MEDICAL APPLICATIONS OF NASA-DEVELOPED SCIENCE AND TECHNOLOGY

QUARTERLY PROGRESS REPORT NO. 2
30 April - 31 July 1965

Task Order Contract No. NASr-63(03)

MRI Project No. 2563-M(E)

For

Technology Utilization Division
Office of Technology Utilization and Policy Planning
Code ATU
National Aeronautics and Space Administration
Washington, D. C. 20546

MRI

MIDWEST RESEARCH INSTITUTE
425 VOLKER BOULEVARD/KANSAS CITY, MISSOURI 64110/AC 816 LO 1-0202

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by

R. W. Fetter
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PREFACE

This quarterly progress report covers project activities from 30 April 1965 to 31 July 1965. The report was prepared by R. W. Fetter, C. C. Craghead, P. L. Smith, and J. Brick, on behalf of the entire project team, which includes Drs. Martin E. Silverstein, Mabelle Cremer, and Aaron Freedman, and other physicians and medical researchers at the Menorah Medical Center.

Approved for:

MIDWEST RESEARCH INSTITUTE

James Alcott

James Alcott, Director
Economic Development Division

30 August 1965

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SUMMARY

Project activities during this quarter have included continuing education of team members through seminars and discussions, literature reviews to establish a state-of-the-art base line for evaluation of NASA technology, and definition of several problem areas in medicine where technology might readily be applied.

Preparations are being made to visit several NASA Research Centers during the next quarter. Specific items of interest at the Centers have been selected for a detailed investigation, but broad areas of the Centers' technology development will be covered in a search for solutions to specific problems.

I. INTRODUCTION

The general approach to the problem of adapting aerospace technology to the field of medicine involved a multidisciplinary team from the medical and physical sciences, capable of recognizing potential application and adapting the technology solutions to medical problems. Initial efforts were directed toward education of the two teams in areas of each other's specialities. The education process is not designed to make expert engineers of doctors or doctors of the engineers. It is primarily aimed at making intelligent conversation possible between members of the two teams so that information can be obtained to permit the identification and definition of specific problem areas within the medical field.

The size and nature of the current program places certain boundaries on the problem areas which can be considered. The effort on this pilot program has therefore been limited to problems which appear to have possible solutions within the realm of NASA developed science and technology. Transfer of NASA technology to provide solutions to medical problems may be direct, as in the case of space medicine developments, or indirect, as with transfers from unrelated fields of technology or through the application of NASA developments now available through commercial suppliers.

II. PROJECT ACTIVITIES

A. Seminars

Additional seminars have been held as part of the continuing team education program. A discussion on transducers for patient monitoring indicated a need for further discussion on the engineering capabilities of transducers and for a survey of the current state of the transducer art as a reference for evaluating new devices as they are announced. A seminar at Menorah Medical Center (MMC) on emergency room equipment and procedures provided an excellent opportunity to see the latest specialized methods required in this area. Several problem areas noticed during this demonstration will receive concentrated effort to provide solutions through technology transfers.

It was noted during the demonstration that our first "transfer" was being used routinely. Although this was not a NASA innovation it is interesting because of the speed with which the transfer was made. Menorah Medical Center personnel had mentioned the need for a quick, simple method for determining whether a patient was still alive. The MRI team arranged for a demonstration at MMC of the Westinghouse "Miniscope." One unit was purchased and is now routinely used to monitor patient heart beat from the moment they enter the emergency entrance. It is expected that further improvement can be made in this system using the NASA developed electrodes and pastes.

B. Problem Identification

Problem identification has been separated into two rather broad categories. The first considers specific problems which may benefit from transfers of NASA technology in areas of instrumentation, transducers, materials, manufacturing methods, telemetry, and general advances in the hard sciences. This "hardware" category should produce improvement in the currently used medical equipment and possibly develop entirely new equipment and methods for specialized uses.

The second category, "software," deals primarily with the transfer of broad areas of information from NASA research to the general medical field. Initially this type of transfer will come primarily from the extensive NASA literature. It will be discussed in the section on literature reviews.

Some of the possible transfers in the "hardware" category include:

1. Hip joint instrumentation: One item of NASA bioinstrumentation technology, which may result in a transfer in the immediate future, is a miniature biotelemetry transmitter designed and developed at NASA's Ames Research Center. This transmitter, which is the subject of NASA Tech Brief 64-10171, is being considered jointly by doctors at the Menorah Medical Center and engineers at MRI for use in a study to determine the deleterious effects (if any) of hip joint fluid pressure variances upon the bone healing and mending process in hip fracture cases. Although this effort began under a separate program, prior to the initiation of the present medical TU effort, it nevertheless represents a significant transfer of NASA instrumentation technology to the medical community. Furthermore, this represents a somewhat ideal case in that the problem input was generated by the medical community and MRI engineers have drawn from their present bank of NASA technology to obtain part of the solution.

2. EKG monitoring by telemetry: A second problem which may involve several NASA innovations is that of monitoring patients who have had heart palpitations but are perfectly normal when they arrive at the hospital for observation. It would be desirable to monitor the cardiac activity of these patients without seriously limiting their normal physical activities. The possibility of monitoring and recording EKG data with a simple, reliable, lightweight telemetry and recording system appears quite promising, particularly in light of the extensive NASA development in these areas.

3. Emergency use of a blood oxygenator: While standard blood oxygenators are widely used for planned surgery cases, there is a definite need for such a device suitable for use in emergency procedures where the current 20-min. setup and priming time would be impractical. Menorah Medical Center provided a demonstration and an educational motion picture showing the many steps necessary to prepare the blood oxygenator for use. Many of the operations involved in this process fall within the field of NASA interest and innovation. Among these are sterilization of equipment, quick connection of multiple tubing for gas and liquids without contamination, valves, and temperature regulation. It is believed that adapting technology from these areas could reduce the current setup time to something less than 5 min., thereby extending the usefulness of the oxygenator to regions not now considered.

C. Literature Review

Several literature searches and reviews have been completed or are in progress.

1. Interpretive report on "Physiological Effects of Impact Deceleration:" At the request of MMC, a review of literature concerning the physiological effects of impact deceleration has been initiated. The purposes of this review are to survey recent NASA and other publications dealing with impact effects, and to prepare an interpretive summary of this material for MMC personnel. The emphasis in the review is being placed on the biodynamic aspects of impact research, such as the development of mathematical models, to represent the behavior of the human body under various impact conditions. About 50 relevant documents have been ordered, and the review is already in progress. The interpretive report will be presented to MMC in written form and will be followed by a discussion session.

In addition, an ARAC computer search has been initiated on this subject to obtain a comparison with the manual search.

2. Bio-instrumentation review: An ARAC computer search of available STAR and AIAA literature has been completed and the abstracts have been received. This was a rather broad search involving the single listing "bio-instrumentation" and covers the years from 1961 to 1964. The 183 items obtained give us a broad picture of NASA technology in this area, but only 17 of the items are of immediate interest on this program.

3. Tech brief evaluation: Seventeen NASA Tech Briefs have been selected for evaluation by the medical team for possible direct application to medical problems. They will also acquaint the team with the general nature of NASA innovations. This evaluation is now in progress on the following items:

1. Ultra-Sensitive Transducer Advances Micro-Measurement Range, Brief 64-10004.

2. Pressure Transducer 3/8-Inch in Size Can be Faired into Surface, Brief 64-10021.

3. Improved Electrode Gives High-Quality Biological Recordings, Brief 64-10025.

4. Encapsulation Process Sterilizes and Preserves Surgical Instruments, Brief 64-10066.

5. Device Induces Lungs to Maintain Known Constant Pressure, Brief 64-10108.

6. Technique Simulates Effect of Reduced Gravity, Brief 64-10146.

7. Subminiature Biotelemetry Unit Permits Remote Physiological Investigations, Brief 64-10171.

8. Digital Cardiometer Computes and Displays Heartbeat Rate, Brief 64-10258.

9. Pneumotachometer Counts Respiration Rate of Human Subject, Brief 64-10259.

10. Vehicle Walks on Varied Terrain, Can Assist Handicapped Persons, Brief 64-10274.

11. Inexpensive, Stable Circuit Measures Heart Rate, Brief 65-10010.

12. Improved Conductive Paste Secures Biomedical Electrodes, Brief 65-10015.

13. Mouthpiece Adapter for Pipettes Protects Mount from Harmful Liquids, Brief 65-10043.

14. Photoelectric Sensor Output Controlled by Eyeball Movements, Brief 65-10079.

15. Simulator Produces Physiological Waveforms, Brief 65-10091.

16. Auxiliary Circuit Enables Automatic Monitoring of EKG's, Brief 65-10142.

17. Digital-Output Cardiotachometer Measures Rapid Changes in Heartbeat Rate, Brief 65-10143.

4. Periodical monitoring: The following is a list of bio-medical and related periodicals that we are now monitoring to keep abreast of recent developments in the field attained both through research efforts and commercial equipment availability.

Aerospace Medicine

American Journal of Medical Electronics

Bio/Medical Instrumentation

Bio-Physics

IEEE Transactions on Bio-Medical Engineering

Medical Electronics and Biological Engineering

Medical Electronic News

Physics in Medicine and Biology

World Medical Electronics and Instrumentation

Medical World News

5. Literature survey of physiological monitoring: A literature survey has been conducted to determine the state-of-the-art in the medical fields to which NASA technology might be transferred. The survey consisted of a review of journals and periodicals concerned with medical electronics and bio-medical engineering and a classification of articles which might be of particular interest to the interdisciplinary project team.

In the first portion of the survey emphasis was placed on obtaining a backlog of developments in physiological monitoring and medical instrumentation. From this study, it is apparent that there are six areas of physiological measurement and monitoring in which the major portion of research and development is being done. These areas are blood pressure measurement, blood flow measurement, endoradiosonde techniques, pulse rate measurements, telemetry systems, and transducer development.

Blood pressure measurement: Most research concerning blood pressure measuring devices is being done in the area of indirect measurement. While direct measurement by means of direct hydraulic coupling to external transducers and by use of miniature endovascular transducers yields a maximum of information, it also requires the puncture of a vessel. For most medical purposes, indirect measurement provides sufficiently accurate information with much less disturbance to the patient.

The two main areas of innovation in this field are devices for continuous, and possibly remote, monitoring of blood pressure; and indicators or meters which rely less on human judgment of the Korotkoff sounds (heard through a stethoscope in the conventional measurement of blood pressure using a sphygmomanometer) and more on the simple reading of a meter calibrated to read magnitude of pressures.

In the first category devices have been developed which automatically measure and record blood pressure for 12 hr. or longer.[1,2] At present, work is being continued to reduce the size (through occlusion of finger arteries rather than arm) and the expense of measurement devices.

In the second category most work is being done in external indirect measurement using transducers which convert either the sound, displacement, or restraining force of arteries into electrical impulses which are used to indicate the blood pressure on a meter. One method picks up the Korotkoff sounds on a sensitive microphone, amplifies them, and sends them through a multivibrator which trips meters upon hearing the first and last sounds, the meters corresponding to systolic and diastolic pressures.[3] Another method employs a transducer which restrains arterial deflection and then measures the restraining force.[4] The force is transformed into electrical impulses which trigger a calibrated meter. These methods provide accurate blood pressure measurements and the first is available at low cost.

Blood flow measurement: The three most widely used types of flowmeters used today are those based on hydromechanic, electromagnetic, and ultrasonic principles. The hydromechanic methods are least popular, the electromagnetic are most widely used, and the ultrasonic are increasing in popularity.

Most hydromechanic methods (Pitot meters, orifice meter, Bristle and pendulum meter, rotameter) are applicable only under surgical conditions and on opened blood vessels. Exceptions are flow signals obtained by a catheter method (pressure gradient computing method) and by a differential pressure device (Venturi meter) surrounding a skin-covered arterial loop.

The most accurate and the smallest of the hydromechanic methods is the Bristle meter.[5] This device consists of a thin needle placed perpendicular to the blood flow; the flow rate is proportional to the force on the needle. Bristle meter measurement has the disadvantages that anticoagulants are necessary and the relationship between force and flow is hard to linearize.

Electromagnetic flowmeters work on the principle (Faraday's) that if a magnetic field is applied perpendicular to the flow of charged particles, such as blood, an electric field will be produced mutually perpendicular to the flow and the magnetic field. Small transducers are used to pick up the electrical impulses of the field. The electromagnetic method has the advantages that (1) blood vessels need not be opened nor foreign objects inserted; (2) the response is essentially instantaneous; (3) the meter can differentiate between forward and backward flow; (4) the calibration is linear and independent of the character of flow (laminar or turbulent); and (5) the calibration is independent of temperature, pressure, density, and viscosity of the blood.[6] The main disadvantage is that surgical implantation is necessary. Work is being done to lower the cost, increase the stability, and reduce the size of these flowmeters.[7,8]

Ultrasonic devices work on two principles; one measures the difference in transit time of high-frequency sound pulses sent upstream and downstream in the blood flow, while the other utilizes back-scattering of ultrasound by moving corpuscles and the resulting Doppler frequency shift. Although surgical implantation is necessary, ultrasonic devices are small and lightweight with good response and accuracy. One of the newest methods developed meets the needs for small transducers by combining catheterization with ultra-sound. This method uses both transit time measurement and phase detection.[9]

Work is also being done to determine flow without surgery in these areas: (1) thermal methods such as hot wire, heated thermocouples, and thermistors; (2) dilution of injected test substance; (3) gas exchange techniques; and (4) methods based on nuclear magnetic resonance.[10]

Endoradiosonde techniques: Endoradiosondes, also called radio pills and radio telemetering capsules, are small radio transmitters used for wireless transmission of physiological information from closed cavities or inaccessible places. While many endoradiosondes are surgically implanted, recent research has lead to the development of small, swallowable capsules which measure the physiological parameters of the gastrointestinal tract.

Endoradiosondes consist of two parts, the transmitter and the receiver. Energizing of the capsule is accomplished either by a small power source enclosed in the capsule or by an external field coupled electromagnetically to an internal tuned circuit. Newly developed transducers enable endoradiosondes to measure temperature, pressure, pH, partial pressure of carbon dioxide and oxygen, chloride ion concentration, enzyme activity, bioelectric potentials and intensity of ionizing radiation.[11] Some capsules are now available commercially.[12]

The foremost problems confronting the further use of endoradiosondes are the need for microminiaturization, a means of tracking the pills in the gastrointestinal tract, and a means of controlling the pill while in the tract. The size has been considerably reduced with the use of external energizing sources and hence the elimination of batteries. Capsules have been developed 8 mm. in diameter, 23 mm. long, and weighing only 1.9 g.[13] Recently a means for tracking the capsules has been developed.[14] Using a powerful externally energized micrometer, a Belgian scientist has developed a controllable capsule used for gastrointestinal measurements.[15] Called the "endomotorsonde", the capsule is independent of the gastrointestinal propulsive forces and externally controllable. It measures 7.6 mm. by 21 mm. and weighs 2.2 g.

Pulse rate measurement: The design of automatic and continuous pulse wave monitors constitutes the main area of innovation in this field. In most mechanized external pulse recorders a sensing device is placed on the skin over a large artery. The periodic pulsation of the arterial segment produces proportionate pressure changes which activate some form of mechanical or electrical transducer.

Since the technique of measurement is well established, most recent developments have been concerned with improvement and miniaturization of the component instruments. In order to obtain high sensitivity, systems have been designed which use both conventional and newly designed transducers.[16,17] Filter circuits are used in conjunction with the transducers in order to eliminate mechanical noise and artifact due to manhandling of the patient and vibrations from machinery attached to the patient.

Telemetry systems: Telemetry of physiological data has been the field of major interest and investigation in medical electronics and, to a larger extent, in space medicine in the past few years. No matter what the measurement, whether it be an electrocardiogram or data from an endoradiosonde, transmission of data from the patient to a receiving unit is necessary. The space effort has required special telemetry systems with accurate reliable performance. Much NASA literature has been published concerning telemetry.[18]

The main concern in telemetry is miniaturizing the size of the transmitter while retaining high quality transmission. The small size is necessary so that the transmitters can be worn comfortably or swallowed to provide transmission of data during normal activity of the subject. Recently, several subminiature, high performance telemetry systems have been developed.[19,20]

Because of the high sensitivity required of telemetry systems, the problem of drifting carrier frequencies due to temperature changes near the transmitters is an area of concern. This is especially true for transmitters worn on the body surface where the body temperature is approximately 12°C higher than room temperature. Recently, work has been done to compensate for this temperature problem.[21]

Transducer development: For the highly sophisticated measurement techniques, both direct and indirect, being used today, new transducers and sensing devices are being designed which are both smaller and more multi-purposed than their predecessors. The "Instrument Society of America" Transducer Compendium lists over 100 different commercially available transducers with bio-medical applications. These transducers measure motion, dimension, pressure, force and torque, flow of materials, sound, temperature, chemical composition, electromagnetic radiation, nuclear and penetrating radiation and humidity.

The types of transducers which are of the greatest use in medicine are those which measure pressure, motion or force, temperature, and sound. These transducers work on a variety of principles. Pressure transducers include the resistance type, capacitance type, inductance type, and photoelectric type. Sound transducers utilize piezoelectric materials and temperature transducers are generally thermistors. Force and motion transducers utilize the strain gage arch.

Most work being done on transducers is to decrease their size without decreasing their accuracy, reliability, or repeatability. Temperature transducers as small as 0.003 in. in diameter are available commercially.[22/]

D. Center Visits

A visit was made to the Manned Spacecraft Center at Houston and discussions were held with the TU staff regarding innovations in the Life Sciences. Several areas of interest were pinpointed for detailed discussion on a future visit.

A visit has been planned to the Flight Research Center at Edwards Air Force Base, California, to discuss a number of new items available at the Center. Information on many of these new items has been obtained from Edwards and studied in preparation for the visit. This advance study will make it possible to be quite specific in discussions with the personnel directly responsible for the item. Among the items to be discussed are:

1. Acoustic Arterial Blood Pressure Sensor.

2. Mass Spectrometer.

3. Miniaturized EKG Recording System.

4. Ear Oximeter Sub-System.

5. Electrode Cement.

III. FUTURE PLANS

Work during the next quarter will include:

1. Continuation of seminars and discussions with emphasis on problem identification and technology transfers.

2. Center visit to Edwards Air Force Base, Ames Research Center, and Manned Spacecraft Center at Houston.

3. Continuation of literature reviews of both periodicals and NASA report literature and establishment of "IN" (interest-need) profiles of team members with the NASA-SDI program.

4. Item evaluation and transfer into areas of need established by the team members.

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