SIMPLE CLINICAL TEMPERATURE TELEMETRY SYSTEM FOR PINNIPEDS

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SIMPLE CLINICAL TEMPERATURE TELEMETRY SYSTEM FOR PINNIPEDS

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Abstract: A telemetry pill was used to monitor core body temperature of penned sea lions. The pill emitted radio frequency (88-108 MHz) pulses at a rate proportional to body temperature. The emitted pulses were received as clicks on a common transistor radio. The pill, which was 1.1 cm diameter and 2.5 cm long, was inserted in a fish which was fed to the sea lion. Range exceeded 5 meters when the sea lion was in the air or in small fresh water pools, whereas immersion in sea water blocked transmission. The 2.5 cm long pills stayed in the animals for several days to weeks. Increasing pill length to 5 cm reduced the time to approximately 2 days. Mean core temperature (4 animals, 97 observations) was 38.1 C, with a standard deviation of 0.4 C. The pill has detected febrile response to disease, and has been used to assist in monitoring postsurgical recovery.

INTRODUCTION

Sea lions present the clinician with a dilemma. To accomplish a physical examination, the clinician must chemically or physically restrain the animal. Therefore, the examination itself may stress the animal so as to disrupt training programs or make the animal hostile; as a result, time and labor are lost. On the other hand, delaying an examination until the clinician is certain that an animal is sick may stall medical treatment until it is too late; at best the prognosis is less favorable.

Radiotelemetry of core body temperature of pinnipeds has been accomplished by several scientists,[1,2,4,5] but the technique has not been adapted for clinical purposes. Knowledge of body temperature, taken from a radio pill in the gastrointestinal tract, can aid the clinician in deciding whether or not to restrain an animal for a more detailed examination. In animals known to have a febrile disease, remote monitoring of temperature gives valuable information on the progress of therapy. Another use of temperature telemetry is the evaluation of postoperative recovery.

The objective was, therefore, to build and test temperature telemetry pills that would satisfy the needs of the clinician. Constraints were that the pill must be small enough to pass through the gastrointestinal tract; it must be rugged to enable re-use after being chewed upon by the animal; it must be simple and inexpensive to construct; and it must have acceptable range of transmission. Fabrication and testing of this system fell into various phases: pill construction, calibration, administration to the animal, data collection, and pill recovery.

PILL CONSTRUCTION

Standard broadcast radio frequencies (88 to 108 MHz) were used to provide a simple, inexpensive* biotelemetry system. The duration of time (approximately 1.5 sec) between radio frequency pulses was chosen as the temperature dependent variable because this technique conserves battery power and an animal's

* An electronics technician can build and calibrate the first pill in 8 hours; later pills in about 4 hours. Replacing batteries takes about 30 minutes and recalibration 1 hour. Parts bought in small quantities cost approximately $20.00; re-used pills need only to have batteries replaced and recalibration. The cost of the pill, therefore, depends mostly on speed of assembly, and success of recovery for re-use.

temperature could be measured using only a transistor radio and stopwatch. The transmitter consisted of a thermistor controlled complementary pair multivibrator, and a Colpitt's oscillator (Fig. 1). Component values were chosen for simplicity in construction, minimum power consumption and physical dimensions, best calibration linearity, and maximum transmission range. The operational life of this transmitter has exceeded 5 weeks on a single set of 60 milliamperehour batteries. It was important that the batteries be fresh (purchases were made directly from the manufacturer and refrigerated until they were used) and that very little heat be used in connecting the battery to circuitry. An electric spot welder was used to connect leads to batteries quickly enough to prevent heat dissipation in the batteries. This provided maximum battery life and prevented the corrosion of circuit components by chemicals released from heat-damaged batteries.

Discrete components were assembled on pre-punched terminal boards, assuring the mechanical integrity of parts and simplifying the layout and maintenance of circuitry. Although volume constraints dictated that the components be in close proximity, particular care was taken to keep leads short in the transmitter section, thereby limiting transmission bandwidth. Several packaging techniques were used, but complete encapsulation of the electronics in plastic test tubes was most successful in preventing fluid from penetrating into the circuitry. Beeswax was first used as a filler inside the test tube, but substitution of dental acrylic as a filler improved the durability of pills. Acrylic prevented damage to circuitry caused by chewing before the pills could be recovered from the animal pens. A 20 cm length of umbilical tape was attached to one end of each pill to aid passage out of the stomach. Pills without the tape had a disturbing tendency to stay in the stomach indefinitely, like a stone.

CALIBRATION

Each pill was calibrated by using a thermal bath, radio receiver, and electronic counter.** The calibration accuracy was not dependent upon the quality of the radio receiver, and the electronic counter was far more accurate than needed for our purposes. As a result, the calibration accuracy was dependent upon the maintenance of a constant temperature in the thermal bath. A thermistor-controlled heating element placed in the

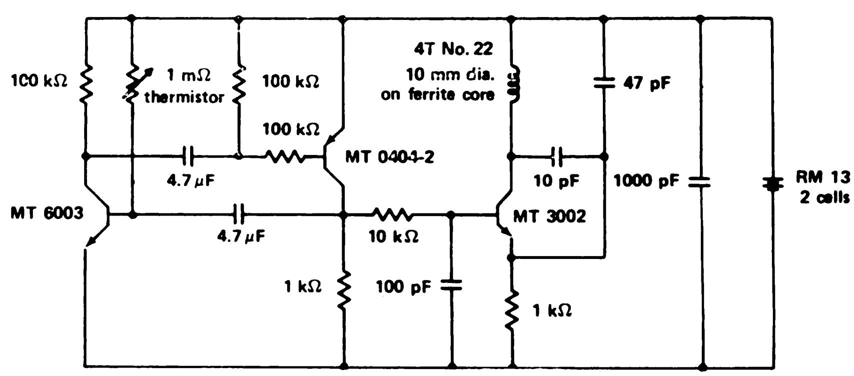

FIGURE 1. Schematic drawing of temparture transmitter.

**The electronic counter is not essential because the clicks can be heard on a radio and timed with a stopwatch. Measurment of elapsed time for 30 clicks is simpler and more accurate than counting the number of clicks transmitted during a fixed period of time.

center of a well-circulated and insulated bath worked best. Temperature was checked using a calibrated mercury bulb thermometer, and calibration accuracy was estimated to be within ± 0.05 C. As many as 20 points were used in calibrating between 34 and 40 C. Because the calibration curves were extremely linear, it was necessary to calibrate only for each degree centigrade (Fig. 2).

Refrigeration greatly reduced the pulse rate of the transmitter, and thereby extended battery life. Units have been stored in a refrigerator several weeks before being used. Also, pills with one battery lead disconnected after calibration may be stored indefinitely. Pills stored in this manner were quickly prepared for use by connecting two wires and applying a cap of acrylic.

ADMINISTRATION TO THE ANIMAL

If the sea lion was taking food, the pill was inserted into a fish to be fed to the animal. The fish had to be small enough to be easily swallowed, but large enough so that the pill could not be detected in the fish by the sea lion. If the fish was suspected of being different, the sea lion usually made a test bite, and some pills were damaged in this fashion.

Sea lions being force-fed on fish were simply given a fish with a pill in it. Pills were given to other species by stomach tube, a method that can be used on tube-fed or anesthetized sea lions.

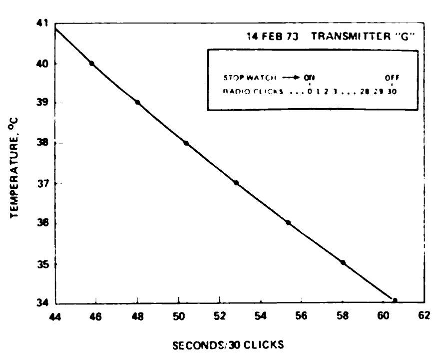

FIGURE 2. Typical calibration curve.

DATA COLLECTION

The sea lion was approached to within 5 m with a radio. Sea water blocked radio transmission beyond a few centimeters, but good signals were obtained from animals swimming in small fresh water pools or resting in air. The signal was monitored as a click on a commercally available, over-the-counter FM transistor radio. The signal from the radio pill simply was tuned in, and a stopwatch was used to measure the time required for 30 clicks to occur. Reference to a calibration chart of temperature versus elapsed time (Fig. 2) gave the core temperature of the animal.

PILL RECOVERY

During the early tests the pills were negatively buoyant (sinkers), diameter was 1.1 cm or less, and length ranged from 2.5 to 4.0 cm. McGinnis[1] reported that dummy transmitters fed to juvenile seals were always passed per rectum if pill diameter was less than 1 cm; pills 1.5 to 2.0 cm in diameter were only occasionally passed. Our pills stayed in the sea lions for periods from several days to many months. Pills of differing density (even those which floated) failed to be expelled in less time. By adding a 20 cm umbilical tape tail to the pill, recovery time was reduced to a mean of 4 days (times ranged from 6 hours to 11 days). Increasing pill length to 5.0 cm reduced pill recovery time to approximately 2 days, and eliminated the need for the tape tail. To date it has not been determined whether the pills were vomited or passed through the intestines. All recovered pills except two were free of feces or vomitus. The two exceptions were found in vomitus, suggesting vomition as a return mechanism. Radiographs provided no insight. Invariably the pills were shown to be in the stomach.

After being expelled from the sea lions, pills were usually played with, chewed upon, and thrown about. It was unusual to find a pill in the cage or pool where it was still accessible to the animal. Although floating pills were more easily retrieved from pools, they were abandoned because they were fragile and easily destroyed by chewing.

A few pills have been lost, presumably down the drain. In these instances, the grill was either inadvertently left off the drain or the sea lion displaced the grill. Occasionally pills may have been thrown into neighbouring pens which did not have grills over the drains. Currently an animal is fed a pill and then placed in a pen having sleats over the cement. This facilitates recovery and reduces chewing damage. Cost per use is reduced because recovered pills require only new batteries and recalibration; the initial material and construction costs are eliminated.

RESULTS

Data were collected from four sea lions which appeared to be healthy and ranged in weight from 20 to 50 kg. Because the chilling effect of a cold meal lasted nearly 1 hour, data taken within an hour after feeding were not included in the calculations. The mean temperature from 97 observations was 38.1 C with a standard deviation of 0.4 C. This temperature was much higher than 37.2 $\pm$ 0.24 C and 36.6 $\pm$ 0.45 C reported for two California sea lions by Southworth.[4] Temperatures taken by rectal thermistors (inserted 25 cm) were 0.3 to 0.5 C lower than core temperatures, accounting for the slightly lower rectal temperatures (37.5 C) reported by Ridgway.[8] One animal's core temperature versus hour of the day was recorded for 4 days (Fig. 3). This recording showed a considerable variation in temperature, but always within well defined limits. These temperature variations could not be correlated with any particular activity; data were collected on hot, sunny, overcast, cool, and rainy days when the animal was wet and dry, awake and asleep(including sleeping while afloat in a pool).

These data suggested that the normal range of temperature for a California sea lion was 37.3 to 38.9 C (two standard deviations above and two standard deviations below the mean). Because sea lion temperatures were so variable, continuous remote temperature sensing was used to determine if temperatures exceeding the normal range of values were truly abnormal. Such excursions were considered normal if the temperature returned to the normal range within a few minutes. Measurement of such extreme temperatures using a non-continuous monitoring technique might unnecessarily have led to restraint and examination of the animal.

In the course of this work a healthy sea lion was fed a pill 3 days before becoming sick (Fig. 4). Although the temperature went up as early as the 4th day, food consumption remained normal until the 8th day when the animal stopped eating. On the 9th day, restraint was used for a physical examination and venapuncture. Blood analysis indicated an elevated white blood cell count. A specific diagnosis was not made, but the

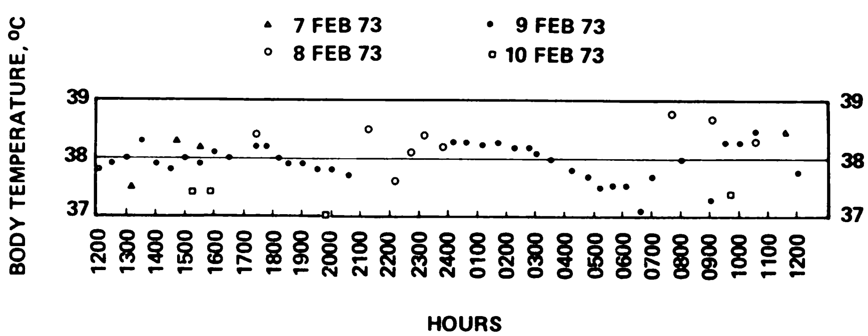

FIGURE 3. Core temperature of California sea lion (Zc 425) on 24-hr. basis.

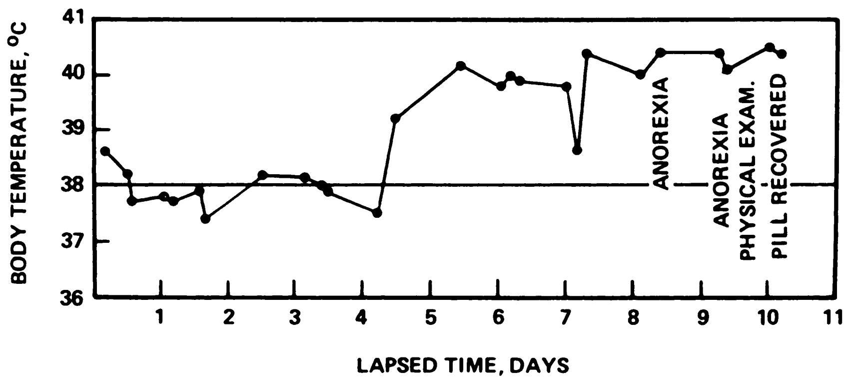

FIGURE 4. Temperature of sick California sea lion (Zc 406).

animal's temperature returned to normal following antibiotic therapy. Although the sea lion was alert and appeared normal throughout the entire period, ill health was strongly indicated by the elevated core temperature recorded by this system long before change of appetite occurred.

Acknowledgment

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