SOUTHWEST RESEARCH INSTITUTE ASSISTANCE TO NASA IN BIOMEDICAL AREAS OF THE TECHNOLOGY UTILIZATION PROGRAM

QUARTERLY PROGRESS REPORT #2

Period Covered: 1 May 1969 - 31 July 1969

Contract No. NASW-1867
SwRI Project No. 13-2538

Prepared for

Chief, Dissemination Branch, Code (UT)
Technology Utilization Division
Office of Technology Utilization
NASA
Washington, D. C. 20546

15 August 1969

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO HOUSTON

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Prepared by: Louis S. Berger
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San Antonio, Texas 78228

Approved:

W. Lyle Donaldson

W. Lyle Donaldson, Director
Department of Bioengineering

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A. INTRODUCTION

1. General

The aeronautical and space activities conducted by the National Aeronautics and Space Administration (NASA) are creating an impressive body of knowledge of great potential scientific and technological usefulness. In carrying out its congressional mandate to disseminate this information for ultimate benefit of the general public, NASA has engaged in an extensive publications program; in particular, publications under the auspices of NASA's Technology Utilization Division (TUD) are specifically aimed at expeditiously transferring NASA developments to the scientific and industrial community.

Special difficulties are encountered when it is attempted to transfer NASA-derived technology, by means of TUD publications alone, to scientists in the biomedical fields. These scientists are particularly overburdened by the copious amounts of published biomedical material; additionally, they are by and large unfamiliar with the language and symbology of the physical and engineering sciences. As a result, technology in physical science and engineering has often not been as effectively transferred to biomedical applications as it deserves to be.

The TUD's investigations of the chain of events leading to the introduction of new products, technological inventions, and methods into medical practice have suggested that the biomedical research teams at medical schools and similar biomedical research institutions play a key role in this process. New discoveries, introduced by these groups, tend to proceed naturally through stages of professional approval, manufacturing interest and participation, on to the level of the practicing physicians, bringing direct health benefits to the public. It would seem an attractive goal to introduce NASA-derived advances at the level of the biomedical research team, and thus to utilize the existing channels to the medical practitioner and his patients for effective technological transfer.

As a result of these investigations, NASA's TUD has developed a general methodology for the solution of this important and special technological transfer problem. Prominently included in this methodology was the establishment of several strategically placed Biomedical Application Teams consisting of appropriately cross-trained and broadly experienced physical and biological scientists. It is the task of the Biomedical Application Team to facilitate and improve the productive interaction between NASA centers and biomedical research teams. Emphasis is on interpersonal contact, in which the cross-trained members of the Biomedical Application Team form an active link between these two groups of scientists. A flexible system is maturing in which both principal groups, NASA personnel and biomedical

researchers, freely and effectively participate in mutually beneficial exchange of skills and knowledge.

2. Participating Personnel

The following scientists are participating in the program:

- Southwest Research Institute Biomedical Application Team
- Southwest Research Institute Personnel (see Table I):

  - Ray W. Ware, M. D., Director
  - Louis S. Berger, Project Manager
  - W. R. Brian Caruth
  - Robert J. Crosby
  - David F. Culclasure
  - Charles J. Laenger, Sr.
  - Samuel G. Schiflett
  - Betty J. Wall
  - Andre G. Buck (West Coast)

- Key Coordinators at User Institutions:

  - F. Hermann Rudenberg, Ph. D., Associate Professor, Department of Physiology, The University of Texas Medical Branch, Galveston, Texas
  - Jack B. Johnson, Chief, Biomedical Instrumentation Section, Southern Research Support Center, Veterans Administration, Little Rock, Arkansas
  - Mr. John Hall, Seattle Handicapped Center, Seattle, Washington
  - Mr. Don Baker, University of Washington, Department of Bioengineering, Seattle, Washington
  - Mr. H. A. Miller, Stanford University School of Medicine
  - N. P. Thompson, M. D., Palo Alto Medical Research Foundation
  - Marcus J. Fuhrer, Ph. D., Departments of Physical Medicine and Rehabilitation, Texas Institute for Rehabilitation and Research
  - V. Mooney, M. D. (SRS), Rancho Los Amigos Hospital, Downey, California

TABLE I

Team Member	Institute Department and Section, Title	Technical Expertise	Team Function	Percent Time on Project
Ray W. Ware, M. D.	Manager Medical Instrumentation Research Section Department of Bio-engineering	Medical Instrumentation, physiologic monitoring; aerospace medicine	Director	25%
Louis S. Berger	Senior Research Engineer Medical Instrumentation Research Section Department of Bio-engineering	Communications proccesses; language perception; mathematical	Project Manager	60%
W. R. Brian Caruth, Ph. D.	Manager Operations Research Department of Electronics Systems Research	Operations Research	Data acquisition and analysis	5%
Robert J. Crosby	Biomedical Research Engineer Medical Instrumentation Research Section Department of Bio-engineering	Electrical Engineering; extensive experience and additional training in bio-medical engineering	Problem Coordinator	25%
David F. Culclasure, Ph. D.	Senior Research Psychologist Medical Instrumentation Research Section Department of Bio-engineering	Human learning and motivation; perception; psychometrics	Problem Coordinator preparation of instructional (briefing) material	50%

TABLE I (Cont'd)

Team Member	Institute Department and Section, Title	Technical Expertise	Team Function	Percent Time on Project
Charles J. Laenger, Sr.	Senior Biomedical Research Engineer Medical Instrumentation Research Section Department of Bio-engineering	Electrical engineer; cross-trained in biology; medical instrumentation	Problem Coordinator	30%
Samuel G. Schiflett	Research Scientist Medical Instrumentation Research Section Department of Bio-engineering	Experimental psychology; zoology	Problem Coordinator	25%
Betty J. Wall	Assistant Research Scientist Medical Instrumentation Research Section Department of Bio-engineering	Information handling; editorial skills, behavioral science	Data analysis; report preparation; participating team member on selected problems	100%
Andre G. Buck	Senior Research Engineer Medical Instrumentation Research Section Department of Bio-engineering	Electrical engineer	Problem Coordinator; participating team member on selected problems	30%

- Other Southwest Research Institute Staff consulted this quarter:

  - C. C. Johnson, Senior Research Engineer, Earth Science Applications Section, Department of Instrumentation Research
  - Fred M. Dickey, Research Engineer, Industrial Systems Section, Department of Instrumentation Research
  - C. Gerald Gardner, Ph. D., Senior Research Physicist, Nondestructive Evaluation Section, Department of Instrumentation Research
  - Wallace L. Anderson, Ph. D., Senior Research Engineer, Industrial Systems Section, Department of Instrumentation Research
  - W. L. Rollwitz, Manager, Electronic Instrumentation Section, Department of Instrumentation Research
  - D. G. Cadena, Jr., Senior Electrical Technician, Antenna Systems Research Section, Department of Applied Electromagnetics
  - James N. Bollinger, Ph. D., Senior Research Biochemist, Analytical and Biochemistry Section, Department of Chemistry and Chemical Engineering

B. SUMMARY OF PROJECT ACTIVITY, METHODOLOGY, INTERFACES

1. Biomedical Problems

During the current reporting period, ten new problem statements were submitted by biomedical researchers. Of these, five have been accepted for processing (WSM-7, BLM-10, BLM-11, SFM-6, and SRS-53). Three problems were temporarily tabled (WSM-6P, SFM-7P, and PLR-5P). These problems were not processed since information was immediately available either from NASA or other sources and was forwarded to the potential Problem Originator for his evaluation before initiating further team action. Two problems were rejected, since their scope was too broad for efficient processing at this time (SFM-8P and RNV-20P). The Problem-Originators of both of these problems were invited to submit a sub-problem having a more restricted scope, selected from their respective problem areas.

A total of forty problems was worked on as will be described in the Case History Supplements - No. 2. Five problems were inactivated for the reasons described in Section C. 2.

Eleven medical problem abstracts were disseminated through the NASA Research Centers, and these are included in Section C. 4. Four new medical problem abstracts (BLM-10, BLM-11, SFM-6, and WSM-7) were prepared but have not yet been disseminated. They are also included in Section C. 4.

Twenty-five visits to Problem Originators were made with direct application to submitted problems. Details of these visits are included in the Case History Supplements - No. 2.

2. Procedure Development

Project procedures have become quite well structured, and a project manual outlining and documenting these procedures is in preparation. As a submitted problem passes through various phases of development, experience has shown that some phases can be formalized, while others must remain more flexible to meet the different needs of the different problems. The two phases which best lend themselves to formalization are the pre-problem phase and the search phase.

In the pre-problem phase, which begins when a problem statement is received from a Problem Originator, the problem, bearing the suffix P, is entered into the Termatrex storage and retrieval system at Southwest Research Institute. The system is also searched at that time to discover possible overlap with problems previously submitted to one of the Biomedical

Application Teams. Any additional information necessary to make the accept/reject decision is gathered by means of interviews, consultation with Institute staff, or preliminary screening searches in the NASA indexes. The decision on whether to accept, reject, table, or perform further pre-problem work on the submitted problem is made following a discussion by the entire project staff in their weekly meeting.

The searching procedure, worked out in conjunction with the regional dissemination centers, requires assignment of the accepted problem to a problem coordinator; preparation of a medical problem abstract; submission of the abstract to the search center; validation of the proposed search strategy in telephone conversations between the search specialist and project staff members; screening and transmitting to the Problem Originator the search returns with appropriate comments in a cover letter; and an acquisition of a search evaluation report from the Problem Originator. The subsequent processing steps depend in large measure on the results of the Problem Originator evaluation.

3. New Institutions

The team director prepared an outline and time table of proposed acquisition of new user institutions. Initial meetings have been completed with the University of Texas Southwest Medical School at Dallas, and a formal presentation to selected researchers is planned for mid-September. Acquisition of other new institutions will be reported as arrangements are completed.

4. Other Project Activities

A photographic slide presentation and narrative describing the Biomedical Application Program to potential user institutions was prepared by Dr. David F. Culclasure of Southwest Research Institute, with the aid of other team members. This material will be used in forthcoming presentations, after approval of the script has been obtained from the sponsor.

In response to a request from Mr. John W. Johnston of George Washington University's Biological Sciences Communication Project, packages on four problems (GLM-19, HUV-17, NWR-1, and WSM-1) were prepared by Mrs. Betty Wall, Biomedical Application Team member, to be used by students at a Summer Institute in Biomedical Research and Technology Utilization conducted at Goddard Space Flight Center.

Mr. James T. Richards, Jr., Project Monitor for the Biomedical Application Program, forwarded a suggestion regarding signal processing techniques from Mr. A. J. Ellner, Marshall Space Flight Center. These suggestions were evaluated by several members of the team, and a brief

report on their findings was prepared and submitted to Mr. Richards. The suggestions proposed very general applications of auto- and cross-correlation techniques to problems of biomedical signal analysis.

C. PROBLEM STATUS SUMMARY

1. Transfers

a. Actual Transfers

WSM-6P, "High Power Infrasonic Wave Generator;" Researchers at the University of Washington School of Medicine are studying the disease atherosclerosis (a lesion of large- and medium-sized arteries) by means of analog mechanical/fluid models. A very low-frequency shaker was needed, and a special NASA/Ames device, developed originally for studies of aerodynamic flutter of wing surfaces, was made available on loan by Ames personnel. The actual experiments have not yet progressed sufficiently to allow reporting of experimental results and of the medical benefits derived.

b. Potential Transfers

Three of the inactivated problems (see Section C. 2) are considered potential transfers: two of these (RNV-10 and NWR-1) because of the potential value of search information furnished, should granting materialize, and one (RNV-13) because of the potential usefulness of the furnished information, should manufacturing contracts for a fiber optics laryngoscope be executed.

2. Problems Inactivated

RNV-10 ■ "Sensors for Measuring Foot-Floor Impact Forces." The Problem Originator is awaiting results of a grant application. (Inactive)

RNV-13 ■ "Improved Laryngoscope for Use in Disabled Children." A contract for manufacturing the item is expected and in negotiation. (Inactive)

RNV-15 ■ "Rapid Multiple Gas Measurement for Medicine." The Problem Originator's other activities require that the problem be considered inactive for the time being. (Inactive)

NWR-1 ■ "Motion Pattern Measurement of Patients." The search was used for background information only, and no directly relevant information appears to have been located. The Problem Originator suggested that the problem be inactivated. (Inactive)

NWR-6 ■ "The Effects of Electromagnetic and Acoustic Fields on Living Organisms." The references were used in grant applications. (Inactive)

SFM-3 ■ "Improved Monitoring of Heart Cell Contraction Parameters." Mr. Buck/Ames performed a series of engineering services. Technical engineering advice was given and used by the Problem Originator, and the posed problem has been solved. (Closed)

SFM-3A ■ "Heart Contraction Force." Research is waiting for results from an earlier phase. Researcher has not yet had time to evaluate search properly. (Inactive)

3. Active Problems - Status

Texas Institute for Rehabilitation and Research

HUV-1 ■ "Reduced Workload Environment for Physically Handicapped Patients"

Transfer in progress: Documentation continues. Status unchanged.

HUV-17 ■ "Automatic Remote Human Movement Analysis"

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

HUV-18 ■ "Microanalysis of Mucous-Secreting Cells"

Arrangements are in progress for a meeting with Manned Spacecraft Center research scientists who have been active in the transfer process. The purpose of the meeting will be transfer documentation.

Baylor College of Medicine

BLM-10 ■ "Computer Programs and Systems for Analysis of the Electrocardiogram"

The problem, new this quarter, has had a literature search performed. The screened search results have been forwarded to the Problem Originator for his review and evaluation. For a descriptive Medical Problem Abstract on this problem, please see Section C. 4a.

BLM-11 ■ "On-Line Analysis of Biochemical Samples Collected Automatically from Patients"

The problem, new this quarter, has had a literature search performed. The screened search results have been forwarded to the Problem Originator for his review and evaluation. For a descriptive Medical Problem Abstract on this problem, please see Section C. 4a.

The University of Texas Medical School
Galveston

GLM-3 ■ "Determination of Local Blood Flow, Blood Gas Concentration, and Blood pH in Small Portion of an Organ"

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

GLM-9 ■ "Measurement of Local Tissue Oxygen Consumption, In Vivo

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

GLM-14 ■ "Repetitive Measurement of Kidney Mass in Intact Animal"

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

The University of Texas Medical School
Galveston (Cont'd)

GLM-15 ■ "Respiration Volume and Rate Measurement in Unencumbered (Free) Child"

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

GLM-17 ■ "Respiratory Gases Measurement"

The Problem Originator is investigating applicability to his problem of the Kubechek/NASA cardiac output estimation technique.

GLM-19 ■ "Measurement of the Velocity of Myocardial Contractions by Noninvasive Means"

Probelm Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

GLM-20 ■ "Lymphocyte Destruction Under Sterile Conditions"

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

The University of Texas Medical School
at San Antonio

SNM-1 ■ "Enhancement of X-Ray Contrast Study Films"

A graded series of x-ray enhancement problems was prepared by the Problem Originator and Team Members and forwarded to Jet Propulsion Laboratory for processing.

Southern Research Support Center

SRS-8A ■ "Acquisition and Telemetry of Heart Rate, Blood Pressure, and Blood Flow in Free-Ranging Dogs"

The Problem Originator plans to travel to San Diego to visit Mr. Dean Franklin of Scripps Institute and Messrs. Pierson and Kemper (of Pierson and Kemper Co.) concerning problems of telemetry and ultrasonic volume blood flow measurement techniques.

A copy of the search results of Research Triangle Institute's related problem, WF-53 (Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins) was sent to the Problem Originator, and he will review the results of the present literature search (SRS-53) which is in progress at WESRAC.

SRS-8B ■ "Methods of Signal Categorization"

Problem Abstract has been disseminated this quarter. A copy is included in Section C. 4b.

SRS-53 ■ "Means of Obtaining the Velocity Spectrum of Blood Flowing in Arteries and Veins"

New problem; this is a special problem where, upon request of another Medical Application Team, a parallel literature search is being run. The unscreened results will be forwarded to the originating team, with a copy to the consultant at Southern Research Support Center.

Rancho Los Amigos Hospital

RNV-12 ■ "Body Temperature Regulation in Congenital Amputees"

A new Problem Originator has taken over the problem. He is becoming acquainted with it, prior to making his research decisions.

RNV-14 ■ "Materials for Prevention of New Decubitus Ulcers"

A Problem Abstract has been disseminated during this quarter. A copy is included in Section C. 4b.

Stanford University School of Medicine

SFM-6 ■ "Small Wide-Band Microphones for Sensing Heart Signals"

New problem. A Technology Utilization Survey in the subject area has been sent to the Problem Originator for review and evaluation. Follow-on action will depend on the results of his review. For a descriptive Medical Problem Abstract, please see the document in Section C. 4a.

Northwest Institute for Rehabilitation and Research

NWR-5 ■ "Numerical Methods for Solutions to Wave Equations in Layered Media of Arbitrary Cross Section"

A Problem Abstract has been disseminated during this quarter. A copy is included in Section C. 4b.

The University of Washington
School of Medicine

WSM-1 ■ "Ultrasonic Coupling Techniques"

A Problem Abstract has been disseminated during this reporting period. A copy is included in Section C. 4b.

WSM-7 ■ "Sensitive Detection for Human Electric Field Application"

A new problem. Search is in progress at Regional Dissemination Center (WESRAC). For a descriptive Medical Problem Abstract, please see the document in Section C. 4a.

4. Active Abstracts

a. New Problems

MEDICAL PROBLEM ABSTRACT

PREPARED FOR THE NASA BY: Southwest Research Institute

For Further Information Contact: David Havemann

OV 4-2000 Ext. 648, Southwest Research Institute, Dept. 13

8500 Culebra, San Antonio, Texas

June 11, 1969 BLM-10

COMPUTER PROGRAMS AND SYSTEMS FOR ANALYSIS OF THE ELECTROCARDIOGRAM

The problem is to identify existing computer programs which provide automatic diagnostic interpretation of the electrocardiogram and to adapt portions of these programs for use on a small multipurpose computer system which will be applicable for multiphasic health screening (multiple testing of large numbers of subjects).

Computer analysis of the electrocardiogram eliminates the need for manual visual interpretation and thus greatly reduces the time and skilled personnel otherwise required. Existing interpretive programs, however, require medium to large size computer systems which are cost prohibitive for routine clinical usage. The integration of various existing programs may allow for the development of a simpler system which will be economically feasible for such applications.

Computer programs for the automatic diagnostic analysis of the electrocardiogram are needed. Those programs which employ simple mathematical diagnostic techniques and which are suitable for adaptation to small computer systems are especially desirable. The requestor would like to know to what computer systems and computer languages these programs have been adapted. Any additional information concerning the types of computer interfacing required would be useful.

Search Terms: Computer, Programs, Electrocardiogram, Analysis, Diagnostic, Screening, Interface.

Before initiating the computer search please call David Havemann to verify the proposed search strategy.

DFH/CAH

MEDICAL PROBLEM ABSTRACT

PREPARED FOR THE NASA BY: Southwest Research Institute

For Further Information Contact: Sam G. Schiflett

OV4-2000, Ext. 648, Southwest Research Institute, Department 13

8500 Culebra, San Antonio, Texas

2 July 1969 BLM-11

ON-LINE ANALYSIS OF BIOCHEMICAL SAMPLES COLLECTED AUTOMATICALLY FROM PATIENTS

The problem is to develop an on-line biochemical monitoring system which will automatically collect and analyze blood and urine samples intermittently from hospitalized patients during the critical stages of their illness and recovery.

At present, biochemical analysis involves collecting the samples manually, transporting the samples to the laboratory for testing and then waiting for the test results. When the patient's condition is changing rapidly, significant alterations in the concentration of vital substances in the blood and urine can be missed because collection is performed too infrequently. Also, critical test results often arrive too late to help the doctor prescribe treatment because of the delay in analyzing the samples. Human errors sometime produce erroneous and misleading biochemical analytic results.

The attending physician needs an accurate, updated, biochemical profile of the patient to give a proper diagnosis and to counteract dangerous trends such as electrolyte imbalance. Therefore, it is essential that the blood and urine samples be obtained frequently (about once every 10 minutes) and that the monitor receive the test results as rapidly as possible.

The Problem Originator requests all available information concerning techniques associated with automatic collection of blood, urine and plasma samples and on-line analysis of the substances contained within the biochemical sample. The substances for which the blood, urine and plasma samples are to be analyzed are: sodium, potassium, carbon dioxide, glucose, urea nitrogen, and enzymes such as serum glutamic oxalacetic transaminase and serum glutamic pyruvic transaminase.

Search Terms: Sampling, Analysis, Automatic, Computer, On-Line, Biochemical, Blood, Urine, Plasma

Before initiating the computer search, please call Sam Schiflett to verify the proposed search strategy.

SGS/RJC

MEDICAL PROBLEM ABSTRACT

PREPARED FOR THE NASA BY: Southwest Research Institute

For Further Information Contact: Andre G. Buck

12623 Valley View Drive, Los Altos, California, Phone (415) 948-5494

Southwest Research Institute Biomedical Application Team

8 July 1969 WSM-7

SENSITIVE DETECTION FOR HUMAN ELECTRIC FIELD APPLICATION

The Problem Area

The investigation and determination of extremely low-level electric fields emanating from the human body in both well and diseased humans.

What is Needed

Instrumentation and methods of measuring and mapping the electric fields generated by humans is needed. Point sensitivity is required to permit mapping. The ability to measure polarity and field direction is also important. It is believed that NASA may have done some work in this area. Certainly NASA has done a great deal in astronautics in measuring extremely low level electromagnetic and electrostatic quantities, and the local area mapping thereof.

Suggested Areas of Investigation

It is possible that NASA has done research in measurement of human fields. A great deal of possibly applicable work has been done by NASA in satellite activity research in the measurement of fields associated with the earth, the sun, solar winds, etc.

MEDICAL PROBLEM ABSTRACT

PREPARED FOR THE NASA BY: Southwest Research Institute

For Further Information Contact: Sam G. Schiflett /Chuck Laenger (Ext. 767)

OV 4-2000 Ext. 648, Southwest Research Institute, Dept. 13

29 July 1969 SFM-6

SMALL WIDE-BAND MICROPHONES FOR SENSING HEART SIGNALS

The Problem Originator states that he has established that, in dogs and baboons, data obtained from an electrocardiogram, a phonocardiogram, and a pulse wave form can yield as much information about the function of the heart as can data obtained from an aortic flow probe or a left ventricular catheter. If nondestructive microphonic sensing techniques could be shown to produce as much reliable and valid data concerning the function of the heart in man as destructive measures, then the nondestructive methods could be medically justified. The potential benefits are: reduction of cost, time, and dangers of surgery.

What is Needed:

The Problem Originator needs to procure small wide-band microphones to sense heart sound signals in man by nondestructive means. Small flat circular microphones (1-2 mm thick and 1 cm in diameter) and small oval-shaped microphones (0.5 cm x 1.5 cm) are needed to sense cardiac sounds and pulse waves in man. The frequency response of the microphones should be from DC-500 Hz with the output leading into an amplifier of moderate impedance.

Search Terms:

Microphone, Sensor, Frequency, DC, Cardiac, Heart, Electrocardiogram, Phonocardiogram, Wide-Band, Miniature, Micro, Nondestructive.

Before initiating the computer search please call Chuck Laenger to verify the proposed search strategy.

SGS/CJL

4. Active Abstracts

b. Problem Abstracts Disseminated This Quarter

D. PARTICIPATION IN SYMPOSIUMS AND MEETINGS

Mr. C. J. Laenger, Sr. attended the National Institutes of Health, National Heart Institute, Artificial Heart Program Conference, 11-13 June 1969, Washington, D.C.

Highlights: Particular attention was given to papers in sessions which related to existing problems and pre-problems in the Biomedical Application Program. Comments on some of the presentations follow:

(1) A Miniature Catheter Tip Capacitance Pressure Transducer by Tom Corbin of Corbin-Farnsworth, Smith Cline Instruments, Inc. This is a transducer developed by NASA/Ames by Mr. Grant Coon under the direction of Mr. Demiff. NASA let a contract to Corbin-Farnsworth to develop fifty units of the capacitance transducer which will be distributed by NIH. These units should be completed within 60 to 90 days. Mr. Corbin said that the units should be reusable a hundred times and that the cost should be under $500 when they go into mass production. He further stated that much of the circuitry has been redesigned and improved.

This work would be of particular interest to Mr. Jack Johnson at Little Rock and to Mr. Joe Canzoneri of TIRR. It would also be of interest to several researchers at the University of Texas Medical School in Galveston.

(2) Chronically Implantable Pressure Transducers by Mr. Jack Chambers of Statham Instruments, Inc. The work discussed had to do with the development of chronically implantable pressure transducers. The possibility of the implant using a thoracic reference was discussed. Information on pressure transducers has been sought by a number of researchers and institutions who utilize the Biomedical Application Team.

(3) Development of a Continuous Blood pO_2 Measuring System. The objective of this development program, which is being performed by Westinghouse Electric Corporation, is to develop a continuous in vivo blood pO_2 measuring system. The system would not be usable or desirable or applicable to Biomedical Application Program problems that SwRI has received because response time is much too slow. It is from 1/2 hr to, at very best, 1 min.

(4) Improved Diagnostic Accuracy in Acute Myocardial Infarction with Multichannel Electrocardiographic Data Acquisition and Analysis. This paper was given by Texas Instruments of Houston. It had to do with a study designed to correlate electrocardiographic and other physiological data. This should be of interest to Dr. Lipscomb at Baylor and to Dr. Rudenberg at Galveston.

(5) Implantable Fuel Cells. Several papers were presented on this subject. We have no problem submissions in this area but a number of potential Problem Originators have expressed interest in the subject.

(6) Energy Transmission Through the Intact Skin. Several papers regarding transmission of and storage of energy through the intact skin by various methods were presented. Again, we have no problem submissions in this area but a number of potential Problem Originators have mentioned interest and potential problems in this area.

(7) Circulatory Assist Devices. Eighteen papers dealing with circulatory devices and physiological effects caused by them were presented. Familiarity with these devices, their functions, and physiological effects was gained. We can anticipate problems relating to these devices and to instrumentation applicable to the artificial heart development in the future. A speaking knowledge of these devices and the program in general will be useful when communicating with such researchers.

This conference is held annually by NHI so that researchers whom they fund can discuss their progress and problems in the presence of others who are receiving funds from the same source. Attendance of this meeting provided a good opportunity to learn of many of the problems faced by many researchers. It also provided an opportunity to learn of solutions that might be applicable to existing problems under consideration by the various Biomedical Application Teams. We would do well to cover this meeting every year.

E. COMMERCIAL PRODUCT AND/OR APPLICATION ENGINEERING ACTIVITY RESULTING FROM TEAM OPERATIONS

One of the submitted problems, RNV-13, "Improved Laryngoscope for Use in Disabled Children," appears to be on the threshold of generating engineering/development activity. Two sources of potential solution have resulted from the Biomedical Application Program activity. The Problem Originator is currently investigating both these sources and is expecting submission of formal proposals from at least one source on the subject problem. Secondly, while performing activities not directly connected with the Application Program, Southwest Research Institute staff members realized that certain technological developments had great potential for application to a commercial problem under investigation by an industrial organization. The company representative's attention was called to the NASA technology; plans to apply the Biomedical Application Team's NASA experience to this technological development are currently being explored by the industrial concern. Hardware funding has been obtained, a proposal has been accepted, and a contract for production of prototypes is expected.

F. INSIGHTS AND CONCLUSIONS

1. Literature Searching

A Southwest Research Institute staff member, not directly connected with the NASA Biomedical Application Program, had occasion to perform a comprehensive search to locate all relevant aerospace research performed in a particular physical science area. Members of the Biomedical Application Team discussed and analyzed the staff member's searching experience with him after the results had been obtained, because the searching problems encountered within a unified physical science discipline search would be heightened and magnified in an interdisciplinary search, which is the usual search performed in the Biomedical Application Program.

The staff scientist observed that the search specialists considered his submitted question in a manner which was too restricted technically. The specialists were not fully aware of all the technological areas which might harbor potential solutions to the submitted question. Therefore, although descriptors were used which appeared entirely logical, it was not realized during the initial search that these descriptors were inadequate for the task. In addition, a second sizeable source of reference omissions was a misspelled descriptor, which had inexplicably been used in its misspelled form many times in the computer storage of the relevant documents. Documents bearing this error were not initially recovered, since only the correct spelling of the descriptor was used in the search.

The inadequacies of the search results were revealed to the search scientist only because of his personal knowledge of the technical area. In addition, he had available a previously prepared, incomplete bibliography relating to the technical subject. The searcher believed that had it not been for these sources of personal knowledge, he would not have caught the deficiencies of the search strategy. When he did become aware that the search produced only partial coverage of the field, he was able to critically review the original search strategy and analyze the major sources of error which, as previously mentioned, were: the absence of appropriate but not at all obvious descriptors that should have been included, but which were easily missed by the search specialist because of his limited technical knowledge; and, secondly, the errors due to the misspelled descriptor problem.

Subsequent search passes were greatly improved because of the inclusion of additional appropriate terms which were suggested by a study of some of the known but previously omitted references, and, speaking generally, because of greatly improved communication between the scientist and search specialists, resulting from extensive face-to-face interviews. The lessons of this experience confirmed the previous experience of the Biomedical Application Team and will be reemphasized in future searches.

2. Number of Active Problems

Particular attention was paid during this project year to factors which would limit the number of problems active during any one period. As described on page 6 of the Quarterly Progress Report No. 1 (15 May 1969), initial procedures for processing submitted problem statements were designed to improve the efficiencies of the accept/reject decision; secondly, continuous review of the active problems included a careful evaluation of whether or not a given problem should continue to be kept on the active list. As a result, the average number of currently active problems is approximately one-half of the previous years' average. This factor allows more visibility, better focus, greater depth of effort, and, we believe, a better chance for successful problem solution with respect to the problems that do remain active. We intend to monitor our problem acquisition rate so that each team member is responsible for approximately five active problems; minor departures from the desired average would be made to accommodate differences in the demands placed on a team by a given problem, the degree of urgency of a submitted problem to the Problem Originator, and the possibility of inactivating current problems.

3. Operations Research Analysis

Dr. W. R. Brian Caruth has been investigating factors related to the transfer process, and the results of his analysis to date are presented in the Appendix.

G. PLANS FOR FOLLOWING QUARTER

During this reporting period, the sponsor reviewed and approved a plan for initiating contacts with new potential user institutions. During the coming quarter, acquisition of new user institutions will be sought according to the proposed procedure. The rate of acquisition of new user institutions will be modulated to maintain a match between project resources and new and old user demands.

Management representatives of the University of Texas Southwest Medical School in Dallas have reacted favorably to the program in initial interviews. It is planned to present a full briefing to a larger group of selected key researchers when academic activity resumes in mid-September. Three other potential new user institutions have been contacted and initial interviews sought. Results of these communications will be reported as they mature.

The periodic review of inactive problems, previously performed in an informal manner, will be put on a formal basis. We will begin the third quarter by a semiannual review of all problems that are neither active nor closed. Based on this review, each problem will be kept in its present inactive status, closed out, or activated. Particular attention will be paid, in making these evaluations, to any relevant new technology that may have become available since the time of the decision to inactivate the problem.

Within the resources of the project, we intend to expand the Team's screening of the search results. Based on the individual search results and problem statement requirements, we will acquire supplementary information, including hard documents, so that the team can evaluate selected portions of the search in depth. This effort should parallel and complement the evaluation effort of the Problem Originator.

APPENDIX

ANALYSIS OF THE TECHNOLOGY TRANSFER PROCESS

ANALYSIS OF THE TECHNOLOGY TRANSFER PROCESS

The three principal objectives of the NASA Biomedical Application Team Program are:

"(1) To identify problems and needs existing in the medical field which appear to be 'solvable' by the application of aerospace science and technology;

(2) To identify the specific technologies or concepts which may lead to solutions of these problems; and

(3) To document these transfers of science and technology so as to achieve maximum utilization of the results of the program."*

The nature of the program is innovative and experimental. Experimental in the sense that variables which may be expected to affect the technology transfer process need to be studied and evaluated. This will lead to increased understanding of the requirements for successful and expedient transfers and the development of technology transfer theory.

The objectives of this analysis are:

(1) Identification of factors and activities contributing to a successful transfer

(2) Identification of the relative contributions of these activities to the transfer process.

Problems included in the analysis at this stage are those which resulted in successful transfers. These problems and certain problem attributes are identified in Table 1. Column 1 of Table 1 identifies the code number for each problem. Column 2 identifies the technology or information made available to the Problem Originator as a result of the Biomedical Application Team efforts on the problem. Column 3 describes the utilization of the technology or information by the Problem Originator. Column 4 indicates the total communications, i.e., total number of visits, telephone communications and letters, made during the course of the problem activities. Column 5 indicates the total number of hours spent on the problem. (The total in this column should correspond to the total cumulative hours column in the monthly reporting form developed by the sponsor.) Columns 6 and 7

*Compendium of the NASA Biomedical Application Team Program, The George Washington University, pp 2-3, as referenced in the Denver Research Institute report on "An Examination of the NASA Biomedical Application Team Program," May 1969.

TABLE 1. PROBLEMS RESULTING IN TECHNOLOGY TRANSFER

Problem Identification	NASA Technology or Information	Technology or Information Utilization	Total Communications	Total Problem Hours	Date Problem Initiated	Date of Transfer	Technical Search*	Abstract
GLM 12	No information on relevant technology	Investigator assured he is working at SOA	NA	1.25	May 1967	Nov.1968	Y	N
GLM 13	Information on appropriate technique	Investigator to use technique described in referenced material	2	.75	May 1967	Oct.1968	N	Y
GLM 15	NASA equipment for non contact measurement of respiration	Prototype to be made available for evaluation	2	2	Aug.1967	Nov.1968	Y	Y
GLM 17	Information on space helmet to measure respiration, and 0_2 and CO_2	Information used in grant application	29	51.4	April 1968	Nov.1968	Y	N
SRS 6	Information on related areas	Information emphasized need for additional research and materially assisted another project at user institution	NA	NA	April 1967	March 1968	Y	N
SRS 8A	Information on related areas	Information to be used to design and develop an operating system	4	11.5	Oct. 1968	Nov. 1968	Y	N
NWR 4	Commercial device used by NASA for weightless exercising	Investigator to procure equipment for clinical and research use	7	11.5	Sept.1968	Nov.1968	N	N

*Y = Yes
N = No

TABLE 1. PROBLEMS RESULTING IN TECHNOLOGY TRANSFER (Cont'd)

Problem Identification	NASA Technology or Information	Technology or Information Utilization	Total Communications	Total Problem Hours	Date Problem Initiated	Date of Transfer	Technical Search	Abstract
SFM 4	Wind tunnel force balance techniques	Investigator to procure equipment	17	41.5	Oct.1968	Nov.1968	N	N
RNV 10	NASA pressure cell, developed for	Pressure cell loan for two pressure cells furnished	24	41.5	July 1968	Nov.1968	Y	N
RNV 11	NASA implantable telemeter system	Equipment demonstrated information used in grant application	18	44	July 1968	Nov.1968	Y	N
RNV 12	Liquid cooled, astronaut under garments	Loan of suit made to investigator	18	16.5	July 1968	Nov.1968	N	N
RNV 16	Automated patient Respiratory detection system	Investigator to use information to construct equipment	13	26	Nov.1968	Nov.1968	N	N
RNV 5A	Equipment to measure pressure in wind tunnel model under stress	Equipment loaned to research to contract prototype	29	48	April 1968	June 1968	Y	N
WSM 4	Heated space underwear	Suits loaned to researcher	13	16	April 1968	Oct. 1968	N	N
NWR 3	Equipment to provide effective radio transmission in and through wind tunnel passages and concrete walls	Tests of recommended frequencies and equipments	8	8	April 1968	June 1968	N	N

TABLE 1. PROBLEMS RESULTING IN TECHNOLOGY TRANSFER (Cont'd)

Problem Identification	NASA Technology or Information	Technology or Information Utilization	Total Communications	Total Problem Hours	Date Problem Initiated	Date of Transfer	Technical Search	Abstract
GLM 4	Capacitance pressure transducer developed for ?	Information on applicable equipment. Equipment not available	NA	NA	March 1967	Nov. 1968	Y	N
GLM 5	Capacitance pressure transducer developed for ?	Information on applicable equipment. Equipment not available	NA	NA	March 1967	Nov. 1968	Y	N
GLM 6	Final report on Mock Circulatory System	Increased investigator awareness of SOA	NA	NA	March 1967	Oct. 1968	Y	N
GLM 8	EEG pickup helmets, telemetry and computer analysis in part of Mercury, Gemini and Apollo programs	Information used in grant application	NA	NA	May 1967	Nov. 1968	Y	N
GLM 10	COSMIC program	Program obtained, used and evaluated	NA	NA	May 1967	Nov. 1968	Y	N

identify respectively the date of problem initiation and the date of problem transfer. Columns 8 and 9 indicate whether problem activities included a technical literature search and/or an abstract dissemination.

Identification of Factors Contributing to Problem Transfer

Documentation on each of the problems included in Table 1 was analyzed to determine the factors that contributed to the problem transfer. Following is an exhaustive list of the factors. Each factor, however, did not necessarily contribute to each problem.

BAT/NASA Institution communications

BAT awareness of NASA technology

Technical literature search by DSC's

Abstract Dissemination

BAT technical knowledge

Originator awareness of NASA technology

Other BAT's experience

Key coordinator awareness of NASA technology

Weighting of Factors Contributing to Problem Transfer

For each problem, Biomedical Application Team personnel were asked to weigh each of the factors so as to reflect the relative contribution of that factor to the problem transfer. The sum of the weights for each problem was 1. These weights were assumed to reflect the importance rating of factors in contributing to particular problem transfers. Table 2 shows the importance ratings of factors by institution, by average for all institutions and by average for those problems that included technical literature searchs.

Although the number of transfers from each institution varies quite considerably, it does appear that the following factors make the most important contribution to successful transfers.

(1) BAT/NASA communications

(2) BAT awareness of NASA technology

(3) Technical literature search.

	No. of Problems in Sample	BAT & NASA Communications	BAT Awareness of NASA Technology	Tech. Literature Search	Abstract	BAT Technical Knowledge	Originator Awareness	Other BAT Experience	Key Coordinator
RNV	5	.42	.46	.12					
WSM	1	.1	.9						
NWR	2	.1	.5				.4		
GLM	9	.2	.2	.43	.11	.01	0	.03	.01
SRS	2	0	.25	.5	0	.25			
SFM	1	1.0							
Average ratings	20	.20	.325	.27	.05	.025	.04	.07	.004
Average ratings for problems with technical literature searches	11	.27	.10	.50		.05	0	.03	.01

Table 2

Importance Ratings of Factors Contributing to Problem Transfers

On an overall basis, the importance rating of a technical literature search is 0.27. However, this figure includes statistics on nine problems that did not include a technical literature search. Analysis of the eleven transfers that did include a technical literature search reveals an importance rating for the searches of 0.50. Thus it would appear that for these problems where a technical search was deemed necessary, the results of the search did make a significant contribution.

Analysis of the transfer statistics further reveal the change in importance rating with time. For example, problems initiated in 1967 and 1968, respectively, had average importance ratings as shown in Table 3. The technical literature searches for problems initiated in 1967 rated 0.48, while the rating for those initiated in 1968 was only 0.11. The comparable ratings for "BAT Awareness of NASA Technology" went from 0.2 to 0.43. Thus, as BAT personnel familiarity with an awareness of NASA technology increases, it appears that the need for technical literature searches may be reduced.

This analysis has been restricted to problems resulting in successful transfers. While the analysis does point out some interesting variations in importance ratings, the results need to be compared with analogous statistics for nontransfer problems. This analysis is proceeding and will be presented in subsequent reports.

	BAT/NASA Communications	BAT Awareness of NASA Technology	Technical Literature	Abstract	BAT Technical Knowledge	Originator Awareness	Other BAT Institutes	Key Coordinator
Problems Initiated in 1967	.2	.2	.48	.11	.01	0	0	0
Problems Initiated in 1968	.3	.43	.11	0	.04	.07	.03	.01

Table 3

Comparison of Importance Ratings for Problems Initiated in 1967 and 1968

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23 May 1969 GLM-14

KIDNEY MASS MEASUREMENT

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23 May 1969 GLM-14

What Is Needed

A method for periodic measurement of the mass of the kidney in a live animal is needed. To study the mechanisms of compensatory hypertrophy after unilateral nephrectomy (surgical removal of one kidney), it is desired to obtain data on the mass changes in the remaining kidney during the process of hypertrophy.

Background

It is a general observation that after removal of one of a pair of organs the remaining organ increases in size and function and compensates for the loss. This is true of the kidneys and is termed compensatory hypertrophy.

The present method for the study of this phenomenon necessitates the sacrifice of the animal subjects at various periods of time following the removal of the first kidney. The remaining kidney is removed and weighed after sacrifice, and its increase in weight and/or volume is a measure of the extent to which hypertrophy has taken place. As normal kidneys in the same animal are already of different size, the procedure must be done on a large number of animals in order to determine the average normal kidney size and to set up a statistically sound experimental series. It would be much more exact to use each animal as its own control; this can be achieved if the kidney mass could be monitored in the live, intact animal. An instrument for making such measurements may develop into an important diagnostic tool, where changes in the shape and size of the kidney, including those provoked by tumors, could be established.

It may be that there exists some method employing radioisotopes or scintillation counting to provide extreme sensitivity, yet not affect the normal progress of growth or compensatory hypertrophy. If at all possible, X-ray measurements should be avoided, as the radiation may alter normal function of the animal's kidney in unpredictable ways. Ultrasonic techniques currently in development may prove applicable. Momentum and G measurements might prove to be feasible.

Whatever technique may be suggested, it must be useable in the living animal (in vivo), must not disturb the test animal's normal functions, and must provide for consecutive measurements of kidney mass or volume. The transducer, if one is employed, cannot encapsulate or drastically disturb the kidney, as this causes hypertension.

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NASA TECHNOLOGY UTILIZATION DIVISION
BIOMEDICAL APPLICATION PROGRAM

GLM-14

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23 May 1969 GLM-15

RESPIRATION VOLUME AND RATE MEASUREMENTS FOR BURNED CHILDREN

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23 May 1969 GLM-15

What Is Needed

A method is needed for measuring the rate and depth of breathing of children who are suffering from severe burns on the upper half of their bodies. The method should not involve connecting tubing to the nose or throat, nor enclosing the body in a plethysmograph.

Background

Present methods of measuring respiration require that the patient breathe through a mouthpiece such as that used by scuba divers or that the patient remain in a plethysmograph (an airtight chamber equipped for pressure and volume measurements). These procedures are undesirable because they restrict the airway or impair the freedom of motion of the patients and are not well tolerated by sick children. The ideal method would allow measurement of the tidal volume (the volume of air moved into and out of the lungs with each breath) without adding any resistance to the airway and without touching or irritating the skin.

Although the change in chest volume does not exactly equal the tidal volume (because of inertia and airway resistance), it may be necessary to compromise accuracy of measurement for the convenience and comfort of the patient by inferring tidal volume from chest motion.

Provision of a suitable method for measuring respiratory volume would casue an increase in the recovery rate of burn victims. Suffering and pain would be lessened, and the enormous expense involved in treating such patients would be reduced.

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June 1969 GLM-19

MEASUREMENT OF THE VELOCITY OF MYOCARDIAL CONTRACTION BY NON-INVASIVE MEANS

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June 1969 GLM-19

Measurement of the Velocity of Myocardial Contraction By Non-Invasive Means

What is Needed

A method for measuring the instantaneous pressure in the chambers of the heart without puncturing the skin.

Background

Suppose that your child was one of the approximately 50,000 children in the United States whose life is in danger because his heart valves are defective. Your doctor knows that, thanks to the development of open heart surgery, it is now possible to replace your child's defective heart valves with artificial ones. The danger is that the operation may do more harm than good. Your child will benefit from the valve replacement only if his myocardium (heart muscle) is in good condition; otherwise, the valve replacement may not help his heart's performance, and will expose him unnecessarily to the danger of a serious operation. The doctor needs to assess the condition of your child's myocardium along with the severity of the valve impairment and weigh these factors carefully in his decision on recommending valve replacement. He also needs to measure the progress of healing after the operation, in time to stop possibly fatal complications.

Present techniques for obtaining the necessary information about the heart valves and myocardial condition require the danger and discomfort of cardiac catheterization. The doctor who first catheterized a human heart (his own) was criticized for performing such a foolhardy experiment. Through the years, new techniques and safety devices such as defibrillators have been developed to reduce the hazard, but it is still not a procedure to be undertaken lightly.

In performing a cardiac catheterization, the doctor uses local anesthesia and cuts through the skin of an arm or leg to expose the large artery and vein, punctures them, and inserts a 2 mm diameter hollow plastic catheter about 1 m long into the vessels. He observes the position of the catheter tip with a fluoroscope, and guides it along the blood vessels until it enters one of the chambers of the heart (Figure 1.). The pressure pulsations are transmitted through a fluid in the catheter to a pressure transducer, and its output is displayed along with the electrocardiogram (ECG) on a strip chart recorder, (Figure 2).

The cardiologist diagnoses the condition of the heart valves and the myocardium from an analysis of the pressure tracings. When the myocardium starts to contract, there is a period of isovolumic contraction, during which the inlet valve has closed, and the pressure in the ventricle is increasing but has not yet caused the outlet valve to open by exceeding the pressure in the aorta. During the isovolumic contraction period, the volume of the ventricle does not change because the closed valves isolate it from the rest of the circulatory system. At present, the best measure of myocardial condition is the rate of change of pressure in the ventricle during isovolumic contraction, which is not affected by the condition of valves or blood vessels. Another important diagnostic parameter is the time delay between the Q wave of the ECG and the peak of the dP/dt curve. The better the heart, the shorter this delay is.

The dangers of cardiac catheterization include unintentional puncture of the blood vessels

or heart walls, formation of blood clots which can be fatal if they stop circulation to the brain or lungs, and ventricular fibrillation, a convulsive, unsynchronized fluttering of the myocardium which is not effective in pumping blood and is fatal within a few minutes if it is not stopped by a powerful electric shock. These hazards are faced every day in the more than 500 hospitals in the United States with active catheterization laboratories, and each of the 16 large laboratories reported in Reference 1 performed an average of 386 catheterization procedures per year. The chances of death from the catheterization procedure is 6% for infants under two months of age, and is 0.45% for the average population.

Is there a way to avoid the dangers of cardiac catheterization and still measure the myocardial contractility, pressure in the ventricles, or time delay between the Q wave of the ECG and the peak of the dP/dt curve?

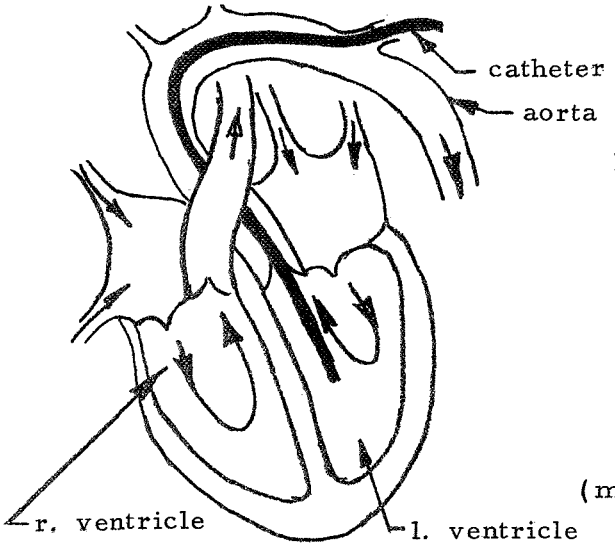

Figure 1. Schematic diagram of the chambers of the heart, with a catheter in the left ventricle.

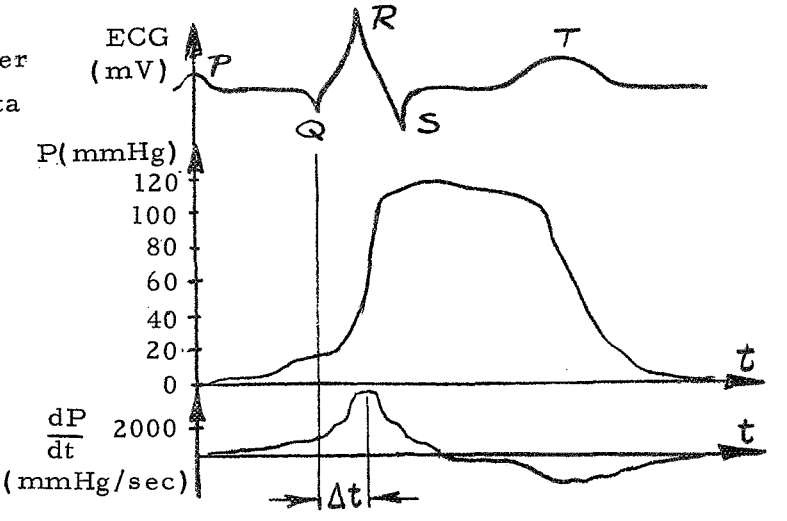

Figure 2. ECG, left ventricular pressure, and first time derivative of pressure.

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GLM-19

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23 May 1969 NWR-5

NUMERICAL METHODS FOR SOLUTIONS TO WAVE EQUATIONS IN LAYERED MEDIA OF ARBITRARY CROSS SECTION

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23 May 1969 NWR-5

What Is Needed

Numerical methods for the solution of differential and integral equations for electromagnetic waves, ultrasonic waves, and heat transfer problems in layered media of arbitrary cross section.

The problem has previously been treated by the classical method, but the classical boundaries do not offer a close match to those encountered in the human anatomy. The use of numerical techniques for the solution of these problems will allow greater flexibility with regard to the boundaries and should also be more easily programmed for a computer solution.

Background

For medical applications, it is desired to predict the heating in tissue due to the application of diathermy or ultrasound. The various layers encountered are fat, muscle, and bone, with cross sections that do not match the classical shapes, i.e., cylinders, rectangles, etc. Heat dissipation and transfer in the various layers determines the temperature rise.

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NWR-5

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17 July 1969 GLM-3

DETERMINATION OF LOCAL BLOOD FLOW, BLOOD GAS CONCENTRATION, AND BLOOD pH IN SMALL PORTION OF AN ORGAN

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17 July 1969 GLM-3

What Is Needed

Sensors which can be implanted in a small portion of the brain of a small laboratory animal such as the rat, which will permit the measurement of regional blood flow, pH, and concentrations of oxygen and carbon dioxide.

Background

The investigator needs to measure blood flow velocity, blood pH, and partial pressure of oxygen and carbon dioxide in the blood which is circulating to a small region of the brain of an experimental laboratory animal. The sensor must be suitable for long-term implantation in the rat's brain, so that the rat will have time to recuperate from the trauma of the operation of implantation. The sensors must be sturdy because the instrumented rat will be subjected to a sharp blow to the head to produce a brain concussion in order to simulate what happens to a human being in an accident. By following the fluctuations in regional blood flow, pH, and metabolic consumption of oxygen and production of carbon dioxide, the investigator hopes to obtain a clearer picture of the response of the human brain to the trauma of a concussion. This should lead to improved techniques for treating patients with head injuries.

The rat's brain occupies a volume of approximately 2 cubic centimeters. The total flow to the entire brain is approximately 1 milliliter per minute, and it is desirable to measure a regional flow of about 10 percent of the total flow or 0.1 milliliter per minute. The normal blood pH range is between pH 7.3 and pH 7.5. The partial pressure of oxygen in blood ranges between 100 millimeters of mercury and 37 millimeters of mercury. The concentration of carbon dioxide in the blood ranges between 39 millimeters of mercury and 45 millimeters of mercury. The desired accuracy of measurement is ± 2% for flow, ± 0.01 pH unit for blood pH, and ± 1 millimeter of mercury for the partial pressure of oxygen and CO_2 in the blood. The implanted sensors should last for at least 4 weeks, and the maximum required depth of extension of the electrodes into the rat's brain is about 2 centimeters from the outer surface of the skull. Electrical connections to the sensors will be made through a flat cable with a subminiature connector fastened to the rat's skull.

Present Approaches

Radioactive gases have been used recently for blood flow estimations, but the size and location of the perfused region are not well defined with present techniques. Investigators have analyzed average arterial and venous blood pH and gas concentrations for the entire brain, but it is desirable to detect regional differences in perfusion. Blood flow in large vessels can be measured through the use of an electromagnetic blood flow transducer, by an ultrasonic Doppler technique, or by thermal methods. The blood pH is measured with a special glass electrode and a sensitive high input impedance millivoltmeter. The partial pressure of oxygen is measured with a membrane polarigraphic technique. The partial pressure of CO_2 in the blood cannot at present be measured directly. Presently available probes are fragile and suffer from poor long-term accuracy because of the coating of tissue which the body deposits on foreign substances. All of the presently available techniques are extremely difficult to miniaturize to the extent needed to explore the regions of the 2-cubic centimeter rat brain.

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17 July 1969 GLM-9

MEASUREMENT OF LOCAL TISSUE OXYGEN CONSUMPTION IN VIVO

PREPARED FOR NASA

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17 July 1969 GLM-9

What Is Needed

The investigator needs to measure oxygen concentration and oxygen uptake in localized regions of the brain and other tissues in experimental animals and in men under varying conditions of stimulation, trauma, and disease. These measurements will be made simultaneously with other electrophysiologic recordings such as the electroencephalogram.

Background

All tissues consume oxygen in the process of metabolizing their nutrients, and the rate of oxygen consumption is a measure of metabolic activity. The investigator hopes to gain a clearer understanding of the response of the brain and other tissues to experimental conditions which simulate those occurring because of disease or injury. This should lead to better therapeutic techniques for treating patients with head injuries or brain disease, with consequent saving of life.

The ideal sensor would measure oxygen consumption directly; however, it would be permissible to measure the difference between the oxygen concentration in the arterial and the venous blood and the regional blood flow. The sensors should be less than 0.5 millimeter in diameter, to reduce the damage done to tissues in inserting the probe. The alkalinity of normal blood is pH 7.4 ± 0.1, and the temperature is $37°C \pm 1°C$. The partial pressure of oxygen in normal arterial blood is 100 millimeters of mercury, while that in the venous blood is 37 millimeters of mercury. An accuracy of ± 2 millimeters of mercury is desired. To be useful, the life of the probe must be at least 4 weeks so that chronic studies can be performed. A response time of 1 second is desirable.

Present Approaches and Limitations

The best available technique for measuring oxygen tension in tissues involves a platinum or gold fiber sensor and a sensitive millivoltmeter. Its response time to changes in oxygen concentration is too slow. It requires that the tissue being analyzed be isolated from the electrical ground which prevents the simultaneous use of the electroencephalograph and other neurophysiological instrumentation.

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17 July 1969 GLM-20

CONTINUOUS DESTRUCTION OF LYMPHOCYTES UNDER STERILE CONDITIONS

PREPARED FOR NASA

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17 July 1969 GLM-20

Introduction

When a person's life depends on his receiving a transplant of vital organs such as the heart or kidneys he must go through a process which will improve the likelihood of his body's accepting the organ instead of destroying it by immune rejection. One of the best ways to suppress the immune reaction is to destroy the patient's lymphocytes (a type of white blood cell which attacks foreign proteins). Present procedures for accomplishing this destruction require that the patient stay in the hospital for a preparation period of about 2 months before the transplant operation, during which time his lymphocyte supply is depleted. This adds a great deal of expense to the already high cost of the actual operation. It is an inefficient use of the hospital facilities, because the only reason for the patient to be there is to have some of his lymph drained periodically, centrifuged, and the lymphocyte-free plasma and proteins returned to his body under sterile conditions to prevent infection. Sterility is essential because lymph is an excellent nutrient for germs, and the already weakened patient's immune defenses, which would normally protect him from infection, are being suppressed in preparation for the organ transplant.

Specifics of Problem

Find a way to destroy the effectiveness of an organ recipient's lymphocytes, while leaving their damaged fragments circulating in the lymph so that the body will not be stimulated to make new lymphocytes. Continuous rather than batch processing is preferred, and the process must maintain the sterility of the lymph without destroying the plasma proteins.

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BIOMEDICAL PROBLEM ABSTRACT

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you".

17 July 1969 SRS-8B

METHODS OF SIGNAL CATEGORIZATION

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17 July 1969 SRS-8B

Background

Electrocardiograms from two strains of dogs are being obtained. Broadly speaking, there appear to be differences between the two categories which are observable through visual inspection by a human. What is sought is a suitable technique for quantifying this visible difference.

What Is Needed

There are several standard techniques for quantifying and comparing time series signals. The most common of these (spectral analysis, auto and cross correlation) may not uncover quantitative information which is fairly simple and uniquely related to the geometric properties of a two-dimensional signal (such as the EKG shape on a strip chart recorder). We are looking for techniques which would be applicable to this problem situation (the situation where available signals are broadly categorizable). What new approaches have been developed to aid both qualitatively and quantitatively in this categorization procedure?

It is hoped that what will be turned up are new concepts of signal categorization which are applicable to the above problem, as well as possibly applicable to similar types of categorization problems. A digital computer is available for signal processing. At the early stage of this problem, actual computer programs are of secondary, although not trivial, interest.

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17 July 1969 RNV-14

MATERIALS FOR PREVENTION OF NEW DECUBITUS ULCERS

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Brief Description

Spinal cord injury patients with sensory loss, while sitting in a wheelchair, develop pressure sores on the sitting surfaces over bony areas. These sores may take from 2 weeks to 4 months to heal, and some require surgical closure. The estimated average cost of a pressure sore is $15,000.

Many different types of cushions are manufactured today which claim to prevent development of pressure sores, yet sores still develop.

Specifics

The most important predisposing causes of ulcers decubitus are protracted pressure from infrequent movement of the patient, trauma and maceration of the skin, and malnutrition. First, the more sensitive subcutaneous and deeper tissues are damaged, and later the skin becomes necrotic. Traumatic pressure on the skin from ill-adjusted supports, or from wrinkled seatcovers or clothing, may cause small breaks in the epidermis, through which infection is introduced. Maceration of the skin often follows soaking of the seat and clothing by perspiration or from urinary or fecal incontinence. Chronic anemia, protein deficiency, or vitamin deficiency, particularly of ascorbic acid (vitamin C), reduce the ability of tissues to resist breakdown under constant pressure or to repair damage when the stress is removed.

Three stages of decubitus are recognized: (1) THREATENED DECUBITUS is indicated by a skin redness which disappears on pressure--the skin and underlying tissues are still soft; (2) INEVITABLE DECUBITUS is diagnosed by a hardening of the underlying tissues with a blue tint or vesicle formation on the overlying skin; (3) ULCER DECUBITUS is characterized by tissue death with slow breakdown and separation from living tissues. When the process is complete, it may reveal enormous destruction, sometimes with exposure to the bone. Infection is common at this latter stage.

Present Practices

The best preventative measure is alertness to the development of decubitus in debilitated patients whose daily exercise is difficult or impossible. Pressure points should be checked at least once a day in an adequate light, and the attending physician should be notified at the earliest evidence of undue redness or trauma. Oversedation should be avoided and mental activity encouraged.

Local measures that lower the incidence of decubitus include change of sitting position, transfers from wheelchair to bed and back, cleanliness and dryness (control of incontinence), relief of pressure, and physiotherapy.

The patient's position is changed every 3 to 4 hours, if conditions permit. An operative turning frame (Stryker frame) facilitates turning paraplegic patients in bed.

Cleanliness and dryness help to prevent maceration. Clothes are changed frequently and are made of materials which are soft, clean, and free from wrinkles and particulate matter. Essential hygienic measures are sponging the skin in hot weather, thorough drying after baths, and cleansing and gentle massage with a hexachlorophene-type antiseptic lotion. An indwelling catheter may be used to control urinary incontinence. Minimizing fecal incontinence by means of enemas is especially important.

Relief of pressure on sensitive areas may be accomplished by using molded foam rubber, air mattresses, water cushions, air cushions, and silicone gel. Lying on sheepskin keeps the patient's skin in good condition and, in some instances, prevents decubitus.

None of these measures is completely satisfactory. Many different types of cushions are manufactured which claim to eliminate the stress forces and lessen the incidence of decubitus pressure sores, but, at best, they only lessen or delay their formation.

What Is Needed

Recommendations are needed for a material and/or design approach which would eliminate the pressure concentrations around bony areas which lead to decubitus. The solution should not cause high shear stresses on skin surfaces. Vertical compressibility, homogeneous pressure distribution, or gradient increases of pressure away from bony surfaces and proper redistribution of forces upon changing of position are desired. Further, lateral stability must be maintained to prevent toppling or dumping of a patient while eliminating concentrated vertical pressure points.

The materials should be lightweight, able to breathe, elastic or reformable when a patient shifts position, and add to his overall comfort.

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22 July 1969 WSM-1

ULTRASONIC ENERGY COUPLING TECHNIQUES

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What Is Needed

A device or material which will improve the efficiency of coupling of ultrasonic energy between the low acoustic impedance of human flesh and the high acoustic impedance of a piezoelectric ceramic transducer.

Background

Ultrasonic energy is a powerful diagnostic tool. It has several advantages over X-rays for examining human tissue. It can be used in the pulse-echo mode to produce real-time information displays similar to radar Type A, B, or PPI scans. With Doppler techniques, it can provide velocity information such as heart wall or valve motion, blood flow velocity, and, in conjunction with a standard occlusive arm cuff, indirect blood pressure. Unlike X-rays, it is well suited for visualizing soft tissues, and, at diagnostic levels, it does no harm to living tissue.

Ultrasonic diagnostic techniques would be more sensitive and have a better signal-to-noise ratio if the impedance match between the piezoelectric transducer and the flesh could be improved. Most modern ultrasonic transducers are made of a piezoelectric ceramic such as lead-zirconate-titanate, which has a characteristic acoustic impedance of about 30×10^5 gm/cm^2 sec, while that of flesh is about 1.5×10^5 gm/cm^2 sec. As a result of this severe mismatch, much of the ultrasonic energy is reflected instead of being transmitted through the interface between ceramic and flesh. The sound power transmission coefficient is given by

$$\alpha_T = \frac{4Z_2Z_1}{(Z_2 + Z_1)^2}$$

In a typical case, $\alpha_T = \frac{4 \times 30 \times 10^5 \times 1.5 \times 10^5}{(31.5 \times 10^5)^2} = 0.181$

where

Z_1 = characteristic acoustic impedance of flesh.

= (density $\times$ conduction velocity) = 1 g/cm$^3 \times 1.5 \times 10^5$ cm/sec,

= 1.5×10^5 g/cm^2 sec

Z_2 = characteristic acoustic impedance of piezoelectric ceramic.

= 7.7 gm/cm$^3 \times 3.9 \times 10^5$ cm/sec = 30×10^5 g/cm^2 sec.

This calculation shows that 82 percent of the incident ultrasonic power is reflected and only 18 percent passes the interface to be used for carrying

information. This loss occurs in both transmitting and receiving, but it is more serious at the receiver interface because the returning echo is usually very weak.

For pulse-echo applications, it is important that the transducer have a low Q (ratio of energy stored to energy lost per cycle) so that it will respond quickly to short pulses, which contain a broad band of frequency components. Present techniques for lowering the Q involve wasting the ultrasonic energy by backing the transducer with a lossy material. The Q could be reduced more efficiently by improving the transfer of energy between the transducer and flesh by coupling them through an acoustical impedance transformer.

A lossless impedance transformer can be made from a quarter-wavelength plate of material which has a characteristic acoustic impedance $Z_t = \sqrt{Z_1 Z_2}$, but the thickness is correct for only one frequency, so this could work for C. W. Doppler, but not for broadband pulse-echo operation.

A better coupling method is needed and sought. If appropriate techniques could be developed, one solution would be a plate of low-loss material with a characteristic impedance which changed gradually from 1.5×10^5 to 30×10^5 gm/cm^2 sec, in a fashion analogous to a tapered electrical transmission line.

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22 July 1969 HUV-17

ANALYSIS OF HUMAN MOTION PATTERNS

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22 July 1969 HUV-17

What Is Needed

A system is desired to automatically describe, in three dimensions, human motion patterns. Applications would pertain to the analysis of normal individuals and patients with various forms of motor disorders. The therapeutic goal is to restore the normal pattern of motion to an affected individual. It would be desirable to measure the patient before, during, and after therapy and to analyze and relate the described motions to a normal pattern of movement. The method of pattern analysis must be completely external to the patient and void of any extraneous sensory input which would bias the validity of the observed patterns, i.e., no restricting physical connection to the patient.

Background

Proposed solutions have involved attaching signal transducers on selected body surfaces and recording incidence times and accelerations in analog form and processing the data either on-line by computer or by hand. However, the attached measuring transducers were unwieldly, uncomfortable, produced extraneous stimulation, and restricted movements which interfered with "natural" motion patterns.

Other approaches to the problem involve photography and video recording of a subject in motion. Each successive picture frame of data is analyzed by measuring distances from fixed reference points on the photograph to specific points on the body such as the knees, toes, wrists, and elbows. The cost of the data reduction process in three dimensions is prohibitive. Video recordings have been made in a single plane of certain "marked" portions of the body while the subject was in motion. Although the analysis is quite laborious, the results can be correlated with other dynamic variables. The limitations are low sampling rate and burdensome data handling procedures.

The sought-for technique should be capable of measuring the kinematics of body segments by noncontacting methods or low inertia "markers." The system should include a means of automated data processing in order to obtain a complete space-time history of selected locations on the body surfaces.

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