ATOMIC ENERGY COMMISSION
DIVISION OF BIOLOGY AND MEDICINE

BIOLOGIC CONSIDERATIONS IN ANATOMIC IMAGING WITH RADIONUCLIDES

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COO-2427-4

PROGRESS REPORT

July 1973 - June 1974

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ABSTRACT

During the past year three publications have been made as a result of the work performed under this contract, reflecting the results of studies based upon the use of diagnostic radiological procedures. A copy of each publication is included in the appendix. The initial publication, "A Study on the Use of Diagnostic Radiology" (appendix A), ~~removed~~ cites the generation of a model describing particular factors which influence the physician in his use of diagnostic radiological procedures. Specifically, three motivating influences are defined and categorized as efficacy, innovation-curiosity habit and defensive medicine. The work that was done as reflected in the second publication, "Identification of Patterns in Diagnostic Attributes in Skull Trauma Cases Using an Entropy Minimax Approach" (appendix B), ~~removed~~ *see COO-2427-2* records the development and validation of a methodology used for obtaining relatively hard scientific measure of diagnostic utility, thus generating the data base referred to in appendix A in order to find statistically meaningful patterns of attributes in relation to outcome states. And finally the third publication, "The Analysis of Decisions and Information in Patient Management" (appendix C), ~~removed~~ gives a detailed description of the method of analysis used to generate the results as found in appendix B. The work as reflected in appendix C also discusses the relation between various methodologies that are available for the analysis of efficacy data.

As a result of the work described in the three publications, an experimental program has been designed with the objective of determining the diagnostic utility of brain, bone and liver scans. The data for these scans is being generated by a three-step process consisting of a prospective questionnaire, an outcome determination and a follow-up questionnaire to determine the disposition of the patient. The services of two medical students have been employed to assure the validity and consistency of the data gathered by these questionnaires. It is projected that in the period of time in which the medical students are acting as research assistants, we will have obtained 150 complete brain scan studies and somewhat fewer bone and liver scan studies. The data thus generated will be processed by a program executed on the IBM model 370-145 in order to determine the diagnostic utility of radiological procedures involving brain, bone and liver scan studies.

This progress report concludes with the financial statement for the contract period from 1 July 1973 to 30 June 1974, detailing the use of expenditures and the surplus of unutilized monies.

PROGRESS REPORT TO THE ATOMIC ENERGY COMMISSION
Contract No. AT(11-1)-2427

I. Introduction

The work performed during the period covered in this progress report has resulted in three publications which are included as appendices to this report. The first of these entitled "A Study On the Use of Diagnostic Radiology," describes in detail the model which we have constructed for the evaluation of the efficacy of diagnostic radiological procedures. The second entitled "Identification of Patterns in Diagnostic Attributes in Skull Trauma Cases Using An Entropy Minimax Approach," gives a description of the results which we obtained in relation to the above mentioned model from a study of some fifteen hundred skull x-ray cases. The final publication entitled "The Analysis of Decisions and Information in Patient Management," provides a review and description of the principal methods for the analysis of efficacy data. A brief resume of the principal results contained in each of these publications is given in Section II below.

A combination of the results obtained in our work over the past year has led to the structuring and initiation of a new experimental program to further investigate diagnostic efficacy with regard to radiological procedures. The experimental design of this program is again based on the use of prospective and retrospective questionnaires. A program has been implemented to obtain data using these questionnaires and to provide validation of that data. Details of

both the questionnaire design and the program for gathering data are given below in Section III. In addition to the experimental design we have also been engaged in the conversion of our data analysis computer programs from the Control Data Corporation 6600 computer to the IBM 370 system located here at Johns Hopkins University. A brief discussion of this effort is contained in Section IV below.

II. Results of Studies of the Use of Radiological Diagnostic Procedures

An important result of our work over the past year has been the generation of a model of the factors which influence the use of diagnostic radiological procedures. This model described in appendix A, serves as one of the bases of our current experimental activity. In effect the model states that there are basically three motivating forces which cause a physician to utilize diagnostic radiological procedures. While not independent or mutually exclusive these three motivating influences may be categorized as 1) efficacy, 2) innovation-curiosity and 3) defensive medicine. We define efficacy as the use of a diagnostic procedure which provides information to the physician, which in turn changes his behavior in the management of the patient. Innovation-curiosity is defined as the use of a diagnostic procedure because the physician wants to see what the result will be. The procedure might even help the patient. The use of a diagnostic procedure in a defensive manner occurs when the procedure is ordered not to benefit the patient but rather to protect the physician from either peer incrimination or perceived legal responsibility. Although it is unlikely that the ordering

of diagnostic procedures is solely motivated by any one of the above considerations it is certainly true that two of the motivating influences namely innovation-curiosity and defensive medicine have an adverse impact on the cost of health care.

In appendix A, Dr. Potchen shows that the practice of defensive medicine may be the major reason for the increasing use of radiological diagnostic procedure. In fact there is evidence from at least two sources which bracket the upper and lower bounds on the amount of diagnostic work which may be attributable directly to the practice of defensive medicine. One study has placed the lower bound at something greater than 7% of all radiological diagnostic procedures while the other study has estimated that the practice of defensive medicine may be a significant influence in as many as 72% of the radiological studies ordered. Given the total dollar value of studies ordered these two bounds can be translated into a dollar cost which lies somewhere between \$400,000,000 dollars minimum and \$1.3 billion dollars maximum.

Dr. Potchen further shows that the threat to doctors in terms of malpractice suits is at most \$10,000,000 dollars and may be as small as \$5,000,000. Thus the amount of money being committed in the practice of defensive medicine can in no way be justified by the magnitude of the threat which the physician faces for having not ordered a particular diagnostic procedure. On the other hand, it has been shown that the principal reason for malpractice suits is the breakdown in rapport between the physician and the patient. Thus Dr. Potchen draws the conclusion that the most effective defense against malpractice is the improvement of communication between the

doctor and the patient rather than the ordering of more diagnostic procedures.

The second motivating influence which has an adverse impact on the cost of medical care is innovation-curiosity. This particular motivation has been justified in the past as being required in order that the physician may develop the experience necessary to determine for himself the efficacy of various diagnostic procedures. Dr. Potchen shows that the presence of a reliable quantitative body of data on the relative merits of various diagnostic procedures would in effect obviate the need for personal experience developed on an ad hoc basis. This observation combined with the impact which such a data base would have on the legal implications of ordering diagnostic procedures motivated us to seek a method by which such a data base could be obtained.

The objective of the work recorded in appendix B was the development and validation of a methodology for obtaining a relatively hard scientific measure of diagnostic utility and thus taking the first step in generating the data base referred to above. The work recorded in appendix B was based on data provided by Dr. John Loop of the University of Washington School of Medicine and concerned some 1500 cases of skull trauma presented in an emergency room setting. The data consisted of clinical observations referred to as attributes accompanied by two outcomes, the first being the doctor's subjective probability of finding a skull fracture and the second being the result of the skull x-ray for each patient. The objective of the analysis was to find statistically meaningful patterns of attributes in relation to these two outcomes.

The actual data analysis was carried out under two sets of assumptions regarding the a priori probability of discovering a patient with a skull fracture in the population presented to the computer program. In the first case the data presented to the program was structured such that the a priori probabilities of a fracture versus a nonfracture case were equal and in the second case the a priori probabilities were adjusted such that they matched the actual probabilities encountered in a clinical setting. Both classes of outcomes were analyzed under each of these assumptions. The first outcome was the answer to the prospective question in which the physician was asked to assess the odds of finding a skull fracture in the particular patient he was examining. The second outcome was the actual result of the x-ray for that patient. Using the first set of outcomes, physician's subjective odds, the computer program generated a series of patterns of attributes versus the odds of finding a skull fracture. These patterns were shown to a number of physicians and their comments regarding these patterns were solicited. The physicians tended to agree that the patterns discovered by the computer program agreed with their subjective feelings as to the principal attributes which would be indicative of finding or not finding a skull fracture.

The program was then run using the same set of attributes but using as the outcome the result of the actual x-ray examination. Again a set of patterns emerged which related attributes to outcomes and again the physicians interviewed agreed that the patterns of attributes were if anything more reasonable than those which emerged using the subjective odds as the outcome. A comparison of the

principal attributes generated under each of the two outcomes showed that certain attributes which the physician considered marginally important in generating his subjective probability had in fact no correlation with the presence or absence of a skull fracture as indicated by the actual x-ray outcome. In addition, the same comparison of attribute lists indicated that certain attributes had absolutely no correlation with either the formation of a physicians subjective odds or the actual presence or absence of a skull fracture. The conclusion is that these attributes which show no correlation must in fact have no diagnostic efficacy and similarly those attributes which were important in the formulation of subjective odds but had no correlation with actual outcome could also be interpreted as having no diagnostic efficacy.

When the input data to the program was restructured in order to accurately reflect the true a priori probabilities of finding a skull fracture in a clinical setting it was shown that the program was able to reproduce the patterns described above. Thus it could be concluded that the actual a priori probabilities of an event are not necessarily a strong determinant in the ability to find patterns of attributes relating to such events.

An additional interesting outcome from this research work was noted when an attempt was made to correlate the reason the physician gave for ordering the x-ray with the observed attributes. When the reason for ordering the x-ray was used as an outcome it was found that no strong pattern emerged. This would suggest that the stated reason for ordering the x-ray was if anything only marginally correlated with the physician's observations regarding

the particular patient. Thus we may conclude that we have observed, at least indirectly, evidence relating to the defensive use of diagnostic procedures.

In conclusion it was apparent from this study that knowledge of the final outcome of these cases i.e., the actual treatment prescribed by the physician, would have allowed us to determine the actual efficacy of the skull x-ray. To determine the efficacy we would have carried out similar computer runs as those above but utilizing for outcomes the actual treatment prescribed by the physician and utilizing the result of the x-ray as an attribute rather than an outcome. Thus we could have determined whether or not the outcome of the x-ray indicating the presence or absence of a skull fracture was in fact a determinant in the choice of treatment for the patient. If the outcome of the x-ray could indeed be shown to be an important factor in the choice of treatment then we could have concluded that it was efficacious and likewise its absence as an important attribute would have led to the conclusion that it was essentially nonefficacious. Unfortunately we did not have the data which would allow us to make this particular determination. However, the possibility of being able to carry out such a determination clearly indicated a path which we could follow to develop a data base regarding a radiological procedure which would allow us to determine its efficacy.

Appendix C provides a detailed description of the method of analysis which was used to generate the results outlined above. In addition this appendix provides a discussion of the relation between the various methodologies available for the analysis of

efficacy data. The methods described include both Bayesian and non-Baysian models along with various behavioral models in addition to the entropy minimax approach which is essentially unstructured. In the interests of generality we will undoubtedly continue to use the entropy minimax approach in our analysis of future data.

III. Experimental Program to Study the Diagnostic Utility of Brain, Liver and Bone Scans

As a direct result of the work described above we have designed an experimental program whose objective is the determination of the diagnostic utility of brain, liver and bone scans. The data required to make the determination is currently being obtained by means of a three-step process consisting of a prospective questionnaire, an outcome determination, and a follow-up questionnaire to determine the disposition of the patient. It is the third step in this process namely the follow-up questionnaire which will distinguish this data from that which was available for our study of skull x-rays.

The design of the questionnaire to be used in this particular study involved a two-step process in which we used an initial questionnaire to test the questions and methodology before finalizing on the questionnaire shown in appendix D. A total of approximately 30 test cases were investigated during the questionnaire design period.

As a result of this series of test cases a number of changes were made in the questionnaire until it finally evolved as a form which would capture the appropriate data with a minimum of effort on both the part of the investigator and the participating doctor. A follow-up questionnaire was also designed in order to capture the information

on the disposition of the patient. An example of this questionnaire is also included in appendix D. In order to assure the validity and consistency of the data gathered on these questionnaires we have elected to employ the services of two medical students to assist in filling out the questionnaires and the gathering of the follow-up data.

The medical students acting as research assistants are responsible for the completion of both the prospective and the follow-up questionnaires. The cases to be studied are selected at random from a list of cases to receive either brain, liver or bone scans on the day following the day in which the prospective questionnaire is to be completed. Once the cases have been selected the research assistant locates the appropriate medical record and fills out a portion of the prospective questionnaire utilizing the physician's notes and other observational data which can be gathered directly from the medical record. He next locates the physician who ordered the particular procedure and fills out those questions which require physician input. Timing is important in this particular regard since the results of the scan are communicated within hours to the physician and consequently if the prospective portion of the questionnaire has not been completed the answers will be biased. The research assistant then allows two days for the written report to reach the doctor requesting the test and then follows up the results of the written report by completion of the follow-up questionnaire.

By utilizing this personal contact form of data collection we feel reasonably certain that we will be able to guarantee the

validity and consistency of the data. In particular we find that a face-to-face interview in which the research assistant obtains directly the answers to the subjective questions usually results in data of a higher quality since the respondent is giving his answers to a knowledgeable individual rather than to an impersonal piece of paper. Thus the respondents' answers to questions tend to be somewhat more thoughtful and somewhat more complete than would be the case on an impersonal questionnaire. Although this method is admittedly time consuming we feel confident that over the period of time which the medical students will have been on this project we will in fact obtain on the order of 150 complete brain scan studies and somewhat fewer liver and bone scan studies.

IV. Data Analysis and Conversion of Programs

The data obtained in the brain, liver and bone scan studies described above will be processed by a program very similar to that used on the skull x-ray data. This particular program is somewhat more advanced than the previous version and will be fully converted to execute on the IBM model 370/145 located at the Johns Hopkins University. A somewhat more powerful version of the same program is currently being converted to execute on the IBM model 360/91 located at the Johns Hopkins Applied Physics Laboratory. We anticipate that initial data processing will be done on the facility located at the University which although somewhat less powerful does have the advantage of economy and convenience. Thus the data processing will be a two stage operation in which the outlines

of interesting patterns in the data will be defined using the smaller computer system and the details of the pattern will be filled in by computer runs on the larger and more expensive system.

A good deal of the program conversion work has been accomplished during the past year. The original programs were set up to execute on a Control Data Corporation model 6600 computer system and the programs had not been previously executed on any IBM equipment. Consequently there was the normal set of problems encountered when converting from one computer system to another however the majority of these have been overcome and the program is now deemed nearly operational. Unfortunately this set of programs had not been previously documented nor exhaustively tested on data with known statistical properties. In fact previous testing had been confined largely to a single set of data in which the objective of the testing was consistency after each program change. We are currently in the process of conducting a fairly exhaustive test of the program using a set of data with known statistical and logical Boolean functions utilizing a random number generator as the input driving source. The results of this activity should be completed shortly and we anticipate the publication of a letter on the results of these tests.

V. Financial Statement

The attached financial statement indicates a surplus of funds in the amount of \$14,534.00 for the period covered in this report. This surplus is due primarily to the delays introduced in the research by Dr. Potchen's move from Washington University to Johns Hopkins University.

Financial Statement for Contract Period July 1, 1973 - June 30, 1974
AEC Contract No. AT(11-1)-2427

<u>Item</u>	<u>Budget</u>	<u>Expended</u>	<u>Unutilized</u>
Personnel	20,650.00	13,591.00	7,059.00
Fringe Benefits	2,891.00	1,903.00	988.00
Supplies	2,769.00	1,782.00	987.00
Domestic Travel	300.00	219.00	80.00
Equipment	1,500.00	786.00	714.00
Computer	<u>1,741.00</u>	<u>928.00</u>	<u>813.00</u>
Total Direct Cost	29,851.00	19,208.00	10,642.00
Indirect Costs	<u>10,149.00</u>	<u>6,257.00</u>	<u>3,892.00</u>
Grand Total	40,000.00	25,465.47	14,534.00