

Within rows means not having a common superscript differ significantly ($P \leq 0.05$).

Table 2 shows the daily and overall correlation coefficients for days 1 to 5. The overall correlation coefficients for B and R, Band T, and R and T were 0.34, 0.65 and 0.80, were respectively. The overall correlation coefficients for ambient temperature with B, R and T were – 0.74, – 0.54 and – 0.76, respectively. However, there were interactions between methods over time which indicates limitations in each method of recording temperature. The correlation coefficient for B and R, B and T, and R with T were variable across the 5 days (Table 2).

Table 2. Correlation coefficients between various temperature measurement techniques for days 1-5 and overall (n=8 animals).

Method	Day 1	2	3	4	5	Overall (d1 – d5)
B/R	.50	-.22	.37	-.08	.27	**.34**
B/T	.73	.65	.45	.23	.40	**.65**
R/T	.62	.00	.57	.11	.72	**.80**
Amb/B	-.63	-.29	-.41	-.36	.31	**-.74**
Amb/R	-.42	.14	.18	.17	-.40	**-.54**
Amb/T	-.40	-.62	-.01	-.45	.03	**-.76**

Figure 3 (a) shows the temperatures of each method (B,T.R) on day 1 while Figure 3 (b), 3 (c), 3 (d) and 3 (e) shows data for days 2, 3, 4 and 5, respectively for one animal (No. 296) . These figures, clearly illustrate the consistently high temperature recorded by rectal and the rumen bolus over the five day experimental period, for this particular animal.

Figure 3 (a) Bolus, rectal and tympanic temperature recordings for animal 296 on day 1

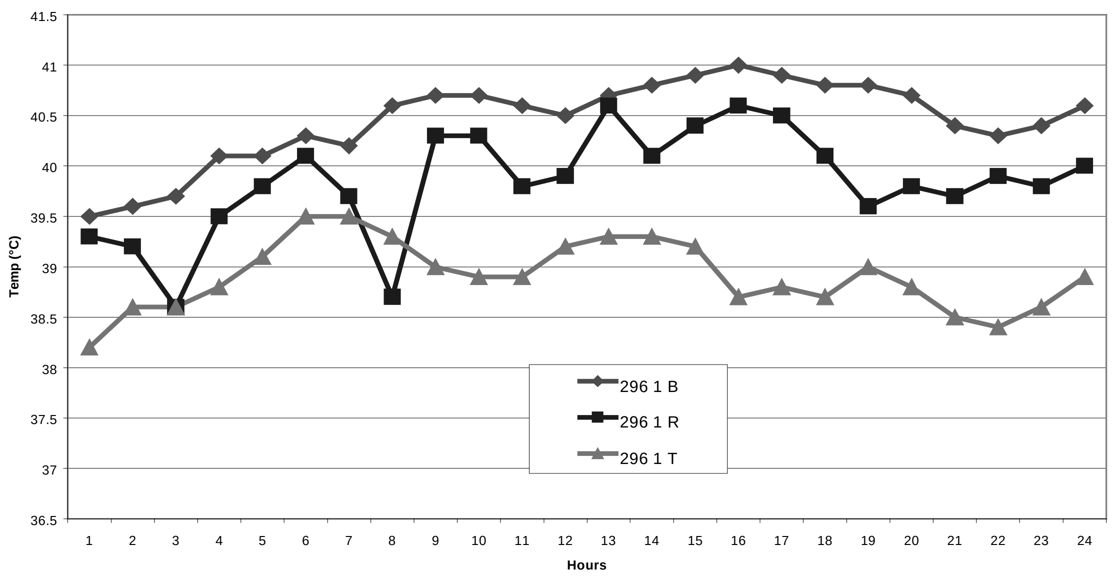


Figure 3 (b) Bolus, rectal and tympanic temperature recordings for animal 296 on day 2

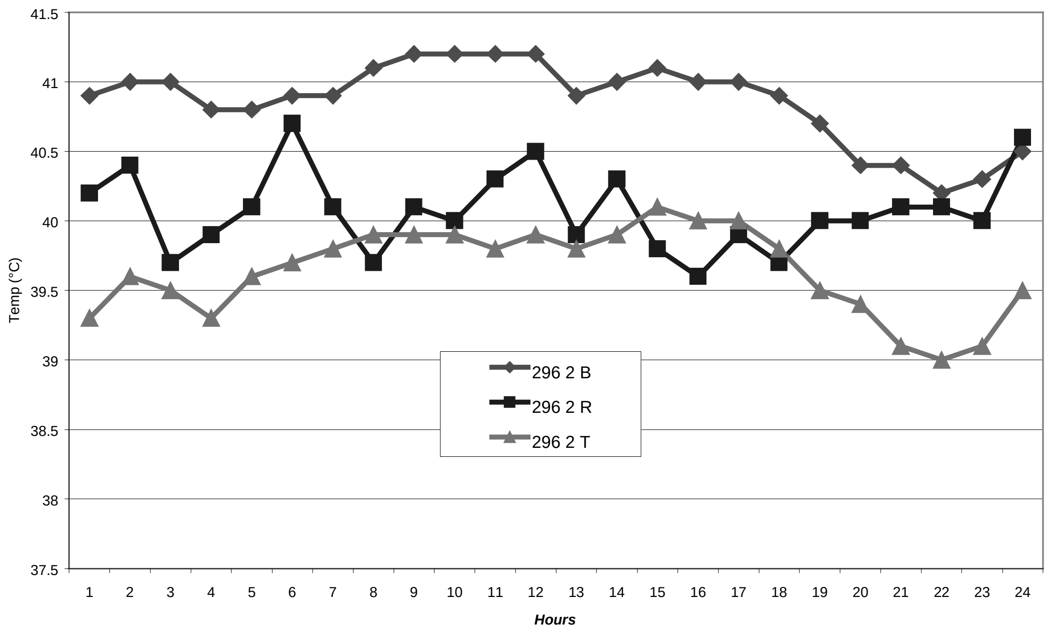


Figure 3 (c) Bolus, rectal and tympanic temperature recordings for animal 296 on day 3

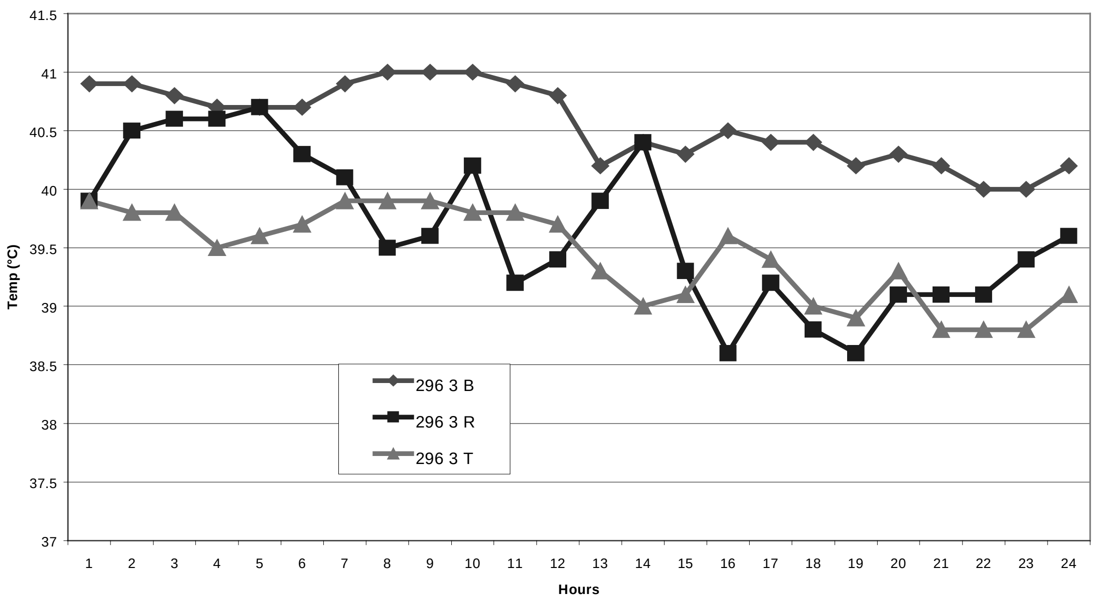


Figure 3 (d) Bolus, rectal and tympanic temperature recordings for animal 296 on day 4

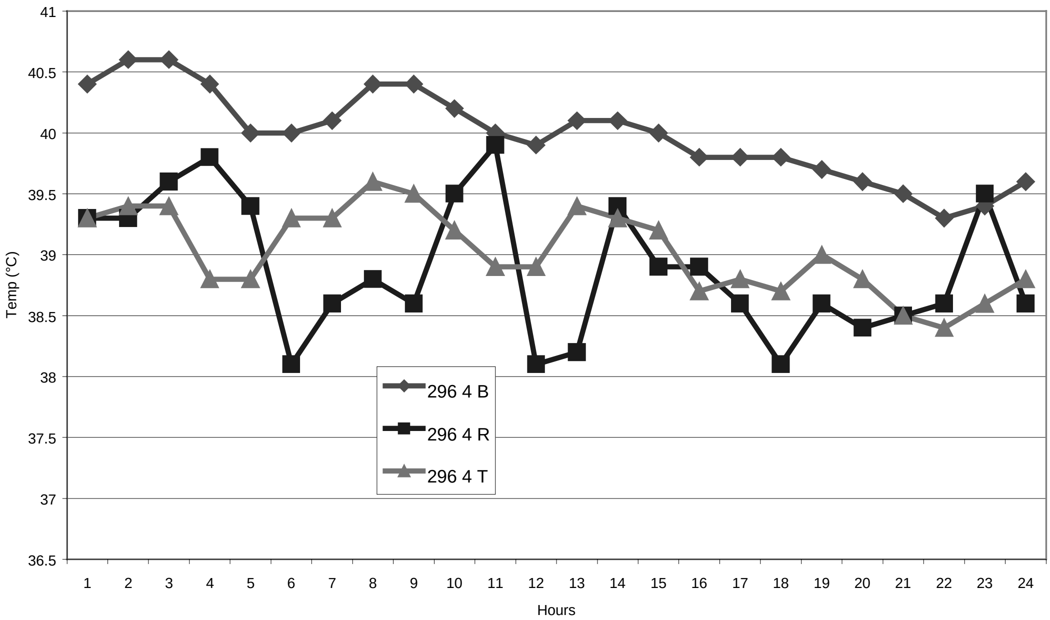
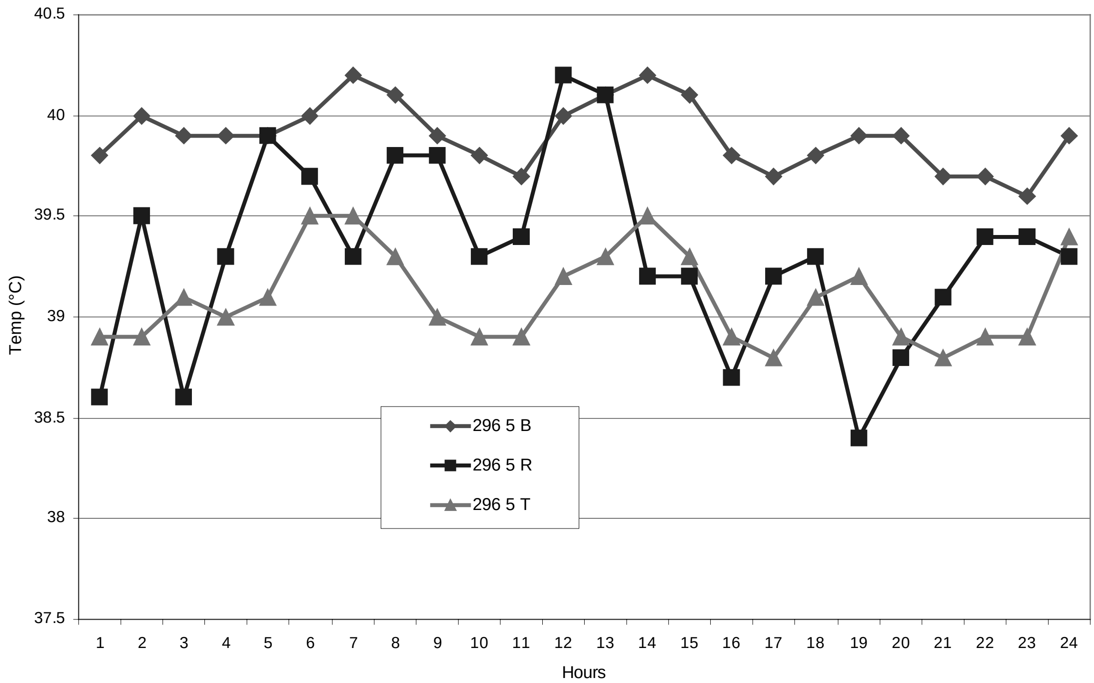


Figure 3 (e) Bolus, rectal and tympanic temperature recordings for animal 296 on day 5



Discussion

Deep body temperature is an important index of the physiological status of an animal. Physical, chemical and in part biological processes are affected by temperature (Brody, 1945; Hales, 1984). This is the first study that compared deep body, tympanic and rectal temperatures. In the present study there was no significant difference ($P > 0.05$) between tympanic and rectal. Similar results were obtained by Hetzel et al. (1987). They found that temperatures transmitted from surgically implanted transponders were on average 0.2^0C higher than rectal temperatures. In contrast Hicks et al. (2001) found temperatures transmitted by boluses implanted in the reticulum were similar to rectal temperatures. Brown-Brandel et al. (2001) and Goodwin, (1998), O'Brien et al. (1998) found rectal temperature was lower ($P < 0.05$) than deep body temperature. The results vary from different studies and there are also differences between species (Goodwin, 1998). Goodwin found that, rectal and subcutaneous temperatures in goats were significantly higher ($P < 0.05$) than tympanic, but rectal and subcutaneous were not different ($P > 0.05$). In horses and sheep rectal temperature was higher ($P < 0.05$) than tympanic and subcutaneous and tympanic was higher ($P < 0.05$) than subcutaneous temperature. Remote monitoring of temperature is feasible at long and short distances in an non-intrusive manner. The transmitters used in this study allowed the registering of data without handling the animal, which could possibly have falsified the results. This makes Radiotelemetry a useful tool for recording body temperature in farm animals.

Conclusions

These data demonstrate that the rumen bolus is an effective means of continuously measuring body temperature however, the efficiency of the bolus needs to be improved. Temperature can also be logged from the tympanic membrane accurately. Securing the probe close to the tympanum for long periods cause problems that need to be resolved before the system can be used routinely.

Summary

Radiotelemetry is a powerful technology for long-term monitoring of physiological functions, such as core body temperature, in an non-invasive manner.

In this study rumen boluses transmitted body temperatures from every animal every hour of every day, up to a distance of one km.

Body temperature can be logged from the ear in cattle fitted with a telemetric tympanic membrane sensor.

Radiotelemetry can be used for practically all experimental conditions and field situations and it will highlight animals displaying elevated temperatures, by sending a message to a mobile phone.

Implications

Radiotelemetry will soon allow one to phone their cow or steer for body temperature, heart-rate or blood pressure. These advances will have massive beneficial implications for the beef and dairy industries. Oestrus detection will at last be a reality in the suckler cow. Pre-determination of parturition will be common place. It will be possible to monitor the welfare of calves at times of stress i.e. post-partum, at weaning and castration. Also it will be possible to routinely monitor the welfare of animals during transport.

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