Acta vet. scand. 1975, *16*, 357—367.

From the Department of Applied Mathematics and Computations, Research Institute of National Defense, and the Department of Anatomy and Histology, Royal Veterinary College, Uppsala, Sweden.

A TELEMETRIC AID IN ESTABLISHING THE CAUSE OF DEATH IN SEMIDOMESTICATED OR WILD ANIMALS

By

Frederik Moëll and *Claes Rehbinder*

MOËLL, FREDERIK and CLAES REHBINDER: *A telemetric aid in establishing the cause of death in semidomesticated or wild animals.* Acta vet. scand. 1975, *16*, 357—367. — Calf mortality among wild and semidomesticated animals, especially reindeer, is established to be high. The authors describe a telemetric method with subcutaneously implanted transmitters which are activated by the lowered body temperature in connection with the death of the animal, enabling it to be found and brought in for pathological examination. Frequency selection, implantation technique and design of transmitter, power source, antenna and surveillance methods are discussed, with a background of commercially available equipment.

telemetry; technical solutions; semidomesticated animals; wild animals; cause of death.

One of the major problems in the maintenance of a stock of semidomesticated or wild animals can be an abnormally high mortality rate from unknown origins. The only observation that can be made is that a significant number of animals are missing with no possibility of ascertaining a cause.

In herds of semidomestic reindeer and wild caribou a high mortality rate in calves, 30—75 %, has been reported (*Kelsall* 1968, *Skenneberg & Slagsvold* 1968, *Rehbinder* 1975). The cause of the calf losses and their interrelationships are only partly known.

Since a high calf mortality rate strongly affects the economy of reindeer herding and modern wildlife management, it is important to clarify and control all major causes of death through pathological investigations so that the proper countermeasures can be taken.

The present method of investigation, a thorough search for dead animals, might bring to light the remains of some of the missing animals. For the pathologist to decide the cause of death from these carcasses is often impossible, due to decay and the activities of predators and scavengers.

We suggest the use of a telemetric method involving the implantation of transmitters in several very young animals in a herd. (The number of animals should be determined according to the circumstances). The transmitters are to be equipped with a thermal sensor, which would activate the transmitter when the ambient, i.e. body, temperature falls below a certain point. By chosing this point correctly, the transmitter would be activated only in animals which are dying or dead.

It should be possible to find the dead or dying animals through detection of the transmitter within a few hours of its activation, thus giving the pathologist good material from which to establish the cause of death. Since the transmitter has a very long inactive life, it should be possible to supervise these animals for several years.

TECHNICAL PROBLEMS AND DEMANDS

Most work in biotelemetry over any greater distance has been done with external transmitters, mostly in the shape of a collar which is attached around the body or neck of the animal (*Cochran & Lord* 1963, *Southern* 1963, *Pettingill & Lancaster* 1965, *Sullivan et al.* 1967, *Knowlton et al.* 1968, *Varney* 1971a, b, *Andersson* 1972, *Craighead & Craighead* 1972, *Schneegas & Franklin* 1972).

An implantable transmitter has harsher restrictions put on it than has a collar transmitter. The greatest difficulty lies in making it small enough to implant in small or young animals and yet obtain the desired characteristics.

These characteristics are:

1. Sufficient range, so that the number of base stations, which are expensive to set up and maintain, can be kept low. This implies a powerful transmitter and an (electrically) long antenna.
2. Sufficiently long transmission time, ranging from several hours up to a few days.

The length of time needed varies with terrain, the area one wishes to cover, climate etc. It should be long enough to allow all animals to be found even under rather severe conditions. In conjunction with the high output power needed for sufficient range, this means a large battery.

These two desiderata, entailing a large battery and a long antenna, conflict with the need for a small transmitter. Further complications arise from the demands for sterility, the need for a biologically inert encapsulation, and the high environmental temperature.

PROPOSED TECHNICAL SOLUTIONS

Transmitter assembly

In view of the present rapid developments in technology, all circuits should be designed when needed. We will therefore not present any detailed electronic solutions or circuits, merely point out some possibilities and general observations, which might be useful.

Electronic circuitry

The electronic components make up only a small part of the total volume and weight of the transmitter assembly. This can vary in complexity from the very simple to the quite sophisticated. *Lutsch* (1972) points to one way of miniaturizing: custom-made circuits with thin- or thick-film technology. Another possibility lies in the adaptation of commercially available circuits for the specific conditions encountered (*Skutt et al.* 1973). Even with the use of discrete components, a moderately complex circuit can be kept small.

Two design features should be pointed out here. One is the use of a pulsed transmitter, i.e. a transmitter which transmits only part of the time. This can be implemented with a low-duty-cycle astable multivibrator, the short "on" time allowing transmission, the longer "off" time giving the interval between the transmitted pulses. *Varney* (1971a, b) covers the subject extensively.

The use of a crystal for controlling the transmitting frequency is essential. One interesting aspect is that there will be no problem of initial temperature drift, since each transmitter will be activated at the same fixed temperature. This should simplify detection apparatus: since the initial performance of the transmitters can be expected to be about the same as their tested behaviour, one knows in advance on what frequencies they can be found. However, once this phase is past, the usual problems with temperature drift can be expected, perhaps slightly lessened by the greater thermal inertia of the body.

To take advantage of this initial benefit, one should choose the transmitter crystals so that they are spread over a fairly small frequency interval, about the same as the base station receiver bandwidth. This would lessen the need for scanning the interesting frequency band, and thus facilitate detection.

Battery

The best known, and most widely used, power source is the mercury cell. It has several advantages: high power density (∾ 100 Wh/kg), low internal resistance, well tested behaviour and characteristics.

Recently, an organic lithium battery has been developed (*Gilmour* 1972). It has a power-to-weight ratio of about twice that of a mercury cell.

Another inorganic lithium battery has just been presented by Sylvania. According to the preliminary specifications, it has a power/weight ratio of 5.5 times that of the mercury cell. It is also said to have excellent temperature characteristics, and a very long shelf life, even in high temperature surroundings.

This cell has recently become commercially available (Anonymous 1974). We feel that it definitely should be used, even in view of its relatively unknown properties. When deciding on battery size, two factors should not be overlooked.

The first is the decrease in battery capacity with time, through internal discharge. This increases with high environmental temperature and sets a limit to the passive life of the transmitter. This is reputed to be much less of a problem with lithium batteries.

Secondly *Kuechle* (1967) points out that the amount of energy available from a mercury battery might be considerably (up to 50 %) less than its nominal rating.

The transmitter and battery assembly could be constructed as two separate subunits, which could allow the salvaged transmitter to be equipped with new batteries, reencapsuled and used again.

Frequency selection

Some work has been done with higher frequencies (*Andersson* 1972), but the frequency used by most workers in the field has been approx. 27 MHz. The main disadvantage connected with the use of this frequency lies in the very low efficiency achieved with the necessarily short antennas.

However, lower frequencies have superior propagation properties, are easier to work with in design, and allow the use of commercially available CB equipment.

Pienkowski (1965) offers curves to calculate the effective range of transmitters under various conditions and with varying radiotechnical parameters.

Calculations made with the help of these curves show conclusively that a frequency of 30 MHz provides good effective range in any terrain with hills or trees. In some situations, another frequency might be superior and the subject should be investigated thoroughly in each case.

Antennas

Receiver antennas

These should be of the direction-sensitive high-gain type, preferably mounted on a mast so that they are raised above local obstacles. Non-directional antennas could be used for monitoring under favourable circumstances, thus facilitating detection.

Transmitter antennas

The antennas most commonly used are tuned loops and tuned whips. The former are practically impossible to implant but might be of interest in secondary projects, for instance in monitoring a herd and its position.

For implantation, there seem to be two possibilities at present. One is a compact high-frequency (150 MHz) antenna, the Motorola Strip-line antenna (*Baldwin* 1972). It is small enough to use on fairly small mammals and should be easy to encapsule and implant due to its shape.

The tuned whip is the most suitable antenna to use in low-frequency work. Its main disadvantage lies in its electrical properties; it can be difficult to tune, and it is electrically very short with a resulting very low efficiency.

Sullivan et al. (1967) has studied the attenuation of radio waves in a conducting medium. His results indicate no great attenuation of frequencies up to 100 MHz, provided that the implantation depth is not unduly large.

A few biological requirements for antenna design are that it should be of a biologically inert material, flexible and smooth so that it can move when the animal grows, and have a softly rounded tip. The final centimeters could be "roughed up" with a file, to anchor it somewhat in the embedding tissue.

It should also be well anchored in the transmitter to prevent it from breaking loose. The transmitter should be so constructed that even if the antenna breaks loose the resultant chemical reactions are minimized, i.e. the body fluids should not reach the battery.

It should be observed that the longest possible antenna should be used, and that following implantation it should be as straight and fixed as possible. Detuning through internal movement is a risk; the problem of tuning a whip antenna must be studied with experimental animals, since it is impossible to make any adjustments after implantation. After a few trial runs, it should be possible to adjust the transmitter so that it will be tuned when implanted.

Encapsulation

To protect the transmitter from the body fluids and to give it mechanical stability, it should be encapsuled. Various materials and procedures for this have been described (*Skutt et al.*) The materials used should be biologically inert and easy to sterilize and keep sterile. Sterilization procedures are also described by *Skutt et al.* Since a continuous development occurs we suggest that prior to deciding on what materials and techniques to use, the latest results from the pacemaker technology should be studied.

Thermal sensor

The thermal sensor, which activates the transmitter when body temperature falls below a certain point, is a thermosensitive reed relay. It is connected between the battery and the transmitter and functions as a power switch. It presents an open circuit, (i.e. no power drain) when in the inactivated state, and a very low resistance when activated. It can be held open below the threshold point with an external magnet. This means that the transmitter assembly can be handled, transported and implanted without draining the battery.

After implantation and subsequent removal of the "holding" magnet, there will be a short period of time while the circuit attains body temperature, during which the transmitter will operate, thus allowing a test of the proper function of the transmitter.

A suitable thermo-sensitive relay is the Hamlin TS 30 B (Hamlin Inc., 1974), which can be obtained in a variety of models.

Biological technique

The rapid growth of the young animal and the necessity of keeping the antenna as straight as possible must be taken into consideration. The method of handling the animals is also of importance (eg. reindeer are mainly roped around the neck with a lasso).

We recommend that the transmitter is implanted subcutaneously craniomedial of the proximal part of the scapula with the antenna inserted along the spine with the help of a long foreign body forceps.

This allows the antenna to be drawn forward while the animal grows, but yet kept straight and in position. Prior to implantation the transmitter is sterilized and stored until use in a suitable desinfectant (*Skutt et al.*).

Surveillance

There are two different solutions to the surveillance problem, namely fixed base stations and mobile stations.

Base stations

These stations are permanent or semipermanent installations from which a continuous or periodic check of radio activity is made. They should be equipped with large directional antennas on high masts, high-quality receivers and powerful transmitters.

The base stations should be movable to permit surveillance of migrating animals; they could be placed in vehicles or caravans. Fixed base stations would allow several programs to be run concurrently, making it possible to study the habits of various animals, equipped with collar transmitters on different frequencies, while the main program is run. One such possibility would be to monitor some animals in the herd, so as to obtain valuable information about the position of the dying animals in relation to the herd. Another possibility would be to tag predators and study how they interact with the herd.

A base station will cover only a limited area. Since they are fairly expensive to set up and maintain, their number should be kept low. All improvements in equipment contributing to fewer base stations such as higher output power and better sensitivity should be considered. This kind of improvement could be achieved through buying the best commercially available, or custom-made, equipment instead of trying to build one's own. The number of base stations and their positions should be determined only after very careful and thorough studies of the area in which they are to be placed. If this area is very large, or other factors such as propagation characteristics would necessitate many base stations, the surveillance could be made from mobile stations.

The base stations must be complemented with small portable receivers. These are to be used in the search for the dead animal in the area which has been outlined from the reading from the base station. The receiver should have a good directional antenna, good sensitivity and adequate battery capacity. It should be easy to handle, since it might be used by personnel who are not qualified technicians. One suitable type of receiver could be a modified CB transceiver, which would offer the additional advantage of two-way radiocontact with the base station. This would simplify the search procedure, since the base stations could give directions to the search personnel.

If possible, people living in the vicinity of the supervised area should be employed to handle receivers and to carry out the search and retrieval. This would reduce the crew needed for the base stations, and their knowledge of the local environment would probably be quite useful.

Mobile stations

In situations where the number of base stations would be uneconomically high, where radio wave propagation is anomalous, or other reasons might warrant it, mobile stations should be used. A mobile station would be a receiver placed in an aeroplane, a helicopter, a car or even a motorcycle. Its advantages compared to the fixed base station are mobility: i.e. a migrating herd can be followed continuously, and load capacity: the dead animal can be retrieved when found and brought in for examination. In some types of terrain, namely swamps, areas with many lakes and streams, rocky and mountaineous country and dense forests where propagation anomalies occur, an aeroplane or helicopter would be the only possible means of retrieving the dead animal.

Furthermore, no or few secondary groups for the search and only a small number of field transceivers are necessary. Also, the number of mobile stations could be kept low.

The main disadvantage of the mobile station is the lack of overall surveillance during the search phase, i.e. after detection. This is caused by its intrinsically shorter range and the fact that it will be covering a small area for a period of time.

In most cases, a compromise between the two could be used: a fixed base station directing mobile units, or a car with two sets of antennas, one for fixed base use, one for mobile.

As usual, the demands of the situation should be studied before a final solution is decided upon.

REFERENCES

Andersson, F.: Design of radio-tracking systems used in South Africa and problems encountered in their application. Proc. Symp. Biotelemetry, Pretoria South Africa 1971. South Africa Council for Scientific and Industrial Res. 1972, p. 303—344.

Anonymous: Lithium battery comes in 1/2 AA size. Electronic Design 1974, *16,* 155.

Baldwin, H. A.: Instrumentation for remote observation of physiology and behaviour. Proc. Symp. Biotelemetry, Pretoria South Africa 1971. South Africa Council for Scientific and Industrial Res. 1972, p. 137—170.

Cochran, W. W. & R. D. Lord Jr.: A radio-tracking system for wild animals. J. Wildlife Management 1963, *27,* 9—24.

Craighead Jr, F. C. & J. J. Craighead: Grizzly Bear Prehiberration and Denning Activities as Determined by Radiotracking. Wild Life Monographs 1972, *32.*

Gilmour, A.: Energy sources for biological telemetering equipment. Proc. Symp. Biotelemetry, Pretoria South Africa 1971. South Africa Council for Scientific and Industrial Res. 1972, p. 255—274.

Kelsall, J. P.: The Migratory Barrenground Caribou of Canada. Ottawa, Canada 1968, 340 pp.

Knowlton, F. T., P. E. Martin & J. C. Hang: A telemetric monitor for determining animal activity. J. Wildlife Management 1968, *32,* 943—948.

Kuechle, L. B.: Batteries for biotelemetry and other applications. BIAC Information Module *M 10,* 1967, 15 pp.

Lutsch, A. G. K.: Design of electronic equipment for telemetry using microcircuits. Proc. Symp. Biotelemetry, Pretoria South Africa 1971. South Africa Council for Scientific and Industrial Res. 1972, p. 363—380.

Pettingill Jr., O. S. & D. A. Lancaster: The Living Bird. Fourth annual of the Cornell Laboratory of Ornitology. The Laboratory of Ornitology at Cornell University, Ithaca, New York 1965.

Pienkowski, E. C.: Predicting transmitter range and life. Bio Science 1965, *15,* 115—118.

Rehbinder, C.: Kalvdödligheten i Ängeså samebys renhjord. (The calf mortality of the Ängeså reindeer herd). Nord. Vet.-Med. 1975, *27,* 241—252.

Schneegas E. R. & G. W. Franklin: The Mineral King deer herd. California Fish and Game 1972, *58,* 133—140.

Skenneberg, S. & L. Slagsvold: Reindriften og dens natur grunnlag. (Reindeer breeding and its fundamental condition). Universitetsförlaget, Oslo 1968.

Skutt, R. H., F. M. Boek, P. Haugstad, J. B. Holter, H. H. Hayes & H. Silver: Low-power implantable transmitters for telemetry of heart rate and temperature from white-tailed deer. J. Wildlife Management 1973, *37,* 413—417.

Southern, W. S.: Equipment and Techniques for Using Radiotelemetry in Wildlife Studies. Northern Illinois Univ., Dept. of Biol. Sciences, Rep. no. 3, 1963, 30 pp.

Sullivan, G. H., C. Hocfener & V. W. Bolic: Electronic Systems for Biological Telemetry. Biotelemetry. Ed. by Slater, Oxford 1963, p. 83—106.

Varney, J. R.: Radiotracking and Telemetering Equipment Design. Final Report. AEC, Contract AT-(45-)-1929. Mimeo Research Associate Montana. Cooperative Wildlife Research Unit., University of Montana, Missoula Montana 1971a, 90 pp.

Varney, J. R.: A Tracking and Telemetry System for Wildlife Research. National Telemetering Conference Rec., IEEF Publ. 71 C 10NTC 1971b, 247—252.

SAMMANFATTNING

En telemetrisk metod för fastställande av dödsorsak hos semidomesticerade och vilda djur.

Kalvdödligheten hos vilda och semidomesticerade djur, bl a renar är hög. Författarna beskriver en telemetrisk metod med subcutant inopererade sändare vilka aktiveras när kroppstemperaturen sjunker i samband med djurets död. Därmed kan djuret snabbt återfinnas och föras in till patologanatomisk undersökning. Frekvens, implantationsteknik, utformning av sändare, batteri, antenn och övervakningsmetoder diskuteras med utgångspunkt från i handeln tillgänglig utrustning.

(Received February 26, 1975).

Reprints may be requested from: C. Rebhinder, Department of Anatomy and Histology, Royal Veterinary College, S-750 07 Uppsala 7, Sweden.