

CURRENT COMMENT

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Radio Telemetry in Patient Monitoring

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The noun *telemetry* and the verb *telemeter* are creeping into everyday usage. In its literal sense, telemetry means the making of measurements from a distance. Telemetry is a very broad term and includes measurements made from afar by sight, sound, through wires, or by the use of radio. It is in this latter sense that telemetry is thought of most frequently. With the increased use of radio as a method of data transmission, telemetry has become almost specifically associated with "measurement by radio waves."

In recent years, most research and development in the field of radio transmission has been directed toward the use of high frequencies (television, video, radar), transmission of signals over long distance, and the transmission of numerous data channels on a single carrier frequency. This research has been most active in industries concerned with communications and guided missiles. Radio telemetry, utilizing frequency modulation, amplitude modulation, or a combination of these techniques has become a standard method of monitoring the performance of high speed aircraft, missiles, and rockets.¹ Special high frequency channels have been allocated for this purpose. When it became apparent that humans might someday be passengers in space vehicles, it became important to devise methods of monitoring, by observation stations on earth, the physiological functions of these passengers. Radio telemetry was the only available method, so information on body temperatures, skin resistance, the electrocardiogram, respiratory rate, etc., simply was added to the numerous channels of information already being sent

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earthward. Because of problems of pressurizable clothing, the linkage between the subject and the powerful radio transmitters was sometimes established by miniature transmitters attached to the subject rather than by direct wires. Thus, was established the practice of "telemetry to the telemeter," which, today, is commonplace.

With the expansion of surgery and anesthesia, everyone has become familiar with the problems of inconvenience, infection, explosive hazards, and management of electrical interference which have accompanied the introduction of more and more electrical and electronic equipment into and near operating rooms. Although much rewarding effort has gone into the design and production of this equipment, there is much room for improvement.

Because the inconvenience of wires and the prevalence of alternating current interference and other artifacts are major factors limiting the use of monitoring equipment, it was decided to try radio telemetry as a tool in patient monitoring. Using miniature self-contained transmitters (fig. 1) tucked away on the operating table or bed, or carried by the patient, recording and display equipment can be located in areas of optimum convenience and easy visibility in or near operating rooms, critical care areas, or in any other location of choice.

Following principles already established²⁻⁸ but concentrating on simplicity, a telemetry system was designed (W. Thornton) with the following objectives in mind:

- (1) Transmitters should be small, entirely self-contained, with short leads to the subject.
- (2) Conventional and relatively inexpensive components should be used.

(3) Special licenses should be unnecessary.
(4) Only a few milliwatts of power should be employed. No external antenna should be necessary. In this application, distance is not an objective.

(5) The hazards of explosion and electric shock should be eliminated.

(6) Reproduction of the physiological signal should be flawless.

(7) A calibration signal must be provided.

(8) Rechargeable, rather than replaceable, batteries should be used for power. Battery power should last at least 12 hours. When not in use, the transmitters should be connected to a trickle charger with little possibility of damage due to overcharge.

(9) Transmitters should be sterilizable (ethylene oxide or cold sterilization).

(10) Receiving equipment should be inexpensive and, wherever possible, unmodified commercial receivers should be used.

(11) The output of the receiver should drive conventional recorders, oscilloscopes, or other display devices.

(12) *At no time should the use of radio telemetry add problems. The system must be simple.*

With the above objectives in mind and using the electrical activity of the heart as a physiological signal of low frequency in the millivolt range, transmitters were designed to meet the above specifications. Experience in several hundred subjects in the operating rooms, recovery rooms, during ordinary hospital activity and mild exercise has shown the following:

(1) An accurate picture of the electrical activity of the heart can be obtained within the ordinary hospital range of audible or visual observation (50–75 feet).

(2) Reproduction of the electroencephalogram is quite satisfactory, but because of the lower voltage or the electrical activity of the brain, additional amplification must be added.

(3) In the reproduction of physiological signals of higher frequencies (electromyogram) or lower frequencies (temperature, skin resistance), by a transmitter designed for electrocardiography, distortion begins to appear. In this problem, certain facts must be recalled: in electronics, the amplification of low frequency signals has always been a problem;

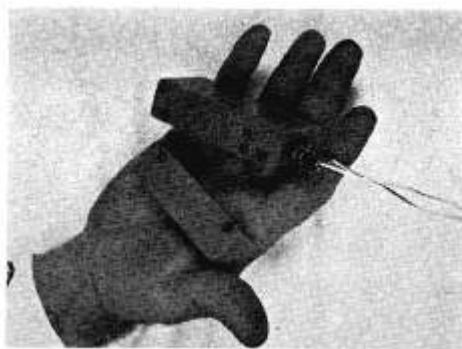


FIG. 1. Miniature radio transmitter. Battery pack (near thumb) plugs into main assembly. Wires lead to electrodes. When not in use, batteries are connected to trickle charger.

and, in “high-fidelity” sound reproduction, distortion is most prominent in the high and low frequencies. For absolutely flawless reproduction of other physiological functions, it is certain that present transmitter design will have to be tailored to the particular function.

(4) Grounding of the subject or transmitter is unnecessary. This is due to the fact that the transmitter is kept near the subject; hence, “floats” at the same relative potential as the subject. Even if the subject touches the “hot” side of 110 volts A.C., electrical interference is minimal. These units have functioned quite satisfactorily in subjects immersed in ice baths for hypothermia. The electrocautery, while in operation, introduces a radio frequency signal which blocks transmission temporarily. It is possible that this source of interference could be filtered out.

(5) Radio telemetry may be used quite satisfactorily in monitoring the electrocardiogram during ordinary hospital activity or during exercise. In this application, electrodes must be placed over bone in order to minimize muscular interference. Ribs, sternum, clavicles, or the sacrum offer convenient areas for electrode placement, and the choice of location depends on the particular wave which is of most interest. As in any electrocardiographic technique, firm fixation of electrodes is imperative. To date, the most satisfactory electrodes are made of dime-sized pieces of silver.

(6) In the resting, unconscious, or anesthetized subject, hypodermic needle electrodes may be used to advantage. Ordinary “banana” plugs are excellent needle adapters. The

selective placement of needles permits the use of any single lead for the electrocardiogram or multiple leads with a lead selector switch may be employed as in conventional electrocardiography.

(7) The amplification of conventional radio receivers permits the use of low-gain (hence, possibly less expensive) display or recording equipment. To date, experience has been gained only with commercial equipment of high quality. Using standard equipment for displaying the receiver output, sensitivity requirements for the electrocardiogram have been reduced from the standard 1 millivolt per centimeter to 0.5–1 volt per centimeter.

(8) In experience at our hospital, direct wire connections have not been replaced by radio telemetry. This may be due to the fact that prior to the introduction of radio telemetry, a very excellent monitoring system was already in use.

At the present time, radio transmitters operate on 8-volt batteries. The current drain is quite small and by present standards, these transmitters *might* be classified as being safe for use in the presence of flammable anesthetic agents. To our knowledge, no certification of this safety factor has been made. Perhaps just as important as the reduction of the hazard of fire and explosion is the fact that radio monitors *cannot* furnish a ground path which may contribute to the ever-increasing hazard of electrocution of the patient and operating room personnel. Further clarification of these issues is to be expected.

One of the principle advantages of radio telemetry lies in the fact that a single transmitter can send and a single receiver can receive many bits of information. This fact is best appreciated by the analogy of the radio transmission and reception of the sounds of a full symphony orchestra. If one thinks of each patient or bed as a radio station and each monitoring apparatus as a receiver, one may observe physiological functions in different patients by tuning from one "station" to another without interference. Likewise, the number of functions that may be observed on a given patient depends only on the number of functions transmitted. Each may be discriminated at the receiving end of the system

just as the ear analyzes the sound of the symphony. All may be displayed or recorded simultaneously and analyzed individually. Radio telemetry allows a tremendously flexible system to be constructed around the basic structure of single transmitters and receivers. This practice is already commonplace in other fields of science. It needs adaptation to the field of medicine.

In considering the modification of older hospitals or in the construction of new hospitals, the use of radio telemetry must be considered not only as a tremendously flexible factor but as a relatively less expensive factor in patient monitoring. There is no reason to feel that radio telemetry is a less accurate or more inconvenient method of monitoring. Certainly, it is more flexible than methods employing direct wire connections. The economic factors need further investigation in view of the cost of alteration of present hospitals and the cost of installation in new construction projects.

The most interesting applications of radio telemetry lie in its barely explored and future possibilities in clinical and experimental medicine. It is to be admitted that many normal values are not known with accuracy. In many cases (*e.g.*, blood pressure, pulse rate, electrocardiogram, basal metabolic rate, blood sugar), the making of a measurement creates a distinctly abnormal situation; hence, an abnormal "normal" value. Radio telemetry has helped to prove this insofar as the resting pulse rate of the dog is concerned.⁸ How often is a sleeping pulse rate taken without awakening the patient? If the electrocardiogram, taken in the recumbent position by a hostile technician shows "non-specific S-T segment changes," what is the nature of the S-T segment when the patient is asleep or is seated in a chair quietly reading the newspaper? What happens to the S-T segment when the patient turns from the sports page to the stock market and finds his stock has dropped three points? With advances in miniaturization, it should be quite simple to design transmitters half as large as an egg which can be carried by the subject with the same convenience as a wrist watch. Transmitters are already available which can be swallowed,⁴ implanted in experimental ani-

mals, or carried around by a cockroach.⁹ The possibilities are infinite.

Another advantage of radio telemetry in physiological monitoring lies in the fact that, using standard subcarrier techniques, it is quite feasible to use commercial tape or belt recording systems for recording, playback and storage of physiological data at a considerable saving of time and money.

At this time, radio telemetry as a tool in physiological monitoring is at least twenty-five years behind the applications of radio telemetry in other fields. It is not yet fool-proof. Its use offers many advantages, and its possibilities are tremendous. If this technique gains popular appeal, it will be most interesting to watch its future development.

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Efficacy of Oxygen Administration

Dr. Thomas F. Hornbein of Washington University School of Medicine, St. Louis, Missouri, evaluated the relative efficiency of a nasal oxygen catheter and K-S disposable oxygen mask (Ohio) for administration of oxygen by comparison of alveolar oxygen tensions in a conscious, resting subject. Alveolar oxygen tensions were measured by elution of 40-cu. mm. aliquots of Haldane samples in a gas chromatograph.

The advantage of the mask results from re-breathing of oxygen-enriched expired air in addition to the basal oxygen flow. Accumula-

tion of carbon dioxide is minimized by re-breathing into a bag of small volume which is washed out by an adequate flow of oxygen.

	Alveolar Po ₂ (mm. Hg) at Oxygen Flow of:	
	4l/minute	6l/minute
Nasal Catheter	210	270
Disposable Mask	350	425

The greater comfort of the mask should also be mentioned, especially as compared to the sensations resulting from administration of high oxygen flows through a nasal catheter.

Meperidine and Propiomazine for Preanesthetic Medication

Captain Paul Davis and Lt. Col. John A. Jenicek of Brook General Hospital in San Antonio, Texas, while utilizing a double blind technique, gave two groups (40 in each) of patients preanesthetic medication on the following basis: one group, meperidine, 0.5 mg. per pound and propiomazine (Largon) 0.15 mg. per pound, the second group only meperidine, 0.5 mg. per pound. The factors of age,

weight, sex and sampling were sufficiently controlled so that subjective and objective data obtained could be statistically analyzed.

The subjective factors of general effect, sedation, presence of apprehension, and ease of induction showed no significant differences in either group. The objective differences considered were respiratory rate, minute volume, tidal volume, and alveolar ventilation. Calcula-