A Nuclear Medicine Technologist Curriculum: Statistics as a Tool in Problem Solution

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Structured curricula in nuclear medicine technology often are inflexible and unable to respond rapidly to the expansion in complexity and sophistication of nuclear medicine technology. Curricula must remain flexible to provide an opportunity to meet changing needs in a rapidly expanding science. The development of new radionuclides, intricate instrumentation, and new nuclear medicine procedures requires that nuclear medicine technologists be provided with an educational experience in evaluating test results and providing quality control in a quantitative rather than a qualitative manner. We have responded to this need by the early introduction of statistics into the curriculum and the integration of statistics teaching with the teaching of physical and clinical problems of nuclear medicine. Statistics has been used as a tool to provide criteria for evaluating in vitro laboratory techniques, instrument quality control, and the intercomparison of test results generated by varied methodology.

The past decade has witnessed a unique growth in the field of nuclear medicine. During 1969 a study was conducted by the Technical Education Research Center, contractors for the Department of Health, Education and Welfare, which sought to define manpower needs and training resources for technicians in nuclear medicine. Their summary of projected needs for the next several years based on interviews at 203 hospitals and questionnaires from 151 hospitals indicated the present number of nuclear medicine technologists in the United States is between 4,000 and 4,600. By 1975 the need for nuclear medicine technologists was projected to be between 8,000 and 12,000 *(1)*. The need was not only for additional personnel but also for highly trained individuals who would be able to assume supervisory responsibility in a nuclear medicine department.

To meet anticipated demands, a 12-month nuclear medicine training program was organized at the St. Louis Veterans Administration Hospital. This program has now been in existence for 5 years and has trained 24 technologists. Having this experience, we would like to report on the curriculum organization and discuss some innovations in the program design.

Planning the Curriculum

In planning the curriculum for such a program we first needed to adequately define the program objectives. These objectives were for the large part defined by the AMA Council on Medical Education in their "Essentials of an Accredited Educational Program in Nuclear Medicine Technology" *(2)*. Their objectives were mainly defined in terms of classroom hours and general type of learning experiences (Table 1). In addition to these minimum requirements, our goal was to train an individual with a superior degree of competence and understanding in the handling of radionuclides and the technical aspects of performing clinical diagnostic procedures using radioactive tracer materials. This individual would have the ability to supervise all routine laboratory procedures, to direct the training of other technologists, and to participate in devising technologically oriented research projects.

To meet our described goals, a balanced curriculum was instituted including formal lectures and seminars, laboratory instruction, and supervised

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Table 1. AMA Essentials of an Accredited Educational Program in Nuclear Medicine Technology

Subject	AMA recommendation	St. Louis VA
Orientation and introduction	4 hr	8 hr
Basic anatomy, physiology, and pathology	40–100 hr	50 hr
Mathematics	20 hr	20 hr
Radiation physics	10–20 hr	20 hr
Nuclear physics and instrumentation	60–100 hr	100 hr
Radiation biology	20–30 hr	20 hr
Radiation protection	15 hr	20 hr
Basic laboratory procedures and techniques	10–50 hr	10 hr
Clinical application of radionuclides	100–150 hr	120 hr
Records and administrative procedures	5 hr	5 hr
Therapeutic radionuclides	10 hr	10 hr
Radiochemistry and radiopharmaceuticals	25 hr	25 hr
Statistics		10 hr

participation in the clinical radioisotope laboratory. The program was basically divided into three segments: formal didactic, organized teaching laboratory, and clinical practicum. The didactic and teaching laboratory occupy the first 5 months and the clinical practicum lasts for the remaining 7 months of the training period. The didactic portion includes formal and informal lectures while the the teaching laboratory includes planned supervised experiments conducted to illustrate various principles of radiation detection and the tracer technique. All experiments are conducted in a training laboratory on training instruments, using rats when appropriate. During this portion, particularly, the trainee is required to demonstrate understanding of instrumentation principles and apply these to specified problems of quantitation and measurement. The remaining segment of the program, clinical practicum, is devoted to the repetitive performance of specific clinical procedures in the participating affiliated hospitals under the supervision of a qualified professional and technical staff.

Addition of Statistics

This curriculum adequately satisfies the basic objectives of the program: i.e., to produce an individual with a thorough understanding and facility in the use of radioactive materials, equipment, methods, and techniques used in nuclear medicine. However, with the goal of training an individual who would be able to rigorously think through any problem situation scientifically, a unique innovation was added to the curriculum. This addition to the program was the simultaneous teaching of both parametric and nonparametric statistics along with physical and clinical principles. These statistics were included in the program to develop in trainees the tools needed for thoughtful gathering and critical analysis of scientific data. In evaluating new procedures and methods, the technologist must be able to choose a valid statistical test whose model most closely approximates the conditions of his research. In maintaining a good system of quality control in the laboratory, the technologist must have knowledge of the meaning of statistical techniques used in the determination of existing relationships.

The need for this addition in our curriculum being apparent to the staff, the next problem involved the selecting and organizing of the proper experiences for meaningful learning. If learning was to be purposeful, the presentation of statistics must be related to the current experiences of the trainees. Meaningful learning would occur in relationship to the degree in which the trainee lived the planned experiences and to the degree to which these experiences were applied. Appropriate are the words of a group of educators:

> Learning experiences are meaningful when they are related to the individual's interests, when they are involved in his living, when they not only contribute to his purposes at the time but enable him to make more intelligent adjustments in the future, when they involve discovery and problem solving rather than formal drill or mere memorization, and when they result in satisfying social relationships *(3)*.

If the proper statistical experiences were chosen and the relationship of these to their future experiences as technologists made apparent to the trainees, it was hoped that this new learning itself would become the motivation for more learning in this area.

The statistic curriculum was basically organized under the assumption that the technology trainees were already motivated to study nuclear medicine by the mere fact that they had applied to the program. Assuming this motivation, several basic principles of what constitutes meaningful learning were applied:

1. Learning is an active process and cannot take place without the activity of the learner.
2. Learning is reacting, experiencing, and doing.
3. Learning will be most meaningful when experiences are arranged in an integrated and continuous fashion.

The first principle mentioned above has been recognized in the field of education and substantiated since early times. Philosophers such as Plato and Socrates emphasized that true learning must be a "dialogue." The dictionary defines a dialogue as a "conversation between two or more persons." In the learning situations the interchange or conversation of thoughts must occur to establish common meanings, promote increased understanding, and build new relationships. The statistics portion of the nuclear medicine technology program was thus organized to promote such a "dialogue." Lectures were planned to acquaint the trainees with the fundamental concepts of statistics and various statistical methods. More than adequate time was alotted for such topics as measures of central tendency and variation, frequency and variation, frequency distribution, sampling, and for the more specific measure of significance, such as Student's t, Pearson's r, and the analysis of variance. Due to the limited mathematical background of some of these individuals, presentations were introduced with the prime goal of establishing more of an intuitive understanding of statistics than a theoretical grounding. To develop this understanding, everyday situations were chosen initially due to the trainees' inexperience in nuclear medicine. Formulas were kept at a minimum, and numerous examples from everyday situations, which the student could easily relate to, were given. At the completion of the day's activities, trainees were given the assignment of designing experiments from everyday situations using knowledge acquired from lectures. This assignment not only required the learner to relate this knowledge to prior experiences, facilitating learning, but provided a basis for the following day's session. This next class period was conducted more or less on a seminar basis with the students making presentations followed by an open discussion. As the trainees progressed, experiments from the field of nuclear medicine were chosen in which statistical measurements could be applied, such as comparison of methods used to measure blood volume. Some of these designed experiments would be carried out in the clinical laboratory when appropriate and practical to substantiate the relevancy of the inclusion of statistics in a curriculum for nuclear medicine technology.

The second principle used was the need for "experiencing" and "living" newly acquired knowledge. William Kilpatrick in his essay, "A Modern Theory of Learning," proposed the theory, quite contrary to conventional theory, that learning consists of the learning of statements having little or no connection with everyday life. His learning theory showed the following characteristics in that it held

> that behaving is typically a part of the learning process; that the learning goes forward best, if not solely, in a situation of concrete personal living; that the learning comes from behavior, not mere repetition of words . . . that the first application of the learning comes, normally, within the experience in which the learning takes place, in fact that the learning comes typically in order to carry on this experience *(4)*.

The quality of these experiences was another quite important consideration for their result could either create a positive or negative attitude toward statistics. John Dewey most effectively substantiated this with his statement,

> A central problem of education is the identification of those present experiences which can live fruitfully and creatively in future experiences *(5)*.

There was thus a necessity to choose live experiences in statistics for our trainees that were worthwhile, purposeful, and obviously related to their training in nuclear medicine technology.

To accomplish this objective the didactic presentation of statistics was placed at the early part of the training session when the trainee would be able to perform certain in vitro laboratory procedures that involved some quantitative measurements without a great deal of knowledge of instrumentation. These clinical lab procedures were planned to pertain to theory given in clinical lectures by the staff physicians. For example, an experience was designed so that the trainee would have an opportunity to perform the same procedure repetitively using slightly different methods. Upon completion of this work the trainee would then proceed to analyze his or her measurements with an appropriate statistical technique to find if there was a significant difference between these methods used to evaluate the same parameter. This clinical experience was easy to create, for the particular nuclear medicine tests chosen were those performed on patients' sera, providing for easy repetition. All experiments were conducted in the training area adjacent to the nuclear medicine laboratory where all equipment and gamma counters are designated solely for training. We felt our students had actually "lived" their statistical orientation. We were also satisfactorily convinced that these trainees with more such experiences would assume responsible positions in the field of nuclear medicine technology and could make not only qualitative decisions but also quantitative ones that would be a service to any laboratory.

Specific areas in which the trainee integrated statistical evaluatory criteria with their clinical nuclear medicine laboratory experience included in vitro laboratory techniques, instrument quality control, and intercomparison of test results generated by varied methods.

An instance of a specific type of problem related to an in vitro laboratory technique is a pipetting exercise. The objective of this exercise is to determine how precise the student is in his pipetting and also if there is a significant difference in an individual's measurements depending on the device used. A dilute sample of radioactivity is prepared and the students are asked to pipette 0.5 ml of the radioactivity repetitively into ten tubes using a manual serologic, manual volumetric, and three different automatic pipetting devices. The trainee will then have made 50 measurements. These samples are counted in a well scintillation detector and the mean standard deviation and coefficient of variation for each set of ten tubes is found to determine variance within pipettes. An analysis of variance is later performed to determine if the variance between pipettes is significant. This experiment is designed to develop in the student technologists an awareness of the possible error that pipetting may introduce into a procedure.

An example of an instrument quality control experience is the use of the chi square test. The objective of this exercise is to evaluate counter behavior statistically. The student is asked to obtain an average value for ten 1-min count measurements on a radioactive source. Chi square is calculated for the data and the value obtained compared with the chi square distribution table. From the table the student can find the probability of obtaining his value of chi square and determine if his instrument is working properly.

Finally, an example of total integration of method variables with a final test result was provided by several thyroid in vitro measurements. The objective of this exercise was to determine if there is a significant difference in the thyroxine concentration in a patient's serum depending on the method used for measurement of this hormone. Excess patient's sera was preserved from the clinical radioisotope laboratory and the concentration of thyroxine in a patient's serum measured by a student using different manufacturers' kits. Having obtained two thyroxine measurements of each patient in the group, the student technologist used the Student's t test for paired data to determine if there was actually a significant difference in the two measurements of the hormone. This experiment gives the student an opportunity to learn different procedures and also to learn the methodology used in the decision of which test procedure is best suited for his laboratory.

Having selected these appropriate learning experiences, it was necessary to organize them so that

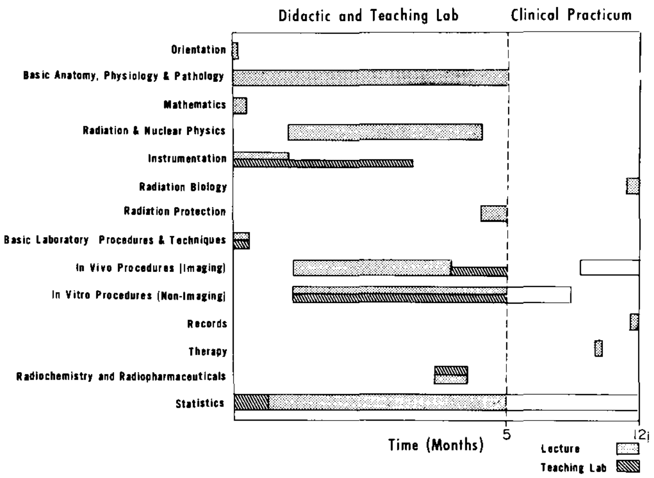

FIG. 1. Time line relationship between didactic and clinical segments of nuclear medicine technology training program.

they became integrated into the established curriculum (Fig. 1). Initially during the didactic portion, principles of statistics were laid down, and various applications were experienced in an organized and sequential fashion. Clinical studies were performed as part of the teaching laboratory portion simultaneously with related theoretical lectures given by the nuclear medicine staff. Studies performed on serum could be easily organized within this framework; however, in those requiring the presence of patients, this schedule was occasionally hard to strictly adhere to. During the remaining 7 months of the program, the clinical practicum portion, the trainees are assigned projects in correlation with their work where statistical tests are applicable.

Summary

In conclusion, we believe statistics can be an integral part of a nuclear medicine technology curriculum in addition to being meaningful to the student technologist. Introduction of statistics early in training allows the trainee to develop a quantitative approach to problem solving in the laboratory.

References

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