Acta vet. scand. 1986, 27, 456—460.

Brief Communication

CONTINUOUS MONITORING OF BODY TEMPERATURE IN PIGS USING NON-INVASIVE EAR CANAL SENSORS

Monitoring of the body temperature in animals kept under intensive production conditions is desirable for a number of reasons: oestrus detection, disease monitoring and stress indication in addition to more specific needs, such as the selection of breeding pigs resistant to malignant hyperthermia and for various research purposes.

The limiting factor to large-scale systematic temperature monitoring programs in cattle and pigs has so far been the lack of suitable temperature sensors which may be permanently secured in a place where the body temperature will be reliably recorded. Additional requirements to be met by the sensors are low cost, small size, resistance to physical and chemical exposures, and efficient transmission of signals between the peripheral sensors and a central recording unit.

Non-invasive techniques for monitoring the deep body temperature have obvious advantages over measurements requiring surgery. Such techniques have been developed in man, and reliable estimates of deep body temperature may be obtained from measuring the skin temperature with zero-heat-flow-methods or guard-techniques (*Togawa* 1979).

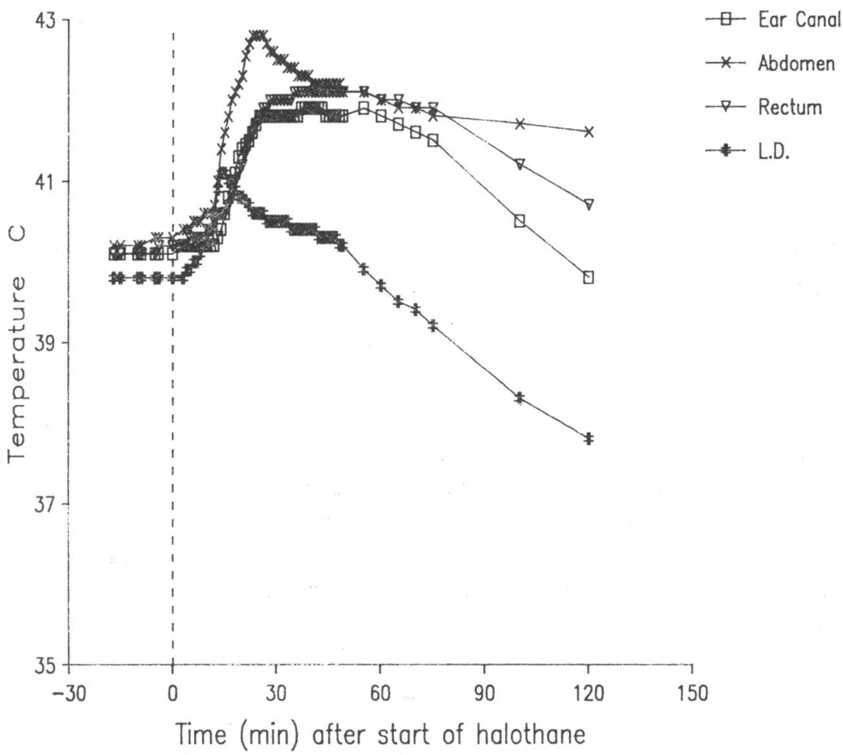
In man the tympanic membrane temperature correlates well with that in the oesophagus and rectum (*Nielsen & Nielsen* 1965).

In cattle too, the tympanic membrane temperature has been considered as reference for deep body temperature in investigations with the purpose to develop telemetric electronic systems for identification and temperature monitoring (e.g. *Baldwin et al.* 1973, *Lira et al.* 1975, *Seawright* 1976, *Holm & Araki* 1979, *Zartman* 1983).

Consequently the temperature in different depths of the ear canal might be investigated as a possible means of temperature monitoring in pigs.

A pilot study has been undertaken to develop and test such an integrated temperature monitoring system, using malignant hyperthermia susceptible pigs as a model. Performance of the system in response to the rapid and extreme changes in body temperature may be evaluated in such animals placed under halothane anaesthesia (cf. *Jørgensen* 1981). The main objective was to evaluate temperature measurements in different organs of malignant hyperthermia susceptible pigs, using a specially designed temperature monitoring system with non-invasive sensors placed in the external ear canal.

The changes in the body temperature during malignant hyperthermia (MH) were studied in 3 malignant hyperthermia susceptible pigs weighing approximately 30 kg. During thiomebumal anaesthesia thermocouples (Ellab type KP-1, RQ-1, and F6) were inserted in the rectum, cavum peritonei (in front of the liver), m. longissimus dorsi and m. biceps femoris. Furthermore 3 sensors were placed in a deep, an intermediate and a superficial position in the ear canal (meatus acusticus externa) according to a review of the anatomical details obtained by casting the meatus acusticus externa from 30 kg pigs. The principle of



F i g u r e 1. Temperature in deep part of the ear canal (□), in front of the liver (×), in rectum (▽), and in m. longissimus dorsi (‡) during malignant hyperthermia in one MH pig. Halothane anaesthesia was initiated at time zero (min). Heart arrest was manifest 48 min after switching to halothane.

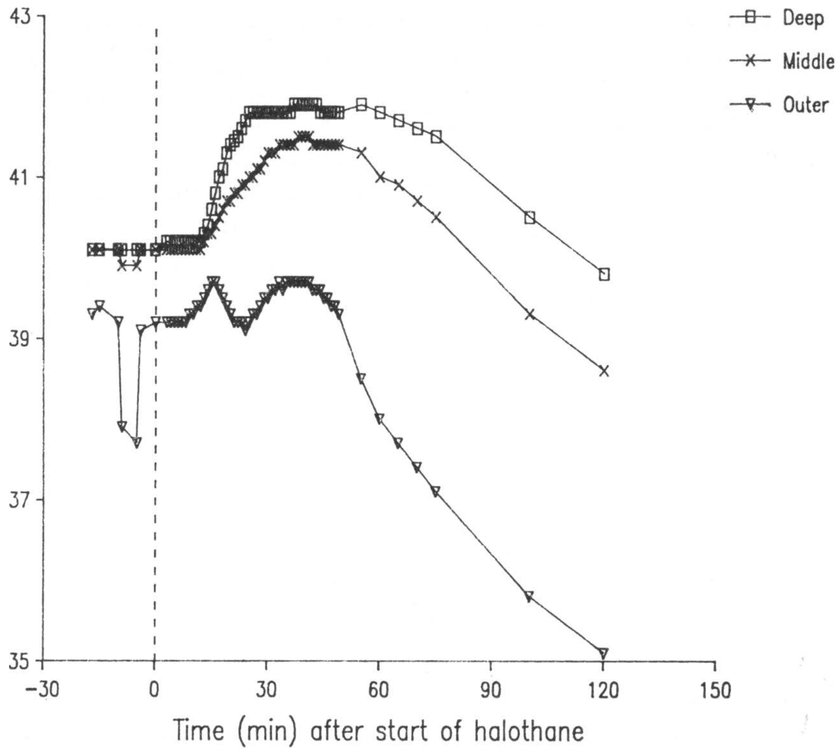


Figure 2. Comparison of outer (▽), middle (×), and deep (□) ear canal temperature during the condition described in the legend to Figure 1. The temperature increases towards the deeper part. The temperature drop in the outer part 5 min before switching to halothane is caused by artificially turning the external ear.

the measuring device is that a resistor with a large temperature coefficient is placed in close contact with the point of measurement. A temperature change results in a change of the resistance and the signal is transmitted to an electronic thermometer. After insertion of all sensors anaesthesia was switched to halothane and continued until malignant hyperthermia was present in its terminal state.

The temperature curves from all 3 pigs were similar. Consequently only results from 1 animal are given (Figs. 1 and 2). During MH the temperature began to decline earlier in m. longissimus dorsi than in the deeper parts of the body and in the ear canal. This is probably a consequence of differences in thermogenesis and heat transfer to and from the tissues via the blood during MH.

In general the correlations between the body temperatures and the deeper part of the ear canal were excellent in the thermogenetic as well as in the post-mortem cooling phase. Consequently, reliable predictions of relevant body temperatures may be obtained from the ear canal readings (Table 1). Ear canal thermosensors were, however, easily dislocated during artificial

Table 1. Regression analysis and prediction of body and rectal temperatures from measured deep external ear canal temperatures (± SEM).

Deep ear canal vs	Intercept (a)	Slope (b)	Coefficient of determination (R^2)	Predicted temperature* ($\hat{y}$)
				x = 39.0°C
Abdominal cavity next to liver	—1.9±2.6	1.06±0.06	0.83***	39.4°±0.14
Rectum	—0.9±1.3	1.03±0.03	0.95***	39.1°±0.07

* Results given ($\hat{y}$) are predictions from the equation: $\hat{y} = a + bx$, where $\hat{y}$ is the predicted value for the deep body or rectal temperature, a and b are determined from the experimental data presented in Fig. 1, and x (in the table: 39.0°) is the temperature recorded from the external ear canal.

*** $P < 0.001$.

movements of the ear. Such movements resulted in looser contact with the wall of the canal and in a longitudinal movement of the sensors relative to the direction of the canal. As the temperature gradient especially between the outer and middle sensor position was large (Fig. 2) the temperature curve from the outer sensor was especially distorted. The temperature drop seen in Fig. 2 from 39.2°C to 37.9°C which occurred 5 min before switching to halothane is a consequence of such a movement. Later experiments with a modified "self-clipping non-invasive spring-loaded" sensor at this position resulted in temperatures closer to the deep body temperature and considerably less influenced by movements of the ear even in unanaesthetised animals (not shown).

As a conclusion of these investigations it is possible during experimental conditions to use the ear canal temperature as indicator of deep body temperature.

For the use under field conditions where the purpose is to determine the degree of stress during transportation, oestrus in sows, or acute febrile situations, the present design of sensors is insufficiently developed. The experimental animals frequently became irritated by the presence of the sensor in the ear canal, and the sensor could not be positioned in the canal in a completely reproducible manner. Preliminary results, however, have indicated that a more peripheral, skin-tight, and for the animal more acceptable location of the sensor in the canal with respect to permanent telemetric monitoring may be obtained in experiments now under way.

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ACKNOWLEDGEMENTS

The study has been supported by grants from the Danish Agricultural and Veterinary Research Council.

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(Received October 17, 1986).

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