

2009 Mississippi Curriculum Framework

Postsecondary Nuclear Medicine Technology

(Program CIP: 51.0905 – Nuclear Medical Technology/Technologist)

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Standards in this document are based on information from the following organizations:

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American Society of Radiologic Technologists

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Nuclear Medicine Technology Certification Board

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Related Academic Standards

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Preface

Postsecondary Nuclear Medicine Technology Research Synopsis

Articles, books, Web sites, and other materials listed at the end of each course were considered during the revision process. These references are suggested for use by instructors and students during the study of the topics outlined.

The community college instructors worked closely with industry and the instructional design specialist in the development of the program and the curriculum framework. The program was developed in response to the number of job openings related to nuclear medicine that are available and projected for the future in the area near the college. The courses were developed based on similar programs in numerous other states.

Curriculum

The following national standards were referenced in each course of the curriculum.

- CTB/McGraw-Hill LLC *Tests of Adult Basic Education, forms 7 and 8 Academic Standards*
- *21st Century Skills*
- *The American Registry of Radiologic Technologist (ARRT) Content Specifications for the Examination in Nuclear Medicine Technology and the Nuclear Medicine Technology Board (NMTCB) Components of Preparedness*

Industry and instructor comments, along with current research, were considered by the curriculum development team during the development process. Specific work with the curriculum included the following:

- A course outline was developed for a 2-year associate degree program and/or certificate of completion program.
- Competencies and objectives were developed based on national certifications and were written to a variety of levels of Bloom's taxonomy.
- References were suggested for each course.
- A Recommended Tools and Equipment list was developed.

Assessment

Students will be assessed using the American Registry of Radiologic Technologists (ARRT) Examination in Nuclear Medicine Technology and/or the Nuclear Medicine Technology Certification Board (NMTCB) exam.

Professional Learning

It is suggested that instructors participate in professional learning related to the following concepts.

- How to use the program Blackboard site
- Differentiated instruction – To learn more about differentiated instruction, please go to http://www.paec.org/teacher2teacher/additional_subjects.html and click on Differentiated Instruction. Work through this online course, and review the additional resources.

Articulation

No articulated credit will be offered upon implementation of this curriculum by the college.

Foreword

As the world economy continues to evolve, businesses and industries must adopt new practices and processes in order to survive. Quality and cost control, work teams and participatory management, and an infusion of technology are transforming the way people work and do business. Employees are now expected to read, write, and communicate effectively; think creatively, solve problems, and make decisions; and interact with each other and the technologies in the workplace. Vocational–technical programs must also adopt these practices in order to provide graduates who can enter and advance in the changing work world.

The curriculum framework in this document reflects these changes in the workplace and a number of other factors that impact local vocational–technical programs. Federal and state legislation calls for articulation between high school and community college programs, integration of academic and vocational skills, and the development of sequential courses of study that provide students with the optimum educational path for achieving successful employment. National skills standards, developed by industry groups and sponsored by the U.S. Department of Education and Labor, provide vocational educators with the expectations of employers across the United States. All of these factors are reflected in the framework found in this document.

Referenced throughout the courses of the curriculum are the 21st Century Skills, which were developed by the Partnership for 21st Century Skills, a group of business and education organizations concerned about the gap between the knowledge and skills learned in school and those needed in communities and the workplace. A portion of the 21st Century Skills addresses learning skills needed in the 21st century, including information and communication skills, thinking and problem-solving skills, and interpersonal and self-directional skills. The need for these types of skills has been recognized for some time, and the 21st Century Skills is adapted in part from the 1991 report from the U.S. Secretary of Labor’s Commission on Achieving Necessary Skills (SCANS). Another important aspect of learning and working in the 21st century involves technology skills, and the International Society for Technology in Education, developers of the National Educational Technology Standards (NETS), were strategic partners in the Partnership for 21st Century Skills.

Each postsecondary program of instruction consists of a program description and a suggested sequence of courses that focus on the development of occupational competencies. Each vocational–technical course in this sequence has been written using a common format that includes the following components:

- Course Name – A common name that will be used by all community/junior colleges in reporting students
- Course Abbreviation – A common abbreviation that will be used by all community/junior colleges in reporting students
- Classification – Courses may be classified as the following:
 - Vocational–technical core – A required vocational–technical course for all students

- Area of concentration (AOC) core – A course required in an area of concentration of a cluster of programs
 - Vocational–technical elective – An elective vocational–technical course
 - Related academic course – An academic course that provides academic skills and knowledge directly related to the program area
 - Academic core – An academic course that is required as part of the requirements for an associate’s degree
- Description – A short narrative that includes the major purpose(s) of the course and the recommended number of hours of lecture and laboratory activities to be conducted each week during a regular semester
 - Prerequisites – A listing of any courses that must be taken prior to or on enrollment in the course
 - Corequisites – A listing of courses that may be taken while enrolled in the course
 - Competencies and Suggested Objectives – A listing of the competencies (major concepts and performances) and of the suggested student objectives that will enable students to demonstrate mastery of these competencies

The following guidelines were used in developing the program(s) in this document and should be considered in compiling and revising course syllabi and daily lesson plans at the local level:

- The content of the courses in this document reflects approximately 75% of the time allocated to each course. The remaining 25% of each course should be developed at the local district level and may reflect the following:
 - Additional competencies and objectives within the course related to topics not found in the state framework, including activities related to specific needs of industries in the community college district
 - Activities that develop a higher level of mastery on the existing competencies and suggested objectives
 - Activities and instruction related to new technologies and concepts that were not prevalent at the time the current framework was developed/revised
 - Activities that implement components of the Mississippi TechPrep initiative, including integration of academic and vocational–technical skills and coursework, school-to-work transition activities, and articulation of secondary and postsecondary vocational–technical programs
 - Individualized learning activities, including work site learning activities, to better prepare individuals in the courses for their chosen occupational areas
- Sequencing of the course within a program is left to the discretion of the local district. Naturally, foundation courses related to topics such as safety, tool and equipment usage, and other fundamental skills should be taught first. Other courses related to specific skill areas and related academics, however, may be sequenced to take advantage of seasonal and climatic conditions, resources located outside of the school, and other factors.

- Programs that offer an Associate of Applied Science degree must include a minimum 15 semester credit hour academic core. Specific courses to be taken within this core are to be determined by the local district. Minimum academic core courses are as follows:
 - 3 semester credit hours Math/Science Elective
 - 3 semester credit hours Written Communications Elective
 - 3 semester credit hours Oral Communications Elective
 - 3 semester credit hours Humanities/Fine Arts Elective
 - 3 semester credit hours Social/Behavioral Science Elective

It is recommended that courses in the academic core be spaced out over the entire length of the program so that students complete some academic and vocational–technical courses each semester. Each community/junior college has the discretion to select the actual courses that are required to meet this academic core requirement.

- In instances where secondary programs are directly related to community and junior college programs, competencies and suggested objectives from the high school programs are listed as Baseline Competencies. These competencies and objectives reflect skills and knowledge that are directly related to the community and junior college vocational–technical program. In adopting the curriculum framework, each community and junior college is asked to give assurances that:
 - students who can demonstrate mastery of the Baseline Competencies do not receive duplicate instruction and
 - students who cannot demonstrate mastery of this content will be given the opportunity to do so.
- The roles of the Baseline Competencies are to do the following:
 - Assist community/junior college personnel in developing articulation agreements with high schools
 - Ensure that all community and junior college courses provide a higher level of instruction than their secondary counterparts
- The Baseline Competencies may be taught as special “Introduction” courses for 3–6 semester hours of institutional credit that will not count toward associate degree requirements. Community and junior colleges may choose to integrate the Baseline Competencies into ongoing courses in lieu of offering the “Introduction” courses or may offer the competencies through special projects or individualized instruction methods.
- Technical elective courses have been included to allow community colleges and students to customize programs to meet the needs of industries and employers in their areas.

In order to provide flexibility within the districts, individual courses within a framework may be customized by doing the following:

- Adding new competencies and suggested objectives
- Revising or extending the suggested objectives for individual competencies
- Integrating baseline competencies from associated high school programs

- Adjusting the semester credit hours of a course to be up 1 hour or down 1 hour (after informing the State Board for Community and Junior Colleges [SBCJC] of the change)

In addition, the curriculum framework as a whole may be customized by doing the following:

- Resequencing courses within the suggested course sequence
- Developing and adding a new course that meets specific needs of industries and other clients in the community or junior college district (with SBCJC approval)
- Utilizing the technical elective options in many of the curricula to customize programs

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Program Description

The Nuclear Medicine Technology curriculum is a flexible program designed to offer a 2-year Associate of Applied Science degree program of study and/or a certificate of completion in Nuclear Medicine Technology. The program is designed to prepare the technologist to perform imaging procedures by administering radioactive materials to patients in a clinical setting. The nuclear medicine technologist is a highly specialized health-care professional who works closely with the nuclear medicine physician. The program is designed to provide the student the knowledge and skills to enter the field as a nuclear medicine technologist and successfully write the certification examinations of the American Registry of Radiologic Technologists (ARRT) and/or the Nuclear Medicine Technology Certification Board (NMTCB) upon successful program completion.

To be admitted into the Nuclear Medicine Program, students must meet the following requirement: completion of an accredited program in radiologic technology.

The curriculum was written to follow the American Society of Radiologic Technologists (ASRT) core curriculum.

Standards are based on ARRT content specifications for the examination in Nuclear Medicine Technology and the NMTCB components of preparedness.

Suggested Course Sequence*
Nuclear Medicine Technology
Associate of Applied Science

FIRST YEAR

3 sch Social/Behavioral Science Elective 11 sch Science/Math Electives** 3 sch Oral Communications Elective <hr style="width: 10%; margin-left: 0;"/> 17 sch	1 sch Introduction to Nuclear Medicine (NMT 2511) 11 sch Science/Math Electives** 3 sch Written Communications Elective 3 sch Humanities/Fine Arts Elective <hr style="width: 10%; margin-left: 0;"/> 18 sch
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SECOND YEAR

2 sch Radiopharmacy (NMT 1142) 3 sch Nuclear Medicine Procedures I (NMT 2523) 1 sch Nuclear Physics (NMT 2611) 2 sch Instrumentation I: Nonimaging (NMT 2712) 6 sch Clinical I (NMT 2816) <hr style="width: 10%; margin-left: 0;"/> 14 sch	3 sch Nuclear Medicine Procedures II (NMT 2533) 3 sch Instrumentation II: Imaging (NMT 2723) 2 sch Radiation Protection (NMT 2732) 1 sch Advanced Computer Applications (NMT 2741) 6 sch Clinical II (NMT 2826) <hr style="width: 10%; margin-left: 0;"/> 15 sch
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SUMMER II

1 sch Seminar Review (NMT 2541) 3 sch Clinical III (NMT 2833) <hr style="width: 10%; margin-left: 0;"/> 4 sch

* Students who lack entry level skills in math, English, science, and so forth will be provided related studies.

** It is suggested that applicants complete the following courses as part of the Science/Math Electives: Physics, General Chemistry, Human Anatomy and Physiology I, Human Anatomy and Physiology II, Algebra, and Statistics.

Suggested Course Sequence*
Nuclear Medicine Technology
Certificate**

Prerequisite: General Chemistry (CHE 1211; CHE 1213)

SUMMER I

1 sch Introduction to Nuclear Medicine
(NMT 2511)

1 sch

FIRST YEAR

3 sch Nuclear Medicine Procedures I
(NMT 2523)

1 sch Nuclear Physics (NMT 2611)

2 sch Instrumentation I: Nonimaging
(NMT 2712)

2 sch Radiation Protection (NMT 2732)

6 sch Clinical I (NMT 2816)

14 sch

3 sch Nuclear Medicine Procedures II
(NMT 2533)

3 sch Instrumentation II: Imaging (NMT
2723)

1 sch Advanced Computer Applications
(NMT 2741)

6 sch Clinical II (NMT 2826)

13 sch

SUMMER II

2 sch Radiopharmacy (NMT 1142)

1 sch Seminar Review (NMT 2541)

3 sch Clinical III (NMT 2833)

6 sch

* Students who lack entry level skills in math, English, science, and so forth will be provided related studies.

** It is suggested that applicants complete the following courses prior to beginning the certificate coursework: Physics, General Chemistry, Oral and Written Communications, Human Anatomy and Physiology, Algebra, and Statistics.

Nuclear Medicine Technology Courses

Course Name: Radiopharmacy

Course Abbreviation: NMT 1142

Classification: Vocational–Technical Core

Description: This course covers the theory and practice of radiopharmacy including preparation, calculation of the dose to be administered, quality control, radiation safety, and applicable regulations. It also deals with the nonradioactive interventional drugs used in nuclear medicine procedures. Students will gain experience in nuclear laboratories, the clinical setting, as well as a centralized radiopharmacy in order to become proficient in this area. (2 sch: 2-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives

1. Discuss basic concepts related to radiopharmacy.
 - a. Differentiate between an isotope and a nuclide, and use the terms appropriately.
 - b. Define the units used to measure radiation, and be able to convert within and between the systems.
 - c. Define and calculate specific activity and specific concentration.
 - d. Differentiate between biological and physical half-lives. Calculate the effective half-life.
 - e. Define and differentiate between carrier, carrier-free, and no-carrier-added radionuclides.
 - f. Describe the components of diagnostic and therapeutic radiopharmaceuticals, the function of each component, and the desirable characteristics for each.
 - g. Discuss the chemical and physical properties of radiopharmaceuticals, and describe the ideal properties for nuclear medicine procedures.
 - h. Discuss the factors considered when selecting a radionuclide to produce radiopharmaceuticals for diagnostic and therapeutic procedures.
 - i. Discuss the importance and implications of clearance times and target-to-background ratio in relation to radiopharmaceuticals.
 - j. Describe the various routes of administration used for radiopharmaceuticals, and give examples of each.
 - k. Discuss the factors considered when selecting a pharmaceutical to produce radiopharmacy for diagnostic and therapeutic procedures.
2. Discuss radiation protection and regulations in radiopharmaceuticals.
 - a. List the federal and state agencies that regulate the use of radioactive materials in nuclear medicine and control licensing of institutions and individuals; describe what each agency controls.
 - b. Describe the sources of radiation exposure in nuclear medicine.
 - c. Discuss the effects of time, distance, and shielding on radiation exposure, and be able to solve mathematical problems related to these factors.
 - d. Describe the methods and precautions used to reduce radiation exposure from external

<p>and internal sources.</p> <p>e. Describe the procedures used to prevent and detect radionuclide contamination.</p> <p>f. Describe the NRC requirements for storage and control of licensed radioactive materials.</p> <p>g. Differentiate between restricted and unrestricted areas; list the restrictions that apply; and describe the signs required for restricted areas and when each is used.</p> <p>h. Describe and explain the quality control program required by the NRC when therapeutic radiopharmaceuticals are used.</p> <p>i. Differentiate between recordable and reportable events and the actions required if they occur.</p> <p>j. Describe the NRC regulations that govern possession and quality control of dose calibrators; measurement of doses; permissible Mo99 concentration in generator eluate; and the use and labeling of syringe and vial shields.</p> <p>k. Describe the NRC regulations that govern storage and dispensing of radioactive volatiles, gases, and aerosols.</p> <p>l. Describe the proper method for receiving, labeling, and shipping packages containing radioactive materials, according to NRC regulations.</p> <p>m. Describe the various methods for disposal of radioactive materials.</p> <p>n. Describe the NRC regulations and the proper methods for performing ambient dose rate surveys and removable contamination surveys.</p> <p>o. Differentiate between an action level and a trigger level, in reference to radioactive contamination.</p> <p>p. Differentiate between minor and major spills, and describe the appropriate actions to be taken in each case.</p> <p>q. Describe and demonstrate radioactive spill containment and cleanup.</p>
<p>3. Explain federal regulations related to control of pharmaceuticals.</p> <p>a. Explain how a new drug is developed and approved for use.</p> <p>b. Discuss the regulations that control use of INDs and NDAs by a nuclear medicine facility.</p>
<p>4. Explain reimbursement as it relates to radiopharmaceuticals.</p> <p>a. Discuss how reimbursement affects the use of various radiopharmaceuticals and what impact this may have on patient care.</p>
<p>5. Describe the components of a radiopharmacy.</p> <p>a. Discuss how safety considerations and efficiency should determine hotlab layout.</p>
<p>6. Explain appropriate guidelines to limit radiation exposure to nuclear medicine patients.</p> <p>a. Discuss the factors that affect the radiation dose to the patient.</p> <p>b. Discuss radiation dose levels for typical nuclear medicine procedures.</p> <p>c. Discuss the hazards to a fetus/embryo or a breast-fed baby when the mother is administered a radiopharmaceutical; explain the procedures and precautions that should be used in these cases.</p>
<p>7. List adverse reactions related to radiopharmaceuticals.</p> <p>a. Define the terms <i>side effects</i>, <i>iatrogenic reactions</i>, and <i>idiosyncratic reactions</i>.</p> <p>b. Describe the potential adverse reactions that can occur during and after administration of a radiopharmaceutical, including the sign and symptoms, causes, actions to be taken, and reporting mechanisms.</p>
<p>8. Examine specific radiopharmaceuticals and their chemical properties.</p>

<ol style="list-style-type: none">a. Discuss oxidation states and their importance in radiochemistry; describe the reduction techniques used in radiopharmacy.b. Discuss the types of chemical bonds found in radiopharmaceuticals and their stability.c. Describe the physical and chemical properties of Tc99m, how it is bound to hydrophilic and lipophilic pharmaceuticals; discuss the undesirable chemical states that can result in each process.d. Describe the tagging processes used to label pharmaceuticals with long-lived radionuclides.e. Describe the various methods for tagging blood components with radionuclides, and potential pitfalls, and the advantages and disadvantages for each method.
<p>9. Describe the operating principles of radionuclide generators.</p> <ol style="list-style-type: none">a. Discuss the principles of operation of radionuclide generators, including the parent-daughter relationship and types of equilibrium.b. Explain how generator activity changes with time and elution, and discuss the factors that effect generator yield.c. Describe the configuration and components of a Mo99/Tc99m generator.d. Explain the difference between wet and dry generators, the advantages and disadvantages of each, and how each is eluted.e. Calculate yield, current activity, and efficiency of a Mo99/Tc99m generator.f. Describe the configuration of a Rb81/Kr81m generator; describe how it is eluted and the effects of time on its activity.
<p>10. Explain the difference between chemical purity and impurity.</p> <ol style="list-style-type: none">a. Differentiate between radionuclidic purity and radiopharmaceutical purity, and discuss potential sources of impurities and the reason these impurities are a concern.b. Describe the methods for determining radionuclidic purity, perform required calculations, state impurity limits, and describe the sources of error.c. Describe the methods for determining radiochemical purity, perform required calculations, and state impurity limits; describe the sources of error.d. Explain how time affects the radionuclidic and radiochemical purity of a radiopharmaceutical.e. Define chemical purity; discuss the sources and effects of the impurities.f. Describe how chemical purity is tested, and state the limits.g. Discuss the importance of pH in radiochemistry, common values, and methods of measurement.h. Describe the various types of particles used in nuclear medicine, the size range for each, and the methods for measurement; state the acceptable range for specific particulate radiopharmaceuticals.i. Describe the normal visual appearance of various radiopharmaceuticals.j. Differentiate between sterility and apyrogenicity; explain how each is achieved, the sources of contamination, effects of contaminants on patients, and methods for maintaining acceptable levels.k. Describe the test method for determining sterility and apyrogenicity. Discuss the advantages and disadvantages of the methods for detecting pyrogens and when each can or must be used and why.
<p>11. Describe steps involved in specific radiopharmaceutical kit preparation.</p> <ol style="list-style-type: none">a. Describe the components found in a lyophilized Tc-99m kit and the purpose of each.

<ul style="list-style-type: none"> b. Discuss the factors that must be considered when reconstituting a lyophilized Tc-99m kit. c. Describe the stepwise process for reconstituting a Tc-99m labeled kit. d. List the documentation requirements when radiopharmaceutical kits are prepared. e. Describe the techniques for compounding radiopharmaceutical kits.
<p>12. Describe PET imaging procedures and corresponding agents.</p> <ul style="list-style-type: none"> a. List commonly used positron emitters that are produced by generator systems or cyclotrons. b. Discuss the physical and chemical characteristics of positron emitters that make them appropriate for nuclear medicine procedures. c. Explain how PET imaging agents are prepared, and discuss the quality control requirements. d. Describe the methods and radiation protection procedures necessary for preparing and administering positron emitters.
<p>13. Describe factors involved in safe radiopharmaceutical dose determination for given procedures.</p> <ul style="list-style-type: none"> a. Discuss the criteria that must be considered when a dose range is developed for a particular radiopharmaceutical and procedure. b. Describe the allowable dose ranges and calibration requirements according to NRC regulations. c. Calculate specific concentration and the volume to be withdrawn for a given dose to be administered. d. Use decay formulas and decay factor tables to account for radioactive decay. e. Calculate doses to be administered for pre-calibration, and calculate unit-dose adjustments. f. Explain why doses to be administered to pediatric patients are calculated differently than adult doses. g. Describe the different methods used to calculate pediatric dosages; discuss the advantages and disadvantages of each; and explain the importance of utilizing minimum and maximum dose limits. h. Calculate pediatric dosages using body mass, Clark's rule, and dose to be administered per unit weight.
<p>14. Describe how radiopharmaceuticals localize in specific organs.</p> <ul style="list-style-type: none"> a. Define and discuss biologic localization of radiopharmaceuticals in humans including plasma clearance, uptake, redistribution, and excretion. b. Describe the various mechanisms of localization, and give examples of each.
<p>15. Describe physical and chemical properties related to diagnostic radiopharmaceuticals.</p> <ul style="list-style-type: none"> a. Discuss the following for each radiopharmaceutical listed on the current NMTCB pharmacy list: alternate names; studies for which it is used; dose ranges and route of administration; chemical and physical properties; method of preparation; biorouting mechanisms, critical organ doses, gonadal dose, and whole body dose; quality control considerations and limits; precautions and adverse reactions; and interfering agents and their effects.
<p>16. List all interventional pharmaceuticals associated with nuclear medicine procedures.</p> <ul style="list-style-type: none"> a. Discuss the following for each pharmaceutical listed on the current NMTCB pharmacy list: alternate names; studies for which it is used; doses ranges and route of

administration; method of preparation; precautions and adverse reactions; signs, symptoms, and actions in case of adverse reaction; and interfering agents and their effects.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)

- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

SUGGESTED REFERENCES

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Course Name: Introduction to Nuclear Medicine

Course Abbreviation: NMT 2511

Classification: Vocational–Technical Core

Description: This course offers an overview of the health-care system specific to nuclear medicine technology. Included are health-care systems, health-care communications, professional ethics and law, patient care, and professional development. (1 sch: 1-hr lecture)

Prerequisite: None

Competencies and Suggested Objectives	
1.	Explain program policies and procedures. <ol style="list-style-type: none"> a. Review the nuclear medicine program student guidelines. b. Discuss the role of a nuclear medicine technologist within the field of nuclear medicine.
2.	Describe characteristics appropriate for the nuclear medicine professional. <ol style="list-style-type: none"> a. Describe cooperation and the importance of acting as a team member at both the departmental and institutional levels. b. Describe professional etiquette in dealing with patients, families, visitors, other health care workers, support staff, and in communications with other facilities (such as physicians' offices). c. Describe conflict prevention and resolution behaviors and techniques in the work setting. d. Describe the importance of the ability to handle difficult people and work situations, such as an angry patient, using behaviors and techniques that diffuse or solve the problem or prevent the situation from worsening. e. Describe the importance of professional behaviors including showing openness to learning; taking initiative and assuming responsibilities as appropriate to training; showing confidence as clinical skills are mastered; and maintaining personal hygiene and a professional appearance. f. Describe the importance of calmness when the department is busy and multiple demands are made on the student. g. Describe ways to handle two or more tasks simultaneously when training and skill level have reached an appropriate level. h. Describe the importance of recognizing problems in the clinical setting, and describe a rational, stepwise process to analyze and attempt to solve the problem. i. Describe the importance of respecting the patient's privacy and maintaining patient confidentiality. j. Describe the importance of obtaining consent for a test from a patient or the appropriate person as required and/or allowed by regulation and/or facility policy.
3.	Discuss the organizational structure within clinical nuclear medicine departments. <ol style="list-style-type: none"> a. Identify the physician who functions as the department head, the administrative technologist, and the clinical instructors. b. Examine the roles of the physician who functions as the department head, the

<p>administrative technologist, and the clinical instructors.</p> <p>c. Describe the role of the nuclear medicine student in the department.</p> <p>d. Describe departmental facilities.</p>
<p>4. Examine nuclear medicine department procedures and protocols.</p> <p>a. Identify the location of specific departmental manuals.</p> <p>b. Describe specific procedures including patient preparation, imaging protocols, acceptable dose range for each clinical affiliate.</p> <p>c. Explain the difference between in-vivo and in-vitro procedures.</p> <p>d. Locate the physician's order, describe medication to be administered, and identify patient's chief complaint on a patient's chart.</p> <p>e. Identify the location of various departments related to nuclear medicine such as cardiology, emergency room, intensive care, and others.</p> <p>f. Identify areas where it is permissible to store food and personal items.</p>
<p>5. Identify the functions of regulatory and advisory groups that determine imaging standards, dose limits, and procedure guidelines.</p> <p>a. Identify the specific roles of the Nuclear Regulatory Commission (NRC), the State Board of Radiologic Health, Occupational Safety and Health Administration (OSHA), Federal Drug Administration (FDA), the Joint Commission on Accreditation of Hospital Organizations (JCAHO), and the Health Insurance Portability and Accountability Act (HIPAA).</p> <p>b. Describe specific evacuation procedures to be followed in the event of a radioactive spill.</p> <p>c. Describe the procedures used for receiving, storing, handling, and returning radioactive materials.</p>
<p>6. Explain proper procedures for communicating with patients.</p> <p>a. Identify appropriate methods for correct patient identification.</p> <p>b. Explain procedures in terms that the patient will understand, making accommodations for cultural differences.</p> <p>c. Communicate expectations during procedure as well as procedure length and special preparations required prior to imaging.</p> <p>d. Explain department policies for dispensing reports to referring physicians.</p>
<p>7. Demonstrate competency in CPR, vital signs, venipuncture, and EKG.</p>

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- A3 Data Interpretation (graph, table, chart, diagram)
- A5 Measurement (money, time, temperature, length, area, volume)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

SUGGESTED REFERENCES

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Joint review committee on educational programs in nuclear medicine technology. (n.d.). Retrieved November 7, 2008, from <http://www.jrcnmt.org/>

Nuclear medicine technology certification board. (n.d.). Retrieved October 7, 2008, from <http://www.nmtcb.org/>

Shackett, P. (2008). *Nuclear medicine technology: Procedures and quick reference* (2nd ed.). Philadelphia, PA: Lippincott/Williams/Wilkins.

Course Name: Nuclear Medicine Procedures I

Course Abbreviation: NMT 2523

Classification: Vocational–Technical Core

Description: This course covers the diagnostic procedures currently in use. (3 sch: 3-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives

1. Describe imaging procedures related to the skeletal system.
 - a. Describe the matrix structure and composition of bone.
 - b. Describe the restructuring and repair process of bone, including the hormonal control system.
 - c. Describe the characteristics and causes of common bone pathologies; identify the population most susceptible to the disease; and give a brief overview of potential treatments.
 - d. Describe the radiopharmaceuticals used for bone imaging including their physical and chemical properties, biorouting, route and method of administration, and discuss the advantages and disadvantages of each agent.
 - e. Specify the dose range for bone imaging agents and discuss the resulting radiation dose to various organs and tissues.
 - f. Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of bone imaging agents.
 - g. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with bone imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
 - h. Describe the preparation of the patient for a bone scan.
 - i. List the indications for a routine bone scan, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - j. Describe the procedures for routine static planar and whole body bone imaging, including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
 - k. List the indications for a three-phase or four-phase bone scan, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities.
 - l. Describe the protocol for three-phase or four-phase bone imaging, including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
 - m. List the indications for a SPECT bone scan, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - n. Describe the procedures for SPECT bone imaging, including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition

parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.

- o. Describe the normal distribution and normal variants seen on bone images, and recognize them on bone studies.
- p. Identify structures on bone images and SPECT slices.
- q. Describe the appearance of various pathologies seen on bone images, and identify these on bone studies.
- r. Describe various artifacts that can occur during bone imaging, and identify these on bone studies.
- s. Discuss the diagnostic and prognostic value of bone imaging procedures.
- t. Explain some common causes of false-negative and false-positive bone studies.
- u. List the indications for bone absorptiometry.
- v. Discuss and compare the methods for evaluation bone density.
- w. Discuss the diagnostic and prognostic value of bone absorptiometry.

2. Describe imaging procedures related to the respiratory system.

- a. Describe the gross anatomy and function of the respiratory system.
- b. Discuss the anatomy and function of the respiratory system at the cellular level.
- c. Outline the flow of blood through the respiratory system.
- d. Describe the characteristics and causes of common respiratory pathologies; identify the population most susceptible to the disease; and give a brief overview of potential treatments.
- e. List the indications for lung perfusion imaging.
- f. List the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of the radiopharmaceutical used for lung perfusion imaging.
- g. Discuss the possible adverse reactions and contraindications for lung perfusion imaging.
- h. Describe the patient preparation necessary for a high-quality study.
- i. Discuss the equipment and basic procedures and processing utilized in lung perfusion imaging.
- j. Identify a normal lung perfusion scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- k. List the indications for gas ventilation imaging.
- l. Compare the physical and chemical characteristics, dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for gas ventilation imaging.
- m. Discuss the possible adverse reactions and contraindications for gas ventilation imaging.
- n. Discuss the special radiation safety considerations and regulations associated with gas ventilation imaging.
- o. Describe the patient preparation necessary for a high-quality study.
- p. Discuss the equipment and basic procedures and processing utilized in gas ventilation imaging.
- q. Identify a normal ventilation scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- r. List the indications for aerosol ventilation imaging.

- s. List the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of the radiopharmaceutical used for aerosol ventilation imaging.
 - t. Discuss the possible adverse reactions and contraindications for aerosol ventilation imaging.
 - u. Discuss the special radiation safety considerations associated with aerosol ventilation imaging.
 - v. Describe the patient preparation necessary for a high-quality study.
 - w. Discuss the equipment and basic procedures and processing utilized in aerosol ventilation imaging.
 - x. Identify a normal aerosol ventilation scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
 - y. Discuss the advantages and disadvantages associated with the ventilation/perfusion and perfusion/ventilation sequences.
 - z. Describe the interpretative criteria for the ventilation/perfusion study, including the probability table for pulmonary embolism.
 - aa. Discuss the diagnostic/prognostic value of the lung ventilation/perfusion study.
 - bb. List the indications for a quantitative lung study.
 - cc. Discuss the equipment and basic procedures and processing utilized in quantitative lung imaging.
 - dd. Identify a normal quantitative lung scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
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3. Describe imaging procedures related to the liver and spleen.
- a. List the indications for liver/spleen imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - b. Describe the radiopharmaceutical used for liver/spleen imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - c. Specify the dose range for liver/spleen imaging, and discuss the resulting radiation dose to various organs and tissues.
 - d. Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of the liver/spleen imaging agent.
 - e. Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with liver/spleen imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - f. Describe the preparation of the patient for liver/spleen imaging.
 - g. Describe the procedures for liver/spleen imaging, including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
 - h. Describe the normal distribution and normal variants seen on liver/spleen studies, recognize them on printed images, and describe the appearance of various pathologies seen on liver/spleen studies and identify these on printed images.
 - i. Describe various artifacts that can occur during liver/spleen studies, and identify these on printed images.
 - j. Discuss the diagnostic and prognostic value of liver/spleen studies and some common

causes of false-negative and false-positive liver/spleen studies.

- k. List the indications for a hemangioma detection study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- l. Describe the radiopharmaceuticals used for hemangioma detection including the physical and chemical properties, birouting, dose preparation, and route and method of administration.
- m. Specify the dose range for hemangioma detection studies, and discuss the resulting radiation dose to various organs and tissues.
- n. Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of the hemangioma detection agents.
- o. Describe the process for tagged red blood cells for hemangioma detection; any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with hemangioma detection; and any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- p. Describe the preparation of the patient for a hemangioma detection study and the procedures for a hemangioma detection study, including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.

4. Describe procedures related to hepatobiliary imaging.

- a. List the indications for hepatobiliary studies, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- b. Describe the radiopharmaceuticals used for hepatobiliary studies including the physical and chemical properties, birouting, dose preparation, and route and method of administration.
- c. Specify the dose range for hepatobiliary studies, discuss the resulting radiation dose to various organs and tissues, and discuss kit and dose preparation and any special precautions that should be taken to assure the quality of the hepatobiliary study agents.
- d. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with hepatobiliary study, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- e. Describe the preparation of the patient for hepatobiliary study.
- f. Describe the procedures for hepatobiliary study, including equipment, protocol, dose and administration technique, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
- g. Describe the interventional procedures that may be used with hepatobiliary studies, including morphine enhancement, cholecystokinin intervention, and gall bladder ejection fraction calculation.
- h. Calculate the gall bladder ejection fraction when given appropriate data.
- i. Describe the normal distribution and normal variants seen on hepatobiliary studies, recognize them on printed images and forms, and describe the appearance of various pathologies seen on hepatobiliary studies and identify these on printed images and forms.
- j. Describe various artifacts that can occur during hepatobiliary studies, and identify these on printed images and forms.

5. Describe imaging procedures related to the endocrine and exocrine systems.
 - a. Describe the gross anatomy and function of both the endocrine and exocrine system and its individual organs.
 - b. Discuss the cellular structure and physiology of each of the organs of the endocrine/exocrine system.
 - c. Discuss blood flow to, from, and through organs of the endocrine/exocrine system.
 - d. Describe the production and secretion of substances from each organ in the endocrine/exocrine system.
 - e. Describe the various feedback mechanisms associated with the endocrine/exocrine system.
 - f. Describe the characteristics and causes of common pathologies of the endocrine/exocrine system as related to nuclear medicine procedures; identify the population most susceptible to the disease; and give a brief overview of potential treatments.
 - g. List the indications for thyroid uptake study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - h. Describe the radiopharmaceuticals used for thyroid uptakes including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - i. Specify the dose range for thyroid uptake studies, and discuss the resulting radiation dose to various organs and tissues.
 - j. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with a thyroid uptake study, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - k. Describe the preparation of the patient for a thyroid uptake study.
 - l. Describe the procedures for a thyroid uptake study, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning, special imaging adaptations, data processing, and potential pitfalls.
 - m. Describe the normal range and normal variants with regard to acquired data and possible sources of error.
 - n. Discuss some common causes of false-negative and false-positive thyroid uptake results.
 - o. List the indications for thyroid imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - p. Describe the radiopharmaceuticals used for thyroid imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - q. Describe the radiopharmaceuticals used for thyroid imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - r. Specify the dose range for thyroid imaging, and discuss the resulting radiation dose to various organs and tissues.
 - s. Discuss any physical or pathological conditions, prior procedures, or medications that

- could contraindicate or interfere with thyroid imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- t. Describe the preparation of the patient for thyroid imaging.
 - u. Describe the procedures for thyroid imaging, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - v. Describe the normal distribution and normal variants seen on thyroid imaging studies and recognize them on printed images; discuss some common causes of false-negative and false-positive thyroid imaging studies.
 - w. Describe various artifacts that can occur during thyroid imaging, and identify these printed images.
 - x. Discuss the diagnostic and prognostic value of thyroid imaging.
 - y. List the indications for parathyroid imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - z. Describe the radiopharmaceuticals used for parathyroid imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - aa. Specify the dose range for parathyroid imaging, and discuss the resulting radiation does to various organs and tissues.
 - bb. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with parathyroid imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - cc. Describe the preparation of the patient for parathyroid imaging.
 - dd. Describe the procedures for parathyroid imaging, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - ee. Describe the normal distribution and normal variants seen on parathyroid imaging studies and recognize them on printed images.
 - ff. Describe various artifacts that can occur during parathyroid imaging identify these on printed images.
 - gg. Discuss the diagnostic and prognostic value of parathyroid imaging.
 - hh. Discuss some common causes of false-negative and false-positive parathyroid imaging studies.
 - ii. List the indications for adrenal imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - jj. Describe the radiopharmaceuticals used for adrenal imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - kk. Specify the dose range for adrenal imaging, and discuss the resulting radiation does to various organs and tissues.
 - ll. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with adrenal imaging, and describe any precautions

- that should be taken and any potential adverse reactions to the radiopharmaceutical.
- mm. Describe the preparation of the patient for adrenal imaging.
 - nn. Describe the procedures for adrenal imaging, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - oo. Describe the normal distribution and normal variants seen on adrenal imaging studies and recognize them on printed images.
 - pp. Describe various artifacts that can occur during adrenal imaging, and identify these on printed images.
 - qq. Discuss the diagnostic and prognostic value of adrenal imaging and some common causes of false-negative and false-positive adrenal imaging studies.
 - rr. List the indications for lacrimal duct imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - ss. Describe the radiopharmaceuticals used for lacrimal duct imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - tt. Specify the dose range for lacrimal duct imaging, and discuss the resulting radiation does to various organs and tissues.
 - uu. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with lacrimal duct imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - vv. Describe the preparation of the patient for lacrimal duct imaging.
 - ww. Describe the procedures for lacrimal duct imaging, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - xx. Describe the normal distribution and normal variants seen on lacrimal duct imaging studies, recognize them on printed images, and describe various artifacts that can occur during lacrimal duct imaging and identify these on printed images.
 - yy. Describe various artifacts that can occur during lacrimal duct imaging, and identify these on printed images.
 - zz. Discuss the diagnostic and prognostic value of lacrimal duct imaging and some common causes of false-negative and false-positive lacrimal duct imaging studies.

- 6. Describe imaging procedures related to the genitourinary system.
 - a. Describe the gross anatomy and function of the major components of the genitourinary system.
 - b. Discuss the cellular structure and physiology of the organs of the genitourinary system.
 - c. Discuss the relationship between renal activity and aldosterone, renin-angiotensin, and ADH.
 - d. Describe the effects of diuretics on renal function.
 - e. Discuss factors that contribute to success or failure of transplanted kidneys.
 - f. Describe the characteristics and causes of common pathologies of the genitourinary

- system as related to nuclear medicine procedures; identify population most susceptible to the disease; and give a brief overview of potential treatments.
- g. List the indications for renal perfusion imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - h. Describe the radiopharmaceuticals used for renal perfusion imaging including the physical and chemical properties, biotrouting, dose preparation, and route and method of administration.
 - i. Specify the dose range for renal perfusion imaging, and discuss the resulting radiation dose to various organs and tissues.
 - j. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with renal perfusion imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - k. Describe the preparation of the patient for renal perfusion imaging.
 - l. Describe the procedures for renal perfusion imaging, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - m. Describe the normal distribution and normal variants seen on renal perfusion imaging studies, recognize them on printed images, and describe various artifacts that can occur during renal perfusion imaging and identify these on printed images.
 - n. Discuss the diagnostic and prognostic value of renal perfusion imaging and some common causes of false-negative and false-positive renal perfusion imaging studies.
 - o. List the indications for performing a renogram, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - p. Describe the radiopharmaceuticals used for renograms including the physical and chemical properties, biotrouting, dose preparation, and route and method of administration.
 - q. Specify the dose range for renograms, and discuss the resulting radiation dose to various organs and tissues.
 - r. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with performing a renogram, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - s. Describe the preparation of the patient to have a renogram.
 - t. Describe the procedures for performing a GFR and ERPF, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - u. Describe the interventional procedures that may be used for performing renograms.
 - v. Describe the normal distribution and normal variants seen on a renogram, recognize them on printed images, and describe various artifacts that can occur when performing a renogram and identify these on printed images.
 - w. Discuss the diagnostic and prognostic value of performing a renogram and some

- common causes of false-negative and false-positive renograms.
- x. List the indications for performing a GFR and ERPF, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - y. Describe the radiopharmaceuticals used for a GFR and ERPF including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - z. Specify the dose range for a GFR and ERPF, and discuss the resulting radiation dose to various organs and tissues.
 - aa. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with performing a GFR and ERPF, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - bb. Describe the preparation of the patient to have a GFR and ERPF.
 - cc. Describe the procedures for performing renograms, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - dd. Describe the normal distribution and normal variants seen on a GFR and ERPF and recognize them on printed images; describe various artifacts that can occur when performing a GFR and ERPF; and identify these on printed images.
 - ee. Discuss the diagnostic and prognostic value of performing a GFR and ERPF. Discuss some common causes of false-negative and false-positive GFR and ERPF.
 - ff. List the indications for performing a renal scan for morphology, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - gg. Describe the radiopharmaceuticals used for a renal scan for morphology including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - hh. Specify the dose range for a renal scan for morphology, and discuss the resulting radiation dose to various organs and tissues.
 - ii. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with performing a renal scan for morphology, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - jj. Describe the preparation of the patient to have a renal scan for morphology.
 - kk. Describe the procedures for performing renal scan for morphology, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - ll. Describe the normal distribution and normal variants seen on a renal scan for morphology, and recognize them on printed images.
 - mm. Describe various artifacts that can occur when performing a renal scan for morphology, and identify these on printed images.
 - nn. Discuss the diagnostic and prognostic value of performing a renal scan for

- morphology; discuss some common causes of false-negative and false-positive renal scan for morphology.
- oo. List the indications for performing a voiding cystogram, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - pp. Describe the radiopharmaceuticals used for a voiding cystogram including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - qq. Specify the dose range for a voiding cystogram, and discuss the resulting radiation doses to various organs and tissues.
 - rr. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with performing a voiding cystogram, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - ss. Describe the preparation of the patient to have a voiding cystogram.
 - tt. Describe the procedures for performing a voiding cystogram, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - uu. Describe the normal distribution and normal variants seen on a voiding cystogram, and recognize them on printed images; describe various artifacts that can occur when performing a voiding cystogram, and identify these on printed images.
 - vv. Discuss the diagnostic and prognostic value of performing a voiding cystogram.
 - ww. Discuss some common causes of false-negative and false-positive results of voiding cystograms.
 - xx. List the indications for performing testicular imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - yy. Describe the radiopharmaceuticals used for a testicular imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - zz. Specify the dose range for testicular imaging, and discuss the resulting radiation doses to various organs and tissues.
 - aaa. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with performing testicular imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - bbb. Describe the preparation of the patient to have testicular imaging and the procedures for performing testicular imaging, including equipment, protocol, dose, and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, data processing, image formatting, and potential pitfalls.
 - ccc. Describe the normal distribution and normal variants seen on a testicular imaging, and recognize them on printed images; describe various artifacts that can occur when performing testicular imaging, and identify these on printed images.
 - ddd. Discuss the diagnostic and prognostic value of performing testicular imaging and

some common causes of false-negative and false-positive results of testicular imaging.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- A1 Numeration (ordering, place value, scientific notation)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)

- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

SUGGESTED REFERENCES

The American registry of radiologic technologists. (n.d.). Retrieved November 7, 2008, from <http://www.artt.org/>

Joint review committee on educational programs in nuclear medicine technology. (n.d.). Retrieved November 7, 2008, from <http://www.jrcnmt.org/>

Nuclear medicine technology certification board. (n.d.). Retrieved October 7, 2008, from <http://www.nmtcb.org/>

Ziessman, H. A., O'Malley, J. P., & Thrall, J. H. (2006). *Nuclear medicine: The requisites* (3rd ed.). St. Louis, MO: Elsevier Mosby.

Course Name: Nuclear Medicine Procedures II

Course Abbreviation: NMT 2533

Classification: Vocational–Technical Core

Description: This course is a continuation of NM Procedures I. More advanced imaging procedures will be covered in this section. It is not exhaustive. Didactic learning is essential even if the student will not obtain clinical experience with each of these procedures. (3 sch: 3-hr lecture)

Prerequisite: Nuclear Medicine Procedures I (NMT 2523)

Competencies and Suggested Objectives

1. Describe procedures related to oncology and inflammation imaging.
 - a. Describe the components of the immune system and their physiology.
 - b. Describe the distribution of lymph nodes.
 - c. Describe the inflammatory processes, and differentiate between acute and chronic.
 - d. Describe the characteristics of a malignancy and the natural processes by which malignancies are produced.
 - e. Describe the characteristics and causes of common pathologies of the inflammatory and malignant diseases as related to nuclear medicine procedures; identify population most susceptible to the disease; and give a brief overview of potential treatments.
 - f. List the indications for radiolabeled white blood cell studies, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - g. Describe the radiopharmaceuticals used for radiolabeled white blood cell studies including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - h. Specify the dose range for radiolabeled white blood cell studies, and discuss the resulting radiation dose to various organs and tissues.
 - i. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with radiolabeled white blood cell studies, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - j. Describe the preparation of the patient for radiolabeled white blood cell studies.
 - k. Describe the procedures for radiolabeled white blood cell studies including equipment for both the study and the tagging process, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
 - l. Describe the normal distribution and normal variants seen on radiolabeled white blood cell studies, and recognize them on printed images.
 - m. Describe various artifacts that can occur during radiolabeled white blood cell studies, and identify these on printed images.
 - n. Discuss the diagnostic and prognostic value of radiolabeled white blood cell studies.

- o. Discuss some common causes of false-negative and false-positive radiolabeled white blood cell studies.
- p. List the indications for gallium imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- q. Describe the radiopharmaceuticals used for gallium imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- r. Specify the dose range for gallium imaging, and discuss the resulting radiation dose to various organs and tissues.
- s. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with gallium imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- t. Describe the preparation of the patient for gallium imaging.
- u. Describe the procedures for gallium imaging including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
- v. Describe the normal distribution and normal variants seen in gallium imaging, and recognize them on printed images.
- w. Describe various artifacts that can occur during gallium imaging, and identify these on printed images.
- x. Discuss the diagnostic and prognostic value of gallium imaging and some common causes of false-negative and false positive gallium scans.

2. Describe procedures related to cardiac imaging.

- a. Outline the flow of blood through the coronary arteries and the systemic circulation, and trace the blood flow through the heart, given a vascular or chamber defect resulting in a shunt.
- b. Describe the various components of the heart's conduction system.
- c. Identify the wave deflections on an electrocardiogram, and describe the part of the cardiac cycle that each deflection represents.
- d. Define the functional parameters of the cardiovascular system, including cardiac output, stroke volume, ejection fraction, and so forth.
- e. Discuss the relationship between abnormal cardiac output and respiratory function.
- f. List the indications, contraindications, and possible adverse reactions associated with exercise stress testing.
- g. Describe the patient preparation necessary for the exercise stress test.
- h. List the equipment utilized for exercise stress testing.
- i. Describe the various exercise stress testing protocols, and discuss the advantages and disadvantages of each.
- j. Discuss each of the pharmacologic interventions including the mechanisms of action, indications, contraindications, adverse effects, administration protocols, patient preparation, antidotes, and the operation of an infusion pump.
- k. Discuss the addition of low-level exercise to a pharmacologic intervention study including indications, contraindications, adverse effects, positive effects, administration protocols, types of low-level exercise, and patient preparation.
- l. Identify a normal electrocardiogram, and be able to locate and identify arrhythmias

- and other abnormalities on a 3-lead ECG tracing.
- m. List the indications for myocardial perfusion/viability imaging.
 - n. Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for myocardial perfusion/viability imaging.
 - o. Discuss the possible adverse reactions and contraindications for myocardial perfusion/viability imaging.
 - p. Describe the patient preparation necessary for a high-quality cardiac study.
 - q. Discuss the equipment and basic procedures and processing utilized in myocardial perfusion/viability imaging.
 - r. Identify a normal myocardial perfusion/viability scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
 - s. List the indications for a gated blood pool scan.
 - t. Describe the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry for Tc-99m labeled red blood cells.
 - u. Discuss contraindications and adverse reactions for a gated blood pool study.
 - v. Describe the patient preparation necessary for a high-quality gated blood pool study.
 - w. Discuss the equipment and basic procedures and processing utilized in gated blood pool imaging.
 - x. Discuss the interventions and additional procedures that may be added to the basic gated blood pool study.
 - y. Identify a normal gated blood pool scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
 - z. List the indications for a first pass angiography procedure.
 - aa. Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for first pass angiography imaging.
 - bb. Discuss contraindications and adverse reactions for first pass angiography.
 - cc. Describe the patient preparation necessary for a high-quality first pass angiography study.
 - dd. Discuss the equipment and basic procedures and processing utilized in first pass angiography.
 - ee. Identify a normal first-pass angiography procedure, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
 - ff. List the indications for infarct imaging.
 - gg. Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for infarct imaging.
 - hh. Discuss contraindications and adverse reactions for infarct imaging.
 - ii. Describe the patient preparation necessary for high-quality infarct imaging.
 - jj. Discuss the equipment and basic procedures and processing utilized in infarct imaging.
 - kk. Identify a normal infarct scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.

ll.	List the indications for a major vessel flow study.
mm.	Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for a major vessel flow study.
nn.	Discuss contraindications and adverse reactions for a major vessel flow study.
oo.	Describe the patient preparation necessary for a high-quality major vessel flow study.
pp.	Discuss the equipment and basic procedures and processing utilized during a major vessel flow study.
qq.	Identify a normal major vessel flow study, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
rr.	List the indications for deep vein thrombosis imaging.
ss.	Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for deep vein thrombosis detection.
tt.	Discuss contraindications and adverse reactions for deep vein thrombosis detection.
uu.	Describe the patient preparation necessary for high-quality deep vein thrombosis detection.
vv.	Discuss the equipment and basic procedures and processing utilized in deep vein thrombosis imaging; identify a normal deep vein thrombosis scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
3.	Describe procedures related to brain imaging.
a.	Describe the gross anatomy and function of the central nervous system.
b.	Discuss the anatomy and function of the central nervous system at the cellular level.
c.	Outline the flow of blood through the central nervous system.
d.	Describe the production of cerebral spinal fluid, and trace the flow of CSF.
e.	Describe the characteristics and causes of common central nervous system pathologies; identify the population most susceptible to the disease; and give a brief overview of potential treatments.
f.	List the indications for cerebral vascular flow imaging.
g.	List and compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for cerebral vascular flow imaging.
h.	Discuss the possible adverse reactions and contraindications for cerebral vascular flow imaging, and describe the patient preparation necessary for a high-quality study.
i.	Discuss the equipment and basic procedures and processing utilized in cerebral vascular flow imaging; identify a normal cerebral vascular flow scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
j.	List the indications for planar brain imaging.
k.	Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for planar brain imaging.

- l. Discuss the possible adverse reactions and contraindications for planar brain imaging, and describe the patient preparation necessary for a high-quality study.
- m. Discuss the equipment and basic procedures and processing utilized in planar brain imaging; identify a normal planar brain scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- n. Identify a normal planar brain scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- o. List the indications for functional brain SPECT.
- p. List and compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for functional brain SPECT imaging.
- q. Discuss the possible adverse reactions and contraindications for functional brain SPECT, and describe the patient preparation necessary for a high-quality study.
- r. Discuss the equipment and basic procedures and processing utilized in functional brain SPECT imaging.
- s. Discuss the interventions and additional procedures that may be added to the basic functional brain SPECT study. Identify a normal functional brain SPECT scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- t. List the indications for positron brain imaging.
- u. Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for positron brain imaging; discuss the possible adverse reactions and contraindications for positron brain imaging.
- v. Discuss the possible adverse reactions and contraindications for positron brain imaging.
- w. Describe the patient preparation necessary for a high quality study.
- x. Discuss the equipment and basic procedures and processing utilized in positron brain imaging and the interventions and additional procedures that may be added to the basic positron brain imaging study.
- y. Identify a normal positron brain scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- z. List the indications for brain tumor imaging.
- aa. Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for brain tumor imaging.
- bb. Discuss the possible adverse reactions and contraindications for brain tumor imaging, and describe the patient preparation necessary for a high-quality study.
- cc. Discuss the equipment and basic procedures and processing utilized in brain tumor imaging.
- dd. Identify a normal brain tumor scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.
- ee. List the indications for cisternography, and compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for cisternography.
- ff. Discuss the possible adverse reactions and contraindications for cisternography and

<ul style="list-style-type: none"> gg. hh. ii. jj. kk. ll. mm. nn. oo. pp. qq. rr. 	<p>the patient preparation necessary for a high-quality study.</p> <p>Discuss the equipment and basic procedures and processing utilized in cisternography; identify a normal cisternogram, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.</p> <p>List the indications for a CSF leak study.</p> <p>Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for a CSF leak study.</p> <p>Discuss the possible adverse reactions and contraindications for a CSF leak study.</p> <p>Describe the patient preparation necessary for a high-quality study.</p> <p>Discuss the equipment and basic procedures and processing utilized for a CSF leak study.</p> <p>Identify a normal CSF leak study, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.</p> <p>List the indications for a CSF shunt patency study.</p> <p>Compare the physical and chemical characteristics, kit and dose preparation, dose and route of administration, biorouting, and dosimetry of each radiopharmaceutical used for CSF shunt patency imaging.</p> <p>Discuss the possible adverse reactions and contraindications for CSF shunt patency imaging.</p> <p>Describe the patient preparation necessary for a high-quality study and the equipment and basic procedures and processing utilized for a patency study.</p> <p>Identify a normal CSF shunt patency scan, and discuss normal variants, abnormal findings, artifacts, and the diagnostic and prognostic value of the study.</p>
<p>4.</p> <ul style="list-style-type: none"> a. b. c. d. e. f. g. 	<p>Describe procedures related to the digestive system.</p> <p>Describe the characteristics and causes of common pathologies of the digestive system as related to nuclear medicine procedures; identify the population most susceptible to the disease; and give a brief overview of potential treatments.</p> <p>Specify the dose range for salivary gland imaging, and discuss the resulting radiation dose to various organs and tissues.</p> <p>Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with salivary gland imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.</p> <p>Describe the preparation of the patient for salivary gland imaging and the procedures for salivary gland imaging, including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.</p> <p>Describe the interventional procedures that may be used for salivary gland imaging, including salivary discharge; describe the normal distribution and normal variants seen on salivary gland studies, and recognize them on printed images.</p> <p>Describe the appearance of various pathologies seen on salivary gland studies, and identify these on printed images.</p> <p>Discuss the diagnostic and prognostic value of salivary gland studies and some common causes of false-negative and false-positive salivary gland studies.</p>

- h. List the indications for esophageal studies, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- i. Describe the radiopharmaceutical used for esophageal studies including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- j. Specify the dose range for esophageal studies, and discuss the resulting radiation dose to various organs and tissues.
- k. Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of esophageal study agents; discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with esophageal studies, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- l. Describe the special radiation safety precautions that must be considered when performing esophageal studies.
- m. Describe the preparation of the patient for esophageal studies.
- n. Describe the procedures for esophageal studies, including equipment, protocol, dose and administration technique, acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
- o. Describe any interventional procedures that may be used for esophageal studies.
- p. Calculate esophageal transit time and percent esophageal reflux when given appropriate data.
- q. Describe the normal results and normal variants seen on esophageal studies, and recognize them in printed form.
- r. Describe the effects of various pathologies on esophageal studies, and recognize them in printed form and various artifacts that can occur during esophageal studies and recognize them in printed form.
- s. Discuss the diagnostic and prognostic value of esophageal studies and some common causes of false-negative and false-positive esophageal studies.
- t. List the indications for a gastric emptying study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- u. Describe the radiopharmaceuticals used for gastric emptying studies including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- v. Specify the dose range for gastric emptying studies and discuss the resulting radiation dose to various organs and tissues; discuss kit and dose preparation and any special precautions that should be taken to assure the quality of gastric emptying study agents.
- w. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with gastric emptying studies, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- x. Describe the special radiation safety precautions that must be considered when performing gastric emptying studies.

- y. Describe the preparation of the patient for gastric emptying studies and the procedure for a gastric emptying study, including equipment, protocol, dose and administration technique (appropriate meal), acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
- z. Describe any interventional procedures that may be used for gastric emptying studies.
- aa. Calculate gastric emptying times and percent gastric emptying when given appropriate data.
- bb. Describe the normal results and normal variants seen on gastric emptying studies, and recognize them in printed form; describe the appearance of various pathologies seen on gastric emptying studies, and identify these in printed form.
- cc. Describe various artifacts that can occur during gastric emptying studies, and identify these in printed form.
- dd. Discuss the diagnostic and prognostic value of gastric emptying studies.
- ee. Discuss some common causes of false-negative and false-positive gastric emptying studies.
- ff. List the indications for a helicobacter pylori (*H. pylori*) detection study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- gg. Describe the radiopharmaceutical used for *H. pylori* detection including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- hh. Specify the dose range for *H. pylori* detection, and discuss the resulting radiation dose to various organs and tissues.
- ii. Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of *H. pylori* detection agent.
- jj. Describe the special radiation safety precautions and regulations that must be considered when performing *H. pylori* detection studies and the preparation of the patient for a *H. pylori* detection study.
- kk. Describe the procedure for *H. pylori* detection, including equipment, protocol, dose and administration technique, acquisition parameters, data processing, and potential pitfalls and the normal results and normal variants seen in *H. pylori* detection studies, and recognize them in printed form.
- ll. Describe the appearance of various pathologies seen in *H. pylori* detection studies, and identify these in printed form; describe various artifacts that can occur during *H. pylori* detection, and identify these in printed form.
- mm. Discuss the diagnostic and prognostic value of *H. pylori* detection studies and some common causes of false-negative and false-positive *H. pylori* detection studies.
- nn. Describe the normal distribution and normal variants seen on a hemangioma detection study, and recognize them on printed images; identify structures on hemangioma detection SPECT slices.
- oo. Describe the appearance of various pathologies seen on hemangioma detection studies, and identify these on printed images and various artifacts that can occur during hemangioma detection studies, and identify these on printed images.
- pp. Discuss the diagnostic and prognostic value of hemangioma detection studies and

- some common causes of false-negative and false-positive hemangioma detection studies.
- qq. List the indications for a GI bleeding scan, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - rr. Describe the radiopharmaceuticals used for GI bleeding scan including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - ss. Specify the dose range for a GI bleeding scan, and discuss the resulting radiation dose to various organs and tissues.
 - tt. Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of the GI bleeding scan agents, and describe the process for tagged red blood cells for a GI bleeding scan.
 - uu. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with a GI bleeding scan, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
 - vv. Describe the preparation of the patient for a GI bleeding scan and the procedures for a GI bleeding scan, including equipment, protocol, dose and administration technique, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
 - ww. Describe the normal distribution and normal variants seen on a GI bleeding scan, and recognize them on printed images; describe the appearance of various pathologies seen on GI bleeding scan, and identify these on printed images.
 - xx. Describe various artifacts that can occur during a GI bleeding scan, and identify these on printed images.
 - yy. Discuss the diagnostic and prognostic value of GI bleeding scans and some common causes of false-negative and false-positive GI bleeding scan.
 - zz. List the indications for Meckel's diverticulum imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - aaa. Describe the radiopharmaceutical used for Meckel's diverticulum imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - bbb. Specify the dose range for Meckel's diverticulum imaging, and discuss the resulting radiation dose to various organs and tissues.
 - ccc. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with Meckel's diverticulum imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
 - ddd. Describe the preparation of the patient for Meckel's diverticulum imaging and the procedures for Meckel's diverticulum imaging, including equipment, protocol, dose and administration technique, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
 - eee. Describe the interventional procedures that may be used for Meckel's diverticulum imaging including administration of glucagon, cimetidine, and pentagastrin.

- fff. Describe the normal distribution and normal variants seen on Meckel's diverticulum studies, and recognize them on printed images; describe the appearance of various pathologies seen on Meckel's diverticulum studies, and identify these on printed images.
- ggg. Describe various artifacts that can occur during Meckel's diverticulum studies, and identify these on printed images.
- hhh. Discuss the diagnostic and prognostic value of Meckel's diverticulum studies. Discuss some common causes of false-negative and false-positive Meckel's diverticulum studies.
- iii. List the indications for a LeVeen shunt study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- jjj. Describe the radiopharmaceuticals used for LeVeen shunt studies including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- kkk. Specify the dose range for a LeVeen shunt study, and discuss the resulting radiation dose to various organs and tissues.
- lll. Discuss any procedures that could contraindicate or interfere with a LeVeen shunt study, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- mmm. Describe the preparation of the patient for a LeVeen shunt study and the procedures for a LeVeen shunt study, including equipment, protocol, dose and administration technique, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
- nnn. Describe the normal distribution and normal variants seen on a LeVeen shunt study, and recognize them on printed images; describe the appearance of various pathologies seen on a LeVeen shunt study, and identify these on printed images; and describe various artifacts that can occur during LeVeen shunt studies and identify these on printed images.
- ooo. Discuss the diagnostic and prognostic value of LeVeen shunt studies. Discuss some common causes of false-negative and false-positive LeVeen shunt studies.
- ppp. List the indications for an intrahepatic pump study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- qqq. Describe the radiopharmaceuticals used for intrahepatic pump studies including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- rrr. Specify the dose range for an intrahepatic pump study, and discuss the resulting radiation dose to various organs and tissues.
- sss. Discuss any procedures that could contraindicate or interfere with an intrahepatic pump study, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- ttt. Describe the preparation of the patient for an intrahepatic pump study and the procedures for an intrahepatic pump study, including equipment, protocol, dose and administration technique, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.

uuu.	Describe the normal distribution and normal variants seen on an intrahepatic pump study, and recognize them on printed images; describe the appearance of various pathologies seen on an intrahepatic pump study, and identify these on printed images.
vvv.	Describe various artifacts that can occur during intrahepatic pump studies, and identify these on printed images.
www.	Discuss the diagnostic and prognostic value of intrahepatic pump studies and some common causes of false-negative and false-positive intrahepatic pump studies.
5.	Describe procedures related to the hematopoietic and lymphatic systems.
a.	Describe the gross anatomy and function of the hematopoietic and lymphatic systems.
b.	Discuss the cellular structure and physiology of the organs and tissues of the hematopoietic and lymphatic systems.
c.	Describe the life cycle of red blood cells and white blood cells.
d.	Explain the role of intrinsic factor in vitamin B12 absorption; describe the biroute of B12 after absorption.
e.	Trace the movement of lymph through the body.
f.	Describe the characteristics and causes of common pathologies of the hematopoietic and lymphatic systems as related to nuclear medicine procedures; identify the population most susceptible to the disease; and give a brief overview of potential treatments.
g.	List the indications for bone marrow imaging, and discuss why a nuclear medicine study would complement or be preferable to other diagnostic modalities in various cases.
h.	Describe the radiopharmaceutical used for bone marrow imaging including the physical and chemical properties, birouting, and route and method of administration.
i.	Specify the dose range for bone marrow imaging, and discuss the resulting radiation dose to various organs and tissues.
j.	Discuss kit and dose preparation and any special precautions that should be taken to assure the quality of the bone marrow imaging agent.
k.	Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with bone marrow imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
l.	Describe the preparation of the patient for bone marrow imaging.
m.	Describe the procedures for bone marrow imaging, including equipment, protocol, dose, administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
n.	Describe the normal distribution and normal variants seen on bone marrow studies, and recognize them on printed images; describe the appearance of various pathologies seen on bone marrow studies, and identify these on printed images.
o.	Describe various artifacts that can occur during bone marrow studies, and identify these on printed images.
p.	Discuss the diagnostic and prognostic value of bone marrow studies.

- q. Discuss some common causes of false-negative and false-positive bone marrow studies.
- r. List the indications for a Schilling test, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- s. Describe the radiopharmaceuticals used for Schilling test including the physical and chemical properties, biorouting, and route and method of administration.
- t. Specify the dose range for Schilling test, and discuss the resulting radiation dose to various organs and tissues.
- u. Describe standard patient preparation for a Schilling test.
- v. Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with a Schilling test, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceuticals.
- w. Describe the procedures for Schilling test, including equipment, protocol, dose, administration technique, sample collection and processing, data processing, and potential pitfalls.
- x. Calculate Schilling test results when given appropriate data, and specify the normal range of values and normal variants seen on a Schilling test.
- y. Describe the effects of various pathologies on a Schilling test.
- z. Describe various artifacts that can occur during a Schilling test.
- aa. Discuss the sources of error that can affect the results of a Schilling test, and discuss methods to prevent such occurrences.
- bb. Discuss the diagnostic and prognostic value of a Schilling test.
- cc. Calculate and prepare solutions from bulk standards.
- dd. State the dilution principle, and demonstrate the ability to apply it to specific problems.
- ee. List the indications for a plasma volume study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- ff. Describe the radiopharmaceutical used for plasma volume study including the physical and chemical properties, biorouting, and route and method of administration.
- gg. Specify the dose range for plasma volume study, and discuss the resulting radiation dose to various organs and tissues.
- hh. Describe the preparation of the standard used to calculate a plasma volume.
- ii. Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with a plasma volume study, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- jj. Describe the preparation of the patient for a plasma volume study.
- kk. Describe the procedures for plasma volume study, including equipment, protocol, dose, administration technique, sample collection and processing, data processing, and potential pitfalls.
- ll. Describe the procedure for correcting for vascular leakage when performing a plasma volume determination.
- mm. Calculate the plasma volume when given appropriate data, and determine the normal range of plasma volume values for a patient given appropriate data.

- nn. Discuss normal variants seen on a plasma volume study, and recognize them in printed form.
- oo. Describe the effects of various pathologies on a plasma volume study.
- pp. Describe various artifacts that can occur during a plasma volume study, and recognize them in printed form.
- qq. Discuss the sources or error that can affect the results of a plasma volume study, and discuss methods to prevent such occurrences.
- rr. Discuss the diagnostic and prognostic value of a plasma volume study.
- ss. List the indications for a red cell mass study, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- tt. Describe the radiopharmaceutical used for red cell mass study including the physical and chemical properties, biorouting, and route and method of administration.
- uu. Specify the dose range for red cell mass study, and discuss the resulting radiation dose to various organs and tissues.
- vv. Describe standard preparation and the method for tagging red blood cells for red cell mass determination, including the function of component used in the process.
- ww. Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with a red cell mass study, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- xx. Describe the preparation of the patient for a red cell mass study.
- yy. Describe the procedures for red cell mass study, including equipment, protocol, dose, administration technique, sample collection and processing, data processing, and potential pitfalls.
- zz. State the rationale for using the hematocrit correction factor when calculating the red cell mass.
- aaa. Calculate the red cell mass when given appropriate data, and determine the normal range of red cell mass values for a patient given appropriate data.
- bbb. Discuss normal variants seen on a red cell mass study, and recognize them in printed form.
- ccc. Describe the effects of various pathologies on a red cell mass study, and recognize them in printed form.
- ddd. Describe various artifacts that can occur during a red cell mass study, and recognize them in printed form.
- eee. Discuss the sources or error that can affect the results of a red cell mass study, and discuss methods to prevent such occurrences.
- fff. Discuss the diagnostic and prognostic value of a red cell mass study.
- ggg. Describe and perform calculation of total blood volume from plasma volume and red cell mass volume data.
- hhh. Determine the normal range of total blood volume values for a patient given appropriate data.
- iii. Describe the effects of various pathologies on a total blood volume study; discuss some of the sources or error that can affect the results of a total blood volume study, and discuss methods to prevent such occurrences.
- jjj. Describe various artifacts that can occur during a total blood volume study.

- kkk. Discuss the diagnostic and prognostic value of a total blood volume study.
- lll. List the indications for red cell survival and sequestration studies, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- mmm. Describe the radiopharmaceutical used for red cell survival and sequestration studies including the physical and chemical properties, biorouting, and route and method of administration.
- nnn. Calculate the degree of red cell sequestration.
- ooo. Specify the dose range for red cell survival and sequestration studies, and discuss the resulting radiation dose to various organs and tissues.
- ppp. Describe standard preparation and the method for tagging red blood cells for red cell sequestration determination, including the function of the components used in the process.
- qqq. Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with red cell survival and sequestration studies, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- rrr. Describe the preparation of the patient for red cell survival and sequestration studies.
- sss. Describe the procedures for red cell survival and sequestration studies, including equipment, protocol, dose, administration technique, sample collection and processing, data processing, and potential pitfalls.
- ttt. Describe the normal range of values and normal variants seen on red cell survival and sequestration studies, and recognize them in printed form.
- uuu. Describe the effects of various pathologies on red cell survival and sequestration studies and recognize them in printed form.
- vvv. Describe various artifacts that can occur during red cell survival and sequestration studies, and recognize them in printed form.
- www. Discuss some of the sources or error that can affect the results of red cell survival and sequestration studies, and discuss methods to prevent such occurrences.
- xxx. Discuss the diagnostic and prognostic value of red cell survival and sequestration studies.
- yyy. List the indications for selective spleen imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
- zzz. Describe the radiopharmaceutical used for selective spleen imaging including the physical and chemical properties, biorouting, and route and method of administration.
- aaaa. Specify the dose range for spleen imaging, and discuss the resulting radiation dose to various organs and tissues.
- bbbb. Describe standard preparation and the method for tagging and denaturing red blood cells for selective spleen imaging.
- cccc. Discuss any physical or pathological conditions or prior procedures that could contraindicate or interfere with selective spleen imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.

dddd.	Describe the preparation of the patient for selective spleen imaging.
eeee.	Describe the procedures for selective spleen imaging, including equipment, protocol, dose, administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, image formatting, and potential pitfalls.
ffff.	Describe the normal distribution and normal variants seen on selective spleen studies, and recognize them on printed images.
gggg.	Describe the appearance of various pathologies seen on selective spleen studies, and identify these on printed images.
hhhh.	Describe various artifacts that can occur during selective spleen studies, and identify these on printed images.
iiii.	Discuss the diagnostic and prognostic value of selective spleen studies. Discuss some common causes of false-negative and false-positive selective spleen studies.
6.	Describe procedures related to radioassay. <ol style="list-style-type: none">Describe the characteristics of a good assay for detecting minute quantities of substances in the blood.Describe how antigens and antibodies are produced.Describe the basic process for competitive radioassay, and explain the data reduction process.State and explain the law of mass action and how it applies to competitive radioassay. Define equilibrium, and state how it applies to competitive radioassay.Describe the basic process for direct method radioassay, and explain the data reduction process.Describe quality control methods used to evaluate assays, curves, and various data, including control solutions, curve analysis, standard deviation, coefficient of variation, and Levy-Jennings plots.
7.	Describe procedures related to receptor imaging. <ol style="list-style-type: none">List the indications for receptor imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.Describe the radiopharmaceuticals used for receptor imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.Specify the dose range for receptor imaging, and discuss the resulting radiation dose to various organs and tissues.Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with receptor imaging, and describe any precautions should be taken and any potential adverse reactions to the radiopharmaceutical.Describe the preparation of the patient for receptor imaging.Describe the procedures for receptor imaging including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.Describe the normal distribution and normal variants seen in receptor imaging, and recognize them on printed images.Describe various artifacts that can occur during receptor imaging, and identify

- these on printed images.
- i. Discuss the diagnostic and prognostic value of receptor imaging and some common causes of false-negative and false positive receptor imaging scans.
 - j. List the indications for scintimammography, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - k. Describe the radiopharmaceutical used for scintimammography including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - l. Specify the dose range for scintimammography, and discuss the resulting radiation dose to various organs and tissues.
 - m. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with scintimammography, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - n. Describe the preparation of the patient for scintimammography.
 - o. Describe the procedures for scintimammography including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
 - p. Describe the normal distribution and normal variants seen in scintimammography, and recognize them on printed images.
 - q. Describe various artifacts that can occur during scintimammography, and identify these on printed images.
 - r. Discuss the diagnostic and prognostic value of scintimammography and some common causes of false-negative and false positive scintimammography.
 - s. List the indications for sentinel node imaging, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - t. Describe the radiopharmaceuticals used for sentinel node imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - u. Specify the dose range for sentinel node imaging, and discuss the resulting radiation dose to various organs and tissues.
 - v. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with sentinel node imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - w. Describe the preparation of the patient for sentinel node imaging.
 - x. Describe the procedures for sentinel node imaging including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
 - y. Describe the normal distribution and normal variants seen in sentinel node imaging, and recognize them on printed images.
 - z. Describe various artifacts that can occur during sentinel node imaging, and identify

- these on printed images.
- aa. Discuss the diagnostic and prognostic value of sentinel node imaging and some common causes of false-negative and false-positive sentinel node imaging.
 - bb. List the indications for lymphoscintigraphy, and discuss why a nuclear medicine study would be preferable to or complement other diagnostic modalities in various cases.
 - cc. Describe the radiopharmaceuticals used for lymphoscintigraphy including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - dd. Specify the dose range for lymphoscintigraphy, and discuss the resulting radiation dose to various organs and tissues.
 - ee. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with lymphoscintigraphy, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - ff. Describe the preparation of the patient for lymphoscintigraphy.
 - gg. Describe the procedures for lymphoscintigraphy including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
 - hh. Describe the normal distribution and normal variants seen in lymphoscintigraphy and recognize them on printed images.
 - ii. Describe various artifacts that can occur during lymphoscintigraphy, and identify these on printed images.
 - jj. Discuss the diagnostic and prognostic value of lymphoscintigraphy.
 - kk. Discuss some common causes of false-negative and false-positive lymphoscintigrams.
 - ll. List the indications for positron imaging, and discuss why this type of nuclear medicine study would be preferable to or complement other nuclear medicine procedures or diagnostic modalities in various cases.
 - mm. Describe the radiopharmaceutical(s) used for positron imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - nn. Specify the dose range for positron imaging, and discuss the resulting radiation dose to various organs and tissues.
 - oo. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with positron imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - pp. Describe the preparation of the patient for positron imaging.
 - qq. Describe the procedures for positron imaging including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
 - rr. Describe the normal distribution and normal variants seen in positron imaging, and recognize them on printed images.

- ss. Describe various artifacts that can occur during positron imaging, and identify these on printed images.
- tt. Discuss the diagnostic and prognostic value of positron imaging.
- uu. Discuss some common causes of false-negative and false-positive positron imaging.
- vv. List the indications for I-131 whole body imaging, and discuss why this type of nuclear medicine study would be preferable to or complement other nuclear medicine procedures or diagnostic modalities in various cases.
- ww. Describe the radiopharmaceutical used for I-131 whole body imaging including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- xx. Specify the dose range for I-131 whole body imaging, and discuss the resulting radiation dose to various organs and tissues.
- yy. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with I-131 whole body imaging, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- zz. Describe special radiation safety considerations and associated with this procedure.
- aaa. Describe the preparation of the patient for I-131 whole body imaging. Describe the procedures for I-131 whole body imaging including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
- bbb. Describe the normal distribution and normal variants seen in I-131 whole body imaging, and recognize them on printed images.
- ccc. Describe various artifacts that can occur during I-131 whole body imaging, and identify these on printed images.
- ddd. Discuss the diagnostic and prognostic value of I-131 whole body imaging. Discuss some common causes of false-negative and false positive I-131 whole body imaging.

8. Observe clinical nuclear medicine procedures involving radionuclide therapy.
- a. Describe the physical properties of radionuclides as they relate to therapeutic applications.
 - b. Discuss the basic concepts of radiobiology.
 - c. Discuss malignant processes.
 - d. Discuss metastatic processes.
 - e. Describe the characteristics and causes of common pathologies of the inflammatory and malignant diseases as related to therapeutic nuclear medicine procedures; identify population most susceptible to the disease; and give a brief over view of potential treatments.
 - f. List the indications for intracavity palliation, and discuss why a nuclear medicine procedure would be preferable to or complement other therapeutic applications in various cases.
 - g. Describe the radiopharmaceutical used for intracavity palliation including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.

- h. Specify the dose range for intracavity palliation, and discuss the resulting radiation dose to various organs and tissues.
- i. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with intracavity palliation, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- j. Describe any special radiation safety considerations and regulations associated with intracavity palliation.
- k. Describe the preparation of the patient for intracavity palliation.
- l. Describe the procedures for intracavity palliation including equipment, protocol, dose and administration technique, administration-to-acquisition times, acquisition parameters, standard positioning and views, special imaging adaptations, data processing, image formatting, and potential pitfalls.
- m. Describe the normal distribution and normal variants seen with intracavity palliation, and recognize them on printed images.
- n. Describe various artifacts that can occur during intracavity palliation, and identify these on printed images.
- o. Discuss the prognostic value (outcome) of intracavity palliation.
- p. List the indications for bone marrow palliation, and discuss why a nuclear medicine procedure would be preferable to or complement other therapeutic applications in various cases.
- q. Describe the radiopharmaceutical used for bone marrow palliation including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- r. Specify the dose range for bone marrow palliation, and discuss the resulting radiation dose to various organs and tissues.
- s. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with bone marrow palliation, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- t. Describe any special radiation safety considerations and regulations associated with bone marrow palliation.
- u. Describe the preparation of the patient for bone marrow palliation.
- v. Describe the procedures for bone marrow palliation including, protocol, dose and administration technique, and potential pitfalls.
- w. Discuss the prognostic value (outcome) of bone marrow palliation.
- x. List the indications for ablation for hyperthyroidism, and discuss why a nuclear medicine procedure would be preferable to or complement other therapeutic applications in various cases.
- y. Describe the radiopharmaceutical used for ablation for hyperthyroidism including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
- z. Specify the dose range for ablation for hyperthyroidism, and discuss the resulting radiation dose to various organs and tissues.
- aa. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with ablation for hyperthyroidism, and

- describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
- bb. Describe any special radiation safety considerations and regulations associated with ablation for hyperthyroidism.
 - cc. Describe the preparation of the patient for ablation for hyperthyroidism.
 - dd. Describe the procedures for ablation for hyperthyroidism including, protocol, dose and administration technique, and potential pitfalls.
 - ee. Discuss the diagnostic and prognostic value of ablation for hyperthyroidism.
 - ff. List the indications for ablation for thyroid carcinoma and discuss why a nuclear medicine procedure would be preferable to or complement other therapeutic applications in various cases.
 - gg. Describe the radiopharmaceutical used for ablation for thyroid carcinoma including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - hh. Specify the dose range for ablation for thyroid carcinoma, and discuss the resulting radiation does to various organs and tissues.
 - ii. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with ablation for thyroid carcinoma, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - jj. Describe any special radiation safety considerations and regulations associated with ablation for thyroid carcinoma.
 - kk. Describe the preparation of the patient for ablation for thyroid carcinoma.
 - ll. Describe the procedures for ablation for thyroid carcinoma including, protocol, dose and administration technique, and potential pitfalls.
 - mm. Discuss the diagnostic and prognostic value of ablation for thyroid carcinoma.
 - nn. List the indications for ablation for palliation of metastatic bone pain, and discuss why a nuclear medicine procedure would be preferable to or complement other therapeutic applications in various cases.
 - oo. Describe the radiopharmaceuticals used for palliation of metastatic bone pain including the physical and chemical properties, biorouting, dose preparation, and route and method of administration.
 - pp. Specify the dose range for palliation of metastatic bone pain, and discuss the resulting radiation does to various organs and tissues.
 - qq. Discuss any physical or pathological conditions, prior procedures, or medications that could contraindicate or interfere with palliation of metastatic bone pain, and describe any precautions that should be taken and any potential adverse reactions to the radiopharmaceutical.
 - rr. Describe any special radiation safety considerations and regulations associated with palliation of metastatic bone pain.
 - ss. Describe the preparation of the patient for palliation of metastatic bone pain.
 - tt. Describe the procedures for ablation for the palliation of metastatic bone pain including, protocol, dose and administration technique, and potential pitfalls.
 - uu. Discuss the prognostic value (outcome) of palliation of metastatic bone pain.
 - vv. Discuss the process and usefulness of imaging with bone palliation agents (if applicable).

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- A1 Numeration (ordering, place value, scientific notation)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)

S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

SUGGESTED REFERENCES

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Steves, A. M., & Wells, P. C. (2004). *Review of nuclear medicine technology: Preparation for certification in nuclear medicine technology* (3rd ed.). Reston, VA: The Society of Nuclear Medicine.

Course Name: Seminar Review

Course Abbreviation: NMT 2541

Classification: Vocational–Technical Core

Description: This course is designed to prepare the student for the NMTCB and ARRT certification examinations. (1 sch: 1-hr lecture)

Pre/corequisite: All NMT courses

Competencies and Suggested Objectives
<p>1. Recall radiation protection guidelines.</p> <ul style="list-style-type: none"> a. Identify patient and personnel protection standards and guidelines as they relate to the biological effects of radiation, radiation protection concepts, NRC regulations, and medical and recordable events. b. Describe procedures related to area and facility monitoring to include basic concepts, survey equipment and techniques, NRC regulations, and radioactive spills. c. Describe procedures for inspection, storage, and disposal of radioactive materials.
<p>2. Review the radionuclides and radiopharmaceuticals used in nuclear medicine studies.</p> <ul style="list-style-type: none"> a. Describe the physical properties of radioactive materials including radioactive decay, interactions with matter, and methodology used in the production of radionuclides. b. Describe the characteristics of specific radiopharmaceuticals including method of localization, half-life, and biodistribution. c. Describe the process used to prepare and administer nuclear medicine pharmaceuticals including kit preparation, dose calculation, dose administration, and radiopharmaceutical labeling.
<p>3. Summarize instrumentation and quality control procedures.</p> <ul style="list-style-type: none"> a. Describe the function of the survey meter, including operating principles, quality control, and record-keeping. b. Describe the operating principles, quality control, and record keeping associated with the dose calibrator. c. Describe types of scintillation detectors, quality control procedures, and record keeping. d. Describe operating principles, quality control, and record keeping associated with the various brands of gamma cameras. e. Describe operating principles, quality control, and record keeping associated with the various PET scanners. f. Describe types of aerosol delivery systems, including operating principles and record keeping. g. Describe the image acquisition process including the detector system, collimator, and acquisition mode. h. Describe processing mechanisms for quantitative analysis, SPECT reconstruction, and data management.
<p>4. Summarize the routine diagnostic and therapeutic procedures to include instrumentation; radiopharmacy; patient preparation, monitoring, and education; imaging techniques; and anatomy and pathophysiology.</p>

- a. Identify the positioning, anatomy, physiology, and pathology for each of the following specific imaging procedure categories:
 - (1) Abscess/infection/inflammation
 - (2) Skeletal imaging
 - (3) Central nervous system
 - (4) Cardiovascular
 - (5) Endocrine
 - (6) Gastrointestinal
 - (7) Genitourinary
 - (8) Lung
 - (9) Lymphoscintigraphy
 - (10) Tumor
 - (11) Shunt studies
 - (12) Therapy

5. Review all aspects of patient care.
 - a. Describe legal and professional responsibilities.
 - b. Provide patient education and safety.
 - c. Utilize universal precautions, and help prevent the spread of infection through disposal of contaminated materials.
 - d. Identify patient condition.
 - e. Describe medical emergencies as they relate to cardiac or respiratory arrest, physical injury or trauma, or other medical disorders.

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Postsecondary Nuclear Medicine Technology

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- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Course Name: Nuclear Physics

Course Abbreviation: NMT 2611

Classification: Vocational–Technical Core

Description: This course covers the concepts and physical properties that govern radioactivity and the interactions of radioactivity with matter. (1 sch: 1-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives	
1.	<p>Explain historical views of the atom.</p> <ol style="list-style-type: none"> Describe the significance of historical contributions to the development of the current concept of the atom. Define basic terms pertinent to the study of nuclear physics.
2.	<p>Identify the structure of the atom.</p> <ol style="list-style-type: none"> Describe the general atomic structure, based on the Bohr model, with reference to other models that have been proposed. Discuss the concepts of orbital shells and quantum numbers as they relate to both the shell designation and the periodic table. Write appropriate s, p, d, and f numbers for a given atom. Diagram an atom, placing electrons in the proper shells. Discuss the quantum theory of electromagnetic radiation. Relate the Pauli Exclusion Principle to the organization of the atom. Explain the structure of the periodic table, discussing the various symbols and abbreviations used in the table. Explain the structure of the trilinear chart of the nuclides, discussing the various symbols and abbreviations used in the chart. Describe the process of ionization. Differentiate between cations and anions.
3.	<p>Describe methods of atomic nomenclature.</p> <ol style="list-style-type: none"> Using A, Z, and X notations, writes any element given. Given A and Z numbers, determine the number of neutrons. Use and explain nuclear shorthand. Define atomic mass units and energy equivalents, and derive the value of one, given the other by mathematical conversion. Describe the electron volt as a measure of energy.
4.	<p>Examine radiation and the atom as related to nuclear medicine.</p> <ol style="list-style-type: none"> Explain the various modes of electromagnetic radiation production. Differentiate between natural and artificial radioactivity. Define <i>radiation</i>. Discuss the concepts and characteristics of wave motion. Given appropriate information, calculate wavelength or energy. Differentiate between Bremsstrahlung and characteristic X-ray production. Describe the use of n-to-p ratios in predicting modes of decay of radionuclides.

<ul style="list-style-type: none"> h. Discuss nuclear structure and the forces associated with nuclear structure and content. i. Describe mass defect and nuclear binding energy. j. Discuss the concepts of binding energy, energy states, and orbital energy levels of electrons. k. Describe the various types of nuclear transformations. l. Predict products of radioactive decay by using the periodic table. m. From a decay scheme, name the parent radionuclide, daughter, half-lives of parent and daughters, types of emissions, energy of emissions, and abundance and origin of the emissions. n. Discuss the curie and becquerel as units of measurement of radioactivity. o. Convert and/or calculate submultiple values of curie and becquerel. p. Determine the decay rate and activity of a source, given the number of nuclei per unit time. q. Define and calculate the decay constant of a radionuclide. r. Determine the mean life of a radionuclide, given the half-life or decay constant. s. Determine the decay factor, given half-life, time, and required decay chart or calculator with ln and ex functions. t. Determine the remaining number of nuclei or remaining activity, given the original quantity and the isotope. u. Determine pre-decay factors, given the isotope and quantity at a specific time. v. Determine the half-life (or elapsed time), given one of two factors, the original quantity, and the final quantity of an isotope. w. Determine the effective half-life, or the biological half-life, given the appropriate data. x. Plot the results of an exponential equation using linear and semilog graph paper. y. Determine the half-life of an unknown radionuclide from the plot of its decay on semilog graph paper. z. Describe the various nuclear reactions, and identify the equations used to express these reactions. aa. Describe radionuclide production methods. bb. Compare the three parent/daughter equilibrium relationships. cc. Calculate generator yield and the time of maximum daughter activity.
<p>5. Name the interactions associated with particulate radiation.</p> <ul style="list-style-type: none"> a. Describe the events that occur when alpha, beta minus, and positron particles interact with matter. b. Discuss the origins of positrons.
<p>6. Describe the interactions associated with gamma and x-radiation.</p> <ul style="list-style-type: none"> a. Describe coherent and Compton scatter. b. Discuss photoelectric effect, pair production, and photodisintegration. c. Differentiate between Bremsstrahlung, characteristic radiation, and Auger electrons. d. Discuss how atomic number and energy affect the interaction of radiation with matter.
<p>7. Explain the attenuation equation.</p> <ul style="list-style-type: none"> a. Discuss the concept of half-value layer, and demonstrate the use of the equation in shielding materials for radionuclides.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Course Name: Instrumentation I: Non-Imaging

Course Abbreviation: NMT 2712

Classification: Vocational–Technical Core

Description: This course includes the principles, operation, and quality control for nonimaging instruments including monitoring equipment, dose calibrators, well counters, uptake probes, liquid scintillation systems, and the gamma probe. It also includes the principles and applications of statistics as they relate to these instruments. (2 sch: 2-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives	
1.	Explain the radioactive decay process. <ol style="list-style-type: none"> Explain the interaction of ionizing radiation with matter. Define the units of measurement for exposure and exposure rate.
2.	Explain gas-filled detector systems used in nonimaging instrumentation. <ol style="list-style-type: none"> Discuss the principles of operation of the pocket dosimeter, Cutie-pie, and dose calibrator. Describe pulse-size characteristics for an ion chamber when operated in the ion chamber region, the proportional region, and the G-M region; describe the gas-detector response as a function of voltage; and state the basic principles of operation of gas detectors. Describe the operation of a dose calibrator, G-M tube survey instrument, and counter. Describe the following quality control procedures for a dose calibrator, stating frequency and allowable variances for each procedure: geometry, linearity, accuracy, precision, and constancy. Describe the components and applications of G-M tubes, including voltage plateau, effects of background, and quenching. Compare the deadtime and accuracy of a Cutie-pie and a G-M counter, and describe situations in which each is most appropriate. Describe the procedure for performing a precision check of a survey meter, and discuss proper maintenance through annual calibration. Compare and contrast the operation, function, and limitations of gas-filled detectors.
3.	Explain scintillation detection systems. <ol style="list-style-type: none"> Discuss the history of scintillation detection system development, and plot a timeline including relevant major events. Describe a rectilinear scanner. List and describe the function of each component of a NaI (Tl) scintillation detector. Discuss scintillation measuring techniques. Describe the characteristics of scintillation detector crystals. Describe the basic physical concepts involved with scintillation spectrometry, the practical operation of the scintillation detector, and the practical operation of the pulse-height analyzer portion of the spectrometer. Given the necessary energy information, determine proper gain settings.

<ul style="list-style-type: none"> h. Describe the basic use of scintillation spectrometers, as well as the importance of proportional linearity between gamma energy and voltage pulse output. i. Operate a solid scintillation counter, and demonstrate this ability by obtaining a gamma ray spectrum using a single-channel analyzer. j. Discuss the characteristics of an energy spectrum in relation to backscatter, forward scatter, and attenuation. k. Discuss the use of scalers, timers, and rate meters in a scintillation detector. l. Given the appropriate information, determine the percent resolution from a FWHM calculation. m. Describe the effects activity has on well counter deadtime. n. Explain the effects of well counter efficiency on the accuracy of wipe tests and nonimaging nuclear medicine studies. o. Calculate well counter efficiency. p. Determine pulse height analyzer (PHA) setting to include a desired energy range, and determine the energies to be included by a specific PHA setting. q. Describe the effects of geometry on sample counting with a well counter or uptake probe. r. Outline specific quality control procedures for a scintillation counter to include the following: window calibration, sensitivity, energy resolution, volumetric evaluation, and chi-square determination. s. Explain the principles of liquid scintillation counting. t. Describe the principle of operation and physical characteristics of a gamma probe system. u. Discuss the various clinical uses of a gamma probe. v. List and describe the quality control procedures to be performed on gamma probe systems.
<p>4. Review and relate statistics related to nonimaging equipment.</p> <ul style="list-style-type: none"> a. Discuss systematic and random error. b. Define precision and accuracy. c. Describe percent error and percent difference. d. Discriminate between populations and samples. e. Differentiate between inductive and descriptive statistics. f. Differentiate between continuous and discrete data. g. Create a frequency table from given data. h. Differentiate between positive and negative skewed distribution. i. Given a set of numbers, calculate the mean, standard deviation, and coefficient of variation. j. List and define the various measures of central tendency, stating their applications in nuclear medicine. k. Given a set of numbers, derive various measures of central tendency. l. Given the necessary information, determine the probability of occurrence of various events.
<p>5. Explain nuclear counting statistics.</p> <ul style="list-style-type: none"> a. Differentiate between a Poisson and Gaussian distribution, as well as describe their use in nuclear medicine. b. Tell what percentage of values for a Gaussian distribution fall within 1, 2, or 3 standard

- deviations.
- c. Calculate the mean and standard deviation of a single count value as related to Poisson distribution.
 - d. Given a set of nuclear counting events, calculate the mean, standard deviation, and coefficient of variation.
 - e. Determine the number of counts to collect in a sample for 68%, 95%, and 99% confidence levels.
 - f. Relate confidence levels to needed accuracy for various nuclear medicine studies.
 - g. Calculate the counting time required to achieve desired levels of statistical reliability.
 - h. Determine a statistically accurate counting rate for a radiation detector.
 - i. Calculate a chi-square test, and obtain a p-value from a given set of data points.
 - j. Given the necessary information, evaluate how well equipment is performing on the basis of a chi-square test.
 - k. Describe the t-test, and discuss its use in nuclear medicine.
6. Identify laboratory equipment used in a nuclear medicine.
- a. Describe the various rotators and shakers that may be used in a nuclear medicine laboratory.
 - b. Discuss the operation and major components of a centrifuge.
 - c. Explain the procedure for calibration of a centrifuge, and state the rationale for such a calibration.
 - d. Describe the calibration of a pH meter, stating the purpose for calibration prior to each use.
 - e. Identify and properly utilize a laboratory thermometer.
 - f. Describe the procedure for calibration of an analytical balance, and state the frequency at which such a calibration should be performed.
 - g. Describe accepted calibration procedures for manual pipettes, automatic pipettes, and pipetting devices, stating allowable variances and frequencies at which such calibration should be done.
 - h. Describe the quality control procedures used to ensure proper operation of an ultrasonic mixer.
 - i. Discuss the quality control and proper maintenance procedures for a microscope.
 - j. Describe a procedure for calibration of a multichannel analyzer using various sealed sources

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures

NMTCB Components of Preparedness

NMTCB2	Instrumentation
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Postsecondary Nuclear Medicine Technology

NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
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- M7 Integers (addition, subtraction, multiplication, division)
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- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject-verb agreement, adjective, adverb)
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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
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Course Name: Instrumentation II: Imaging

Course Abbreviation: NMT 2723

Classification: Vocational–Technical Core

Description: This course deals with in-depth information on the components, use, and quality control of the various types of systems used for gamma and positron imaging. (3 sch: 3-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives

1. Describe the physical properties that affect the resolution and efficiency of collimators.
 - a. State the characteristics of the parallel-hole, diverging, converging, pinhole, slant-hole, and fan-beam collimators as they relate to the Anger scintillation camera.
 - b. State the physical parameters and uses of low-energy, medium-energy, and high-energy collimators.
 - c. Describe the characteristics of various types of collimators and how each collimator affects image size, resolution, and acquisition speed.
 - d. Select the most appropriate collimator for various studies.
 - e. Define septal penetration, and describe how it is minimized by collimator design.
 - f. Describe the components of a scintillation camera and the function of each.
 - g. Describe the physical and chemical properties of gamma camera crystals. Discuss the effects of crystal thickness on resolution and efficiency.
 - h. Describe how the crystal detects radiation and how light is converted into a pulse.
 - i. Describe how photomultiplier tubes increase the signal.
 - j. Explain why only a portion of incidence radiation is detected and why there is variability in the pulses produced by a monoenergetic source.
 - k. Describe the types and number of photomultiplier tubes used in gamma cameras, explaining the rationale for various types and configurations.
 - l. Explain how the pulse height analyzer determines the pulse to be accepted.
 - m. Explain the methods for selection of PHA window setting; be able to select parameters given the appropriate information and to determine the energies included in by a specific window setting.
 - n. Explain the function of the x, y, and z signals used in a gamma camera system, discussing the significance of the signals in the production of an accurate image on the display system.
 - o. Explain the relationship of the z signal to spectrometry.
 - p. Describe the following components of the Anger scintillation camera, giving the function of each component.
 - (1) Scaler and rate meter
 - (2) Spectrometer
 - (3) Automatic peak tracking
 - (4) Rotation orientation
 - (5) Spectrum display

- (6) Multichannel analyzer
- (7) Imaging systems
- (8) Light pipes
- (9) Flood field correction devices
- q. Describe the function and use of the following components of the camera system.
 - (1) Cathode ray tube
 - (2) Multiformat programmer
 - (3) Variable persistence scope
- r. Discuss the relationship of dot size to formation of the image for various dynamic and static imaging procedures.
- s. Describe the effects of astigmatism and focus on the final image.
- t. Discuss the significance of phosphor color in production of diagnostic images.
- u. Explain the difference between a persistence and a photographic scope.
- v. Discuss advantages and disadvantages of various types and speeds of film in making hard copy images.
- w. Discuss the advantages and disadvantages of computer-enhanced images versus camera CRT images.
- x. Discuss the purpose and use of multiple lenses on a multiformat imager.
- y. Discuss the dead time and framing time considerations with multiformat images.
- z. List the features and accessories that must be available in order for a camera to be used as a mobile system.
- aa. Describe methods for evaluating the spatial resolution of a collimator for an Anger scintillation camera.
- bb. Describe measurements that can be performed in evaluating collimator performance.
- cc. Differentiate between intrinsic and extrinsic resolution as they relate to gamma camera resolution, and describe procedures used to measure each.
- dd. List and discuss factors related to camera sensitivity.
- ee. Describe a method for evaluating the linearity of an Anger camera.
- ff. Define the term *field uniformity*.
- gg. Describe in detail the various factors that cause camera nonuniformity, stating the resulting potential effect on image quality.
- hh. Describe the different approaches to uniformity correction used by various camera manufacturers.
- ii. Define the term *resolving time*.
- jj. List count rate limitations for various systems, and describe their effects on the resulting image.
- kk. Given the necessary information, calculate the count density of an imaging study performed on an Anger scintillation camera.
- ll. Discuss the effect on an image when the wrong energy level collimator is used.
- mm. Describe the effect on an image when the following situations occur.
 - (1) Cracked or fractured crystal
 - (2) Improper PM tube calibration
 - (3) Improper pulse-height analyzer calibration
 - (4) Improperly focused CRT
 - (5) Unclean CRT

2. Describe the principles of operation and performance characteristics of multicrystal

cameras.
<ol style="list-style-type: none"> a. Describe ways in which a multicrystal imaging system is more quantitative in measuring and detecting radiation than the Anger scintillation camera. b. Compare image quality and spatial resolution between a single crystal and a multicrystal imaging system. c. Identify the uses of a multicrystal imaging system that makes such a system a viable imaging instrument. d. Compare single crystal cameras, multicrystal cameras, and image intensifier cameras, with respect to detection efficiency versus gamma ray energy.
<ol style="list-style-type: none"> 3. Describe the principles of operation and crystal characteristics of solid state detector systems when compared to Anger camera performance. <ol style="list-style-type: none"> a. Describe the basic difference between a solid state and Anger camera system. b. Discuss the advantages and disadvantages of CZT crystal applications compared to traditional NaI (Tl) crystals.
<ol style="list-style-type: none"> 4. Examine tomographic imaging systems. <ol style="list-style-type: none"> a. Discuss the basic designs and principles that enable the construction of tomographic images with the use of SPECT, PET and/or PCD imaging systems. b. Compare acquisition parameters of SPECT imaging with those of planar imaging. c. Compare acquisition parameters of PET, SPECT, and PCD imaging. d. List and describe factors that limit statistical accuracy in SPECT imaging. e. Give a step-by-step explanation of the backprojection method of reconstruction, taking into consideration various correction parameters. f. Describe iterative reconstruction. g. Discuss the use of multiple pinhole or slant pinhole collimators in the production of tomographic images. h. Discuss the selection criteria related to the open frame and axial collimators used in PCD imaging. i. Discuss the crystal thickness requirements of a PCD system. j. Describe the 511 keV collimators used on SPECT systems to acquire images using positron-emitting radionuclides. k. List the various types of crystals used in PET systems. l. Describe the components of a PET and a PCD system. m. Define and describe iterative reconstruction. n. List conditions or pathologies for which tomographic imaging procedures are advantageous over planar imaging. o. State radiopharmaceutical requirements that must be satisfied in order to perform a PET or PCD study. p. Discuss the activity limitations related to open frame and axial collimators. q. Compare acquisition parameters of PET, PCD, and SPECT. r. Describe the factors that must be considered when selecting a filter. s. Define terms such as ramp filter, cutoffs, and Fourier reconstruction and filtering. t. Describe how annihilation allows for PET and PCD imaging. u. Compare the sensitivity, resolution, and signal-to-noise ratio for the three methods of imaging with 511 keV photons. List the studies that can be performed satisfactorily using each method.
<ol style="list-style-type: none"> 5. Discuss the quality control of imaging systems.

- a. Describe the method of window calibration (peaking-in) on a scintillation camera.
 - b. Outline the steps in a comprehensive quality control program for a scintillation camera.
 - c. Differentiate between spatial resolution and sensitivity, and describe the procedure for their determination.
 - d. Discuss the effect of improper window calibration on the image.
 - e. Describe the effects of camera linearity, focus and astigmatism, and object-to-detector geometry on the image.
 - f. Compare and contrast intrinsic versus extrinsic quality control measurements on a scintillation camera.
 - g. Evaluate in terms of size, shape, and uniformity a given set of flood images.
 - h. Evaluate in terms of resolution and linearity a given set of phantom images.
 - i. Discuss the effects of sudden temperature changes, shock, and other environmental changes on a scintillation camera.
 - j. Describe the procedure for determining the MTF of an imaging system.
 - k. Identify special problems that occur when SPECT quality control procedures are performed, addressing specifically uniformity, linearity, and center of rotation.
 - l. Outline the procedure for performing a center of rotation acquisition/reconstruction with a line source and/or point source.
 - m. Describe the use of a specially designed resolution phantom in SPECT quality control.
 - n. Describe the quality control procedures related to PET and PCD imaging systems.
6. Describe procedures for care and maintenance of film and film processors.
 - a. Name the two basic components of any film, and compare their relative thickness.
 - b. Define speed and latitude in relationship to the characteristics of emulsion.
 - c. List the factors that contribute to the deterioration of a film.
 - d. State the proper temperature and humidity for storage of film and developing chemicals.
 - e. Explain the effects of freezing temperatures on the expiration date of film.
 - f. Explain the effects of static electricity on film—why it occurs and how it can be eliminated.
 - g. Define *film fog*, and list factors that cause it.
 - h. List sources of unsafe light that can be found in a darkroom.
 - i. Describe the chemical composition of film emulsion.
 - j. Differentiate between the latent and visible image.
 - k. Describe the effects of temperature and humidity on the latent image.
 - l. Describe how latent and manifest images are produced on film in relation to the presence of silver compounds.
 - m. Describe, in order, the steps involved in automatic film processing.
 - n. Discuss the chemical composition of the fixer and developer, and explain the function of each component.
 - o. State the optimum temperature for automatic processing, and discuss the effect on developed film when the temperature is either too hot or too cold.
 - p. Differentiate between single and double emulsion films.
 - q. Demonstrate the proper technique for loading and unloading various types of film cassettes, including Polaroid film.

- r. Outline a quality control program for film handling and storage and for processor maintenance.
- s. Demonstrate the proper way to clean an automatic processor.
- t. Discuss the principles of silver reclamation and why the process is important.
- u. State the purpose for using a sensitometer or densitometer as part of a quality assurance program.
- v. Given a set of data, plot relative log exposure versus density (R and D) curves.
- w. Explain the procedure for determining replenishment rates of a film processor.
- x. Perform routine maintenance and quality control on an automatic processor.
- y. Explain the effects of temperature and chemical changes on film in the various stages of processing.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures

NMTCB Components of Preparedness

NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
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- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)

- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

SUGGESTED REFERENCES

- The American registry of radiologic technologists.* (n.d.). Retrieved November 7, 2008, from <http://www.arrrt.org/>
- Christian, P. E., & Waterstram-Rich, K. M. (2007). *Nuclear medicine technology and PET/CT technology and techniques* (6th ed.). St. Louis, MO: Mosby.
- Joint review committee on educational programs in nuclear medicine technology.* (n.d.). Retrieved November 7, 2008, from <http://www.jrcnmt.org/>
- Mettler, F. A., Jr., & Guiberteau, M. J. (2006). *Essentials of nuclear medicine imaging* (5th ed.). Philadelphia, PA: Saunders Elsevier.
- Nuclear medicine technology certification board.* (n.d.). Retrieved October 7, 2008, from <http://www.nmtcb.org/>
- Steves, A. M., & Wells, P. C. (2004). *Review of nuclear medicine technology: Preparation for certification in nuclear medicine technology* (3rd ed.). Reston, VA: The Society of Nuclear Medicine.

Course Name: Radiation Protection

Course Abbreviation: NMT 2732

Classification: Vocational–Technical Core

Description: This course covers the principles and applications of radiation protection, as well as the applicable regulations. Individual regulations will also be covered in detail in content areas where they apply, such as radiopharmacy, instrumentation, and radionuclide therapy. (2 sch: 2-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives	
1.	Review basic radiation protection principles and terminology. <ol style="list-style-type: none"> Describe the characteristics of gamma, X-ray, beta, and alpha radiation, including half-lives and energies of principal emissions. Define the various units of exposure, absorbed dose, relative biologic effectiveness, quality factors, and dose equivalent. Perform calculations using radiation units, and convert standard units to their Systeme International equivalents.
2.	Review regulation of radiation exposure and use of radioactive materials. <ol style="list-style-type: none"> Discuss the mission of each of the following agencies in relation to the field of nuclear medicine: NRC, DOT, EPA, and FDA. Discuss federal, state, and institutional licenses. Discuss the various federal and state regulatory documents that are pertinent to nuclear medicine.
3.	Review dose and exposure limit recommendations and regulations. <ol style="list-style-type: none"> Define the terms associated with dose and exposure limit recommendations and regulations (EDE, TEDE, DDE, CEDE, SDE, LDE, DAC, ALI, occupational and public dose, unrestricted and restricted areas). Discuss the occupational limits in relation to whole body total effective dose equivalent, individual organs, lens of the eye, skin and extremities, summation of internal and external exposures, minors, and emergency exposures. Discuss the embryo/fetal limits for an occupationally exposed worker. Define the exposure limits for the general public. Discuss the ALARA philosophy, including the principles, recommended levels, and radiation protection programs in Title 10 CFR Part 20. Define the exposure rates, access, and signage requirements for restricted and unrestricted areas.
4.	Review survey instruments and personnel monitors. <ol style="list-style-type: none"> Discuss the regulations pertinent to the possession of detection and monitoring equipment. Describe the various types of survey instruments, and discuss the advantages and disadvantages of each device. Explain the regulations concerning personnel monitoring.

<ul style="list-style-type: none"> d. Describe the bioassay procedure performed after the use of radioiodine. e. Discuss personnel exposure records, and be able to interpret exposure reports. f. Describe the procedures involved with the notification of exposure levels and prior exposures.
<p>5. Describe practical methods of radiation protection.</p> <ul style="list-style-type: none"> a. Discuss the principles associated with time, distance, and shielding. b. Describe the applications associated with time, distance, and shielding. c. Perform calculations associated with time, distance, and shielding.
<p>6. Discuss regulations related to possession of radioactive materials.</p> <ul style="list-style-type: none"> a. Discuss licensed materials and their use in humans, as controlled reference sources, and exempt sources. b. Define the activity inventory limits. c. Discuss the regulations associated with sealed sources, including inventory and leak tests. d. Describe the regulations pertaining to lost sources.
<p>7. Identify individual involved in institutional oversight documentation (according to NRC regulations).</p> <ul style="list-style-type: none"> a. Explain the role of a radiation safety officer, including the responsibilities, training requirements, and delegation of authority. b. Discuss the responsibilities, composition, meeting frequency, and records of the radiation safety committee. c. Explain the Quality Management Program in detail, including radionuclides covered by the program, written directives, patient identification, following directives, recordable and reportable events, program review, and records.
<p>8. Discuss specific radiation safety procedures related to nuclear medicine.</p> <ul style="list-style-type: none"> a. Discuss the protection of radiation workers, including regulations, posting notices, radiation safety education, notification and reports, workers' rights, and declaration of pregnancy. b. Describe the general safety rules involved with working with unsealed radioactive sources. c. Discuss the use of shields and labels, and explain the pertinent regulations. d. Describe the regulations associated with the use of radioactive liquids and the preparation of kits and dose ranges. e. Explain the regulations involved with the use of radioactive gases and aerosols, as well as the storage of volatiles and gases, room concentration limits, negative pressure requirements, calculation of room clearance time, postings, and the handling of iodine-131 liquid.
<p>9. Discuss patient protection associated with radioactive material.</p> <ul style="list-style-type: none"> a. Discuss the regulations and requirements associated with the measurement of doses to be administered. b. Explain the regulations and methods of labeling patient doses. c. Compare and contrast the regulations, definitions, and procedures pertaining to reportable (misadministrations) and recordable events.
<p>10. Discuss safe receipt and shipping practices for radioactive material packages.</p> <ul style="list-style-type: none"> a. Describe the procedures, and list the regulations pertaining to the receipt of radioactive materials.

<ul style="list-style-type: none"> b. Discuss the regulations, procedures, and labels associated with the shipping of radioactive materials.
<p>11. Describe waste disposal procedures and regulation.</p> <ul style="list-style-type: none"> a. Describe waste that is exempt from disposal regulations. b. Discuss the regulations and procedures pertinent to decay in storage. c. List the regulations and procedures associated with discharge into the sewer and atmosphere. d. Explain the regulations and procedures associated with transfer to an authorized recipient.
<p>12. Describe survey procedures associated with radioactive contamination.</p> <ul style="list-style-type: none"> a. Discuss the regulations, instrumentation, and procedures pertinent to ambient dose rate surveys. b. Explain the regulations and procedures associated with removable contamination surveys. c. Define minor and major spills. d. Describe the procedures involved with the decontamination of minor and major spills.
<p>13. Discuss radiation safety procedures associated with radionuclide therapy.</p> <ul style="list-style-type: none"> a. List the regulations associated with radionuclide therapy. b. Discuss the responsibilities of the radiation safety officer and the authorized user. c. Explain the procedures associated with therapeutic dose administrations including patient identification, written directives, and informed consent. d. Describe release and isolation criteria, and discuss limited restrictions. e. Explain the safety precautions that are necessary for patients in radiation-based isolation. f. Describe the measurement of exposure rates including surveys of restricted and unrestricted areas, safe distance markers, and calculated nursing time. g. Discuss procedures in case of death, autopsy, or emergency surgery.
<p>14. Examine NRC rules and regulations as they apply to nuclear medicine.</p> <ul style="list-style-type: none"> a. List the regulations found in Title 10 CFR Part 19. b. Describe the documents and locations of postings of notices to workers. c. Discuss instructions to workers and notification and reports to individuals. d. Explain request for inspections to include rights, requests, and employee protection. e. List the regulations found in Title 10 CFR Part 20. f. Discuss the purpose and implementation of a radiation protection program. g. List the radiation dose limits for occupational workers and members of the public. h. Describe surveys and monitoring including requirements, equipment, and conditions requiring monitoring of external and internal occupational doses. i. Discuss the control of exposure from external sources in a restricted area. j. Explain respiratory protection, and discuss the controls used to restrict internal exposure in restricted areas. k. Discuss the storage and control of licensed material. l. Describe a variety of precautionary procedures and requirements. m. Explain the regulations associated with waste disposal, decay in storage, and release into sanitary sewerage. n. Describe the various reports and records required by the NRC in 10CFR20. o. List the regulations found in Title 10 CFR Part 35.

- p. Discuss the ALARA concept, and describe a model program.
- q. List the ALARA investigational levels I and II for whole body and extremities.
- r. Describe the responsibilities and training requirements of a radiation safety officer.
- s. Discuss the responsibilities and composition of a radiation safety committee.
- t. Explain the purpose of a quality management program, and discuss patient identification and written directives.
- u. Define recordable and reportable (misadministration) events.
- v. Describe the regulations associated with the possession, use, calibration, and quality control requirements for dose calibrators.
- w. Explain the calibration and quality control regulations for survey instruments.
- x. Discuss the requirements and records associated with the measurement of radiopharmaceutical doses.
- y. Explain the authorization of calibration and reference sources.
- z. Describe the regulations associated with the use of vial and syringe shields, as well as labeling requirements.
- aa. Discuss the regulations pertinent to the management of a mobile nuclear medicine service.
- bb. Explain the regulations associated with the storage of volatiles and gases, as well as decay in storage.
- cc. Define the permissible molybdenum-99 concentration.
- dd. Explain the limits involved in the control of aerosols and gases.
- ee. Discuss the regulations associated with the use of radiopharmaceuticals for therapy.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause-effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)

Postsecondary Nuclear Medicine Technology

- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Mettler, F. A., Jr., & Guiberteau, M. J. (2006). *Essentials of nuclear medicine imaging* (5th ed.). Philadelphia, PA: Saunders Elsevier.

Nuclear medicine technology certification board. (n.d.). Retrieved October 7, 2008, from <http://www.nmtcb.org/>

Steves, A. M., & Wells, P. C. (2004). *Review of nuclear medicine technology: Preparation for certification in nuclear medicine technology* (3rd ed.). Reston, VA: The Society of Nuclear Medicine.

Course Name: Advanced Computer Applications

Course Abbreviation: NMT 2741

Classification: Vocational–Technical Core

Description: This course combines knowledge of computers and specific applications for the acquisition and processing of nuclear medicine studies. In addition, this course covers the configuration, function, and application of computers in nuclear medicine. Students will gain experience performing data acquisition, manipulation, and processing. (1 sch: 1-hr lecture)

Prerequisite: Introduction to Nuclear Medicine (NMT 2511)

Competencies and Suggested Objectives
<p>1. Describe the types of computers used in nuclear medicine image acquisition and processing.</p> <ol style="list-style-type: none"> Compare and contrast analog and digital computer systems and signals. Explain the differences between minicomputers, microcomputers, mainframes, and supercomputers. Differentiate between hardwired and programmable computers.
<p>2. Recall the number systems unique to computers.</p> <ol style="list-style-type: none"> Define and/or describe decimal, binary, octal, and hexadecimal number systems. Define computer terminology such as bit, byte, word, and so forth. Provide the binary coded decimal equivalent of the numbers 4, 7, 13, and 79 using an 8-bit word length. Describe how the binary coded decimal equivalent of 79 stored in an image memory location changes when an additional count is added to that location.
<p>3. Identify the general structure of computer hardware.</p> <ol style="list-style-type: none"> Describe the organization and function of the central processing unit of a computer. Describe how information is stored in a computer memory, including various memory systems in the discussion. State factors that determine actual computer memory capacity and speed of operation. Compare and contrast systems that operate as RAM versus ROM memory devices. Discuss various memory storage devices relative to their access time and advantages and disadvantages of each. Discuss the difference between magnetic tape and magnetic disk for storage of computer information. Discuss the various types of input/output devices. Discuss the rationale for the use of light pens and joysticks. Define terminology related to computer languages. Define and describe the function of the ADC device. Discuss parameters that affect the performance of the CPU. Describe various types of microprocessors. Discuss the difference between direct access and sequential storage devices. Describe the characteristics and uses of smart cards and optical cards. List the rules for proper care of floppy diskettes to prevent damage.

4. Identify the general components of computer software.
 - a. List several examples of software, and define each type.
 - b. Discuss the function of the operating system.
 - c. List several common operating systems, and describe various applications of each.
5. Describe the communications systems incorporated in nuclear medicine/radiology departments.
 - a. Discuss various types of communications channels, and compare the advantages and disadvantages of each type.
 - b. Discuss the parameters that determine transmission rates.
 - c. Describe the hardware required for communications between computer systems.
 - d. Discuss various types of communication networks.
6. Describe types of data management systems incorporated in nuclear medicine/radiology departments.
 - a. Discuss the purpose of file and data management.
 - b. Describe types of file organization.
 - c. Define a database, and list the types of database organization methods.
7. Describe how Internet capabilities relate to nuclear medicine.
 - a. Define the Internet.
 - b. Recognize the codes that delineate top level domains, and describe how they relate to the Internet organization.
 - c. Describe the purpose of an Internet access provider.
 - d. Discuss the various services available on the Internet.
8. Describe computer systems specific to nuclear medicine.
 - a. Discuss buffers and zoom as they relate to nuclear medicine computers.
 - b. Compare list mode acquisition to histogram and frame acquisition, explaining the advantages and disadvantages of each approach.
 - c. Diagram and/or describe how the computer performs a multigated acquisition study.
 - d. Discuss matrix types and sizes for word and byte mode, and give examples of each.
 - e. List advantages and disadvantages in using hardwired computers and image processors in nuclear medicine.
 - f. Compare and contrast the various types of display systems used on nuclear medicine computers.
 - g. List data processing operations that are essentially cosmetic treatments of the image, and explain briefly how each is accomplished.
 - h. List non-cosmetic data processing functions of a computer used in imaging, and define the term *functional image*.
 - i. Describe the relationship between a ROI and a histogram generated from a dynamic study.
 - j. Describe the use of the computer in the development and administration of quality assurance testing of imaging equipment.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT3 Instrumentation and Quality Control

NMTCB Components of Preparedness

NMTCB2 Instrumentation

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Course Name: Clinical I

Course Abbreviation: NMT 2816

Classification: Vocational–Technical Core

Description: This course integrates didactic learning into the practical setting. Record keeping and quality control results are an integral part of all procedures. (6 sch: 18-hr clinical)

Corequisite: Nuclear Medicine Procedures I (NMT 2523)

Competencies and Suggested Objectives	
1.	Discuss facility policies related to the nuclear medicine department and hospital. <ol style="list-style-type: none"> a. Locate the facility policy manual, the department procedure manual, and fire and emergency equipment. b. Perform fire safety, health emergency, and disaster procedures according to facility policies and procedures. c. Adhere to OSHA and state health department safety policies. d. Locate supplies within the department and obtain supplies, as necessary, from in-house sources. e. Schedule patients for nuclear medicine studies following facility procedures. f. Maintain patient and department records as required by state and federal regulations and facility policies.
2.	Describe all aspects of patient care. <ol style="list-style-type: none"> a. Explain nuclear medicine procedures to patients and their families, and appropriately answer their questions concerning the procedures and the radiation involved. (The student should be able to explain frequently performed procedures without reference to notes. The student should be able to explain less frequently performed procedures after referring to the procedure manual.) b. Use communication techniques appropriate to the patient's age group, physical/mental/emotion state, and ability to communicate. c. Identify the patient using procedures established by regulation and/or facility protocols. d. Verify requisitions and assess the appropriateness of the indication for the test; determine if the patient can perform/tolerate the test; and take the appropriate action if the indication is questionable or if a diagnostic study may not be obtained. e. Transport and transfer the patient safely using proper body mechanics. f. Practice infection control in all circumstances. g. Prevent, and when necessary, control patient-related radionuclide contamination. h. Provide for the patient's basic needs, as appropriate for a nuclear medicine technologist. i. Monitor support equipment (such as IV pumps and oxygen supplies) for the patient while in the nuclear medicine department. j. Measure pulse, respiration, and blood pressure. k. Administer radioactive and nonradioactive drugs by the following routes, as allowed by federal and state regulations, and facility policy, using septic technique, universal precautions, and required protocols:

<ul style="list-style-type: none"> (1) Intravenous injection (2) Injection through an existing angiocatheter (3) Oral (4) Inhalation (5) Intramuscular injection (6) Subcutaneous injection (7) Urinary catheter <ul style="list-style-type: none"> l. Assist the physician with intrathecal and intracavitary injections. m. Assist the physician with administration of therapeutic radionuclides. n. Place in intravenous catheter, as allowed by state regulation and facility policy, using septic technique, universal precautions, and required protocols.
<ul style="list-style-type: none"> 3. Demonstrate characteristics appropriate for the nuclear medicine professional. <ul style="list-style-type: none"> a. Demonstrate cooperation, and act as a team member at both the departmental and institutional levels. b. Demonstrate professional etiquette in dealing with patients, families, visitors, other health care workers, support staff, and in communications with other facilities (such as physicians' offices). c. Demonstrate conflict prevention and resolution behaviors and techniques in the work setting. d. Demonstrate the ability to handle difficult people and work situations, such as an angry patient, using behaviors and techniques that diffuse or solve the problem or prevent the situation from worsening. e. Demonstrate professional behaviors including showing openness to learning; taking initiative and assuming responsibilities as appropriate to training; showing confidence as clinical skills are mastered; and maintaining personal hygiene and a professional appearance. f. Demonstrate calmness when the department is busy and multiple demands are made on the student. g. Perform two or more tasks simultaneously when training and skill level have reached an appropriate level. h. Recognize problems in the clinical setting and demonstrate a rational, step-wise process to analyze and attempt to solve the problem. i. Respect the patient's privacy, and maintain patient confidentiality. j. Obtain consent for a test from a patient or the appropriate person as required and/or allowed by regulation and/or facility policy.
<ul style="list-style-type: none"> 4. Demonstrate radiation protection practices. <ul style="list-style-type: none"> a. Use survey meters properly. b. Wear personal monitoring devices, and perform personal surveys as required by regulation and facility policy. c. Correctly read and evaluate radiation exposure reports. d. Utilize appropriate radiation safety precautions and procedures. e. Follow facility and regulatory guidelines when checking in packages containing radioactive materials and when preparing radioactive materials for shipment. f. Monitor waste and store radioactive waste according to facility and regulatory requirements. g. Determine when radioactive waste can be disposed of as nonradioactive waste

<p>according to regulations.</p> <ul style="list-style-type: none"> h. Perform surveys and wipe tests for radionuclidic contamination according to regulatory and facility requirements. i. Demonstrate correct procedures for cleanup when radionuclidic contamination is identified. j. Demonstrate correct procedures for containing and cleaning up a radioactive spill. k. Demonstrate preparation of an isolation room to be used for a patient who has received a high dose of I131, and demonstrate the procedure for surveying and cleaning the room prior to returning it to regular use.
<p>5. Perform procedures related to non-imaging instrumentation.</p> <ul style="list-style-type: none"> a. Check the functional status of a survey meter. b. Correctly employ a survey meter to detect radioactive contamination (or sources). c. Select parameters, and correctly use a well counter for counting wipes and samples. d. Select parameters, and correctly use an uptake probe to perform in vivo counting. e. Perform daily quality control checks on a well counter and/or uptake probe, such as background counts, constancy, and/or sensitivity. f. Perform a chi-square test on a well counter and/or uptake probe. g. Perform an energy resolution test on a well counter and/or uptake probe. h. Select parameters, and correctly position radioactive materials in a dose calibrator for correct measurement. i. Perform daily quality control checks on a dose calibrator, including background check and constancy. j. Perform a linearity test on a dose calibrator. k. Perform an accuracy test on a dose calibrator. l. Perform geometric variation tests on a dose calibrator. m. Demonstrate proper use of manual and semiautomatic pipettes when measuring radioactive standards and/or samples.
<p>6. Perform procedures related to imaging instrumentation.</p> <ul style="list-style-type: none"> a. Select the appropriate camera and collimator for various nuclear medicine studies. b. Select appropriate camera and/or computer parameters for various nuclear medicine studies. c. Perform uniformity tests on a gamma camera. d. Perform linearity and resolution tests on a gamma camera. e. Perform uniformity correction map acquisition procedures. f. Perform the center of rotation test on a SPECT camera.
<p>7. Perform computer applications.</p> <ul style="list-style-type: none"> a. Use standard nuclear medicine computer programs to correctly draw regions of interest for various quantitative nuclear medicine studies. b. Perform cardiac axis orientation using standard cardiac myocardial perfusion processing programs. c. Use standard nuclear medicine computer programs to produce histograms or other graphs for various quantitative nuclear medicine studies. d. Select and apply filters to nuclear medicine studies as required. e. Prepare comparative displays of images on screen or on hard copy. f. Perform subtraction studies using standard nuclear medicine computer programs. g. Adjust image contrast to provide maximum image enhancement without decreasing the

accuracy of the study. h. Present computer generated data in appropriate forms for various nuclear medicine studies.
8. Apply correct radiopharmacy techniques. a. Select and confirm the appropriate radiopharmaceutical for various nuclear medicine studies. b. Perform thin layer chromatography on radiopharmaceuticals. c. Check reconstituted kits and tagged blood cells for acceptable appearance. d. Test generator eluate for molybdenum content. e. Label syringes and vials containing radiopharmaceuticals as required by regulations and facility protocols. f. Prepare radiopharmaceuticals from freeze-dried kits, including calculating amount of eluate and saline to be added. g. Prepare radiopharmaceutical doses from bulk kits, including calculating volume to drawn. h. Adjust unit doses to provide doses different from that provided at the calibration time, including calculating volume to be discarded. i. Withdraw blood to be used for tagged blood cells. j. Tag red blood cells. k. Tag white blood cells (if state regulations and facility policy allow).
9. Perform diagnostic procedures according to departmental procedure manual. a. Maintain patient safety throughout procedures. b. Acquire images at the appropriate times, according to protocol. c. Acquire images at the appropriate projections, according to protocol. d. Acquire additional views as needed, at the appropriate time and/or projection. e. Adapt standard techniques to accommodate patient needs and/or limitations. f. Process and print data according to protocol. g. Format and print images according to protocol. h. Evaluate images and/or data for artifacts and possible errors, and take appropriate actions if artifacts or errors are suspected. i. Label images and graphical data according to protocol. j. Complete all paperwork, and obtain previous studies, X-ray file folders, and so forth, and present completed imaging study to physician for review as required by protocol. k. Collect urine and/or blood samples at appropriate intervals and in correct containers. l. Prepare samples for counting according to protocol. m. Count samples and standards using appropriate settings and geometry. n. Prepare standards according to protocol. o. Use appropriate settings and geometry for in vivo counting. p. Process data from non-imaging studies according to protocol. q. Evaluate non-imaging data for possible errors, and take appropriate actions if errors are suspected. r. Complete all paperwork, and obtain previous studies, X-ray file folders, and so forth, and present completed non-imaging study to physician for review as required by protocol.
10. Observe radionuclide therapy. a. Confirm patient identification.

<ul style="list-style-type: none"> b. Confirm written directive. c. Calibrate therapy dose. d. Reiterate instructions given to patient by physician.
<ul style="list-style-type: none"> 11. Perform clinical competencies. <ul style="list-style-type: none"> a. Perform two skeletal clinical competencies. b. Perform two respiratory clinical competencies. c. Perform two gastrointestinal clinical competencies (hepatobiliary, liver/spleen). d. Perform two endocrine/exocrine clinical competencies. e. Perform one genitourinary clinical competency. f. Perform one abscess/infection clinical competency. g. Perform two tumor/antibody clinical competencies.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

R1	Interpret Graphic Information (forms, maps, reference sources)
R2	Words in Context (same and opposite meaning)
R3	Recall Information (details, sequence)
R4	Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
R5	Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
M1	Addition of Whole Numbers (no regrouping, regrouping)
M2	Subtraction of Whole Numbers (no regrouping, regrouping)
M3	Multiplication of Whole Numbers (no regrouping, regrouping)
M4	Division of Whole Numbers (no remainder, remainder)
M5	Decimals (addition, subtraction, multiplication, division)
M6	Fractions (addition, subtraction, multiplication, division)
M7	Integers (addition, subtraction, multiplication, division)
M8	Percents
M9	Algebraic Operations

Postsecondary Nuclear Medicine Technology

- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Course Name: Clinical II

Course Abbreviation: NMT 2826

Classification: Vocational–Technical Core

Description: This course continues the integration of didactic learning into the practical setting. Record keeping and quality control results are an integral part of all procedures. (6 sch: 18-hr lecture)

Corequisite: Nuclear Medicine Procedures II (NMT 2534)

Competencies and Suggested Objectives	
1.	Review facility policies related to the nuclear medicine department and hospital. <ol style="list-style-type: none"> a. Locate the facility policy manual, the department procedure manual, and fire and emergency equipment. b. Perform fire safety, health emergency, and disaster procedures according to facility policies and procedures. c. Adhere to OSHA and state health department safety policies. d. Locate supplies within the department and obtain supplies, as necessary, from in-house sources. e. Schedule patients for nuclear medicine studies following facility procedures. f. Maintain patient and department records as required by state and federal regulations and facility policies.
2.	Review all aspects of patient care. <ol style="list-style-type: none"> a. Explain nuclear medicine procedures to patients and their families, and appropriately answer their questions concerning the procedures and the radiation involved. (The student should be able to explain frequently performed procedures without reference to notes. The student should be able to explain less frequently performed procedures after referring to the procedure manual.) b. Use communication techniques appropriate to the patient's age group, physical/mental/emotion state, and ability to communicate. c. Identify the patient using procedures established by regulation and/or facility protocols. d. Verify requisitions, and assess the appropriateness of the indication for the test; determine if the patient can perform/tolerate the test; and take the appropriate action if the indication is questionable or if a diagnostic study may not be obtained. e. Transport and transfer the patient safely using proper body mechanics. f. Practice infection control in all circumstances. g. Prevent, and when necessary, control patient-related radionuclide contamination. h. Provide for the patient's basic needs, as appropriate for a nuclear medicine technologist. i. Monitor support equipment (such as IV pumps and oxygen supplies) for the patient while in the nuclear medicine department. j. Measure pulse, respiration and blood pressure. k. Administer radioactive and nonradioactive drugs by the following routes, as allowed by federal and state regulations, and facility policy, using septic technique, universal

precautions, and required protocols:

- (1) Intravenous injection
- (2) Injection through an existing angiocatheter
- (3) Oral
- (4) Inhalation
- (5) Intramuscular injection
- (6) Subcutaneous injection
- (7) Urinary catheter

- l. Assist the physician with intrathecal and intracavitary injections.
- m. Assist the physician with administration of therapeutic radionuclides.
- n. Place in intravenous catheter, as allowed by state regulation and facility policy, using septic technique, universal precautions, and required protocols.

3. Display characteristics appropriate for the nuclear medicine professional.

- a. Demonstrate cooperation, and act as a team member at both the departmental and institutional level.
- b. Demonstrate professional etiquette in dealing with patients, families, visitors, other health care workers, support staff, and in communications with other facilities (such as physicians' offices).
- c. Demonstrate conflict prevention and resolution behaviors and techniques in the work setting.
- d. Demonstrate the ability to handle difficult people and work situations, such as an angry patient, using behaviors and techniques that diffuse or solve the problem or prevent the situation from worsening.
- e. Demonstrate professional behaviors including showing openness to learning; taking initiative and assuming responsibilities as appropriate to training; showing confidence as clinical skills are mastered; and maintaining personal hygiene and a professional appearance.
- f. Demonstrate calmness when the department is busy and multiple demands are made on the student.
- g. Perform two or more tasks simultaneously when training and skill level have reached an appropriate level.
- h. Recognize problems in the clinical setting, and demonstrate a rational, step-wise process to analyze and attempt to solve the problem.
- i. Respect the patient's privacy, and maintain patient confidentiality.
- j. Obtain consent for a test from a patient or the appropriate person as required and/or allowed by regulation and/or facility policy.

4. Display radiation protection practices.

- a. Use survey meters properly.
- b. Wear personal monitoring devices, and perform personal surveys as required by regulation and facility policy.
- c. Correctly read and evaluate radiation exposure reports.
- d. Utilize appropriate radiation safety precautions and procedures.
- e. Follow facility and regulatory guidelines when checking in packages containing radioactive materials and when preparing radioactive materials for shipment.
- f. Monitor waste and store radioactive waste according to facility and regulatory requirements.

<ul style="list-style-type: none"> g. Determine when radioactive waste can be disposed of as nonradioactive waste according to regulations. h. Perform surveys and wipe tests for radionuclidic contamination according to regulatory and facility requirements. i. Demonstrate correct procedures for cleanup when radionuclidic contamination is identified. j. Demonstrate correct procedures for containing and cleaning up a radioactive spill. k. Demonstrate preparation of an isolation room to be used for a patient who has received a high dose of I131, and demonstrate the procedure for surveying and cleaning the room prior to returning it to regular use.
<p>5. Carry out procedures related to non-imaging instrumentation.</p> <ul style="list-style-type: none"> a. Check the functional status of a survey meter. b. Correctly employ a survey meter to detect radioactive contamination (or sources). c. Select parameters and correctly use a well counter for counting wipes and samples. d. Select parameters and correctly use an uptake probe to perform in vivo counting. e. Perform daily quality control checks on a well counter and/or uptake probe, such as background counts, constancy and/or sensitivity. f. Perform chi-square test on a well counter and/or uptake probe. g. Perform an energy resolution test on a well counter and/or uptake probe. h. Select parameters and correctly position radioactive materials in a dose calibrator for correct measurement. i. Perform daily quality control checks on a dose calibrator, including background check and constancy. j. Perform a linearity test on a dose calibrator. k. Perform an accuracy test on a dose calibrator. l. Perform geometric variation tests on a dose calibrator. m. Demonstrate proper use of manual and semiautomatic pipettes when measuring radioactive standards and/or samples.
<p>6. Carry out procedures related to imaging instrumentation.</p> <ul style="list-style-type: none"> a. Select the appropriate camera and collimator for various nuclear medicine studies. b. Select appropriate camera and/or computer parameters for various nuclear medicine studies. c. Perform uniformity tests on a gamma camera. d. Perform linearity and resolution tests on a gamma camera. e. Perform uniformity correction map acquisition procedures. f. Perform the center of rotation test on a SPECT camera.
<p>7. Carry out computer applications.</p> <ul style="list-style-type: none"> a. Use standard nuclear medicine computer programs to correctly draw regions of interest for various quantitative nuclear medicine studies. b. Perform cardiac axis orientation using standard cardiac myocardial perfusion processing programs. c. Use standard nuclear medicine computer programs to produce histograms or other graphs for various quantitative nuclear medicine studies. d. Select and apply filters to nuclear medicine studies as required. e. Prepare comparative displays of images on screen or on hard copy. f. Perform subtraction studies using standard nuclear medicine computer programs.

<ul style="list-style-type: none">g. Adjust image contrast to provide maximum image enhancement without decreasing the accuracy of the study.h. Present computer-generated data in appropriate forms for various nuclear medicine studies.
<p>8. Use correct radiopharmacy techniques.</p> <ul style="list-style-type: none">a. Select and confirm the appropriate radiopharmaceutical for various nuclear medicine studies.b. Perform thin layer chromatography on radiopharmaceuticals.c. Check reconstituted kits and tagged blood cells for acceptable appearance.d. Test generator eluate for molybdenum content.e. Label syringes and vials containing radiopharmaceuticals as required by regulations and facility protocols.f. Prepare radiopharmaceuticals from freeze-dried kits, including calculating amount of eluate and saline to be added.g. Prepare radiopharmaceutical doses from bulk kits, including calculating volume to drawn.h. Adjust unit doses to provide doses different from that provided at the calibration time, including calculating volume to be discarded.i. Withdraw blood to be used for tagged blood cells.j. Tag red blood cells.k. Tag white blood cells (if state regulations and facility policy allows).
<p>9. Carry out diagnostic procedures according to departmental procedure manual.</p> <ul style="list-style-type: none">a. Maintain patient safety throughout procedures.b. Acquire images at the appropriate times, according to protocol.c. Acquire images at the appropriate projections, according to protocol.d. Acquire additional views as needed, at the appropriate time and/or projection.e. Adapt standard techniques to accommodate patient needs and/or limitations.f. Process and print data according to protocol.g. Format and print images according to protocol.h. Evaluate images and/or data for artifacts and possible errors, and take appropriate actions if artifacts or errors are suspected.i. Label images and graphical data according to protocol.j. Complete all paperwork, and obtain previous studies, X-ray file folders, and so forth, and present completed imaging study to physician for review as required by protocol.k. Collect urine and/or blood samples at appropriate intervals and in correct containers.l. Prepare samples for counting according to protocol.m. Count samples and standards using appropriate settings and geometry.n. Prepare standards according to protocol.o. Use appropriate settings and geometry for in vivo counting.p. Process data from non-imaging studies according to protocol.q. Evaluate non-imaging data for possible errors, and take appropriate actions if errors are suspected.r. Complete all paperwork and obtain previous studies, X-ray file folders, and so forth, and present completed non-imaging study to physician for review as required by protocol.
<p>10. View radionuclide therapy.</p>

<ul style="list-style-type: none"> a. Confirm patient identification. b. Confirm written directive. c. Calibrate therapy dose. d. Reiterate instructions given to patient by physician.
<p>11. Carry out clinical competencies and electives.</p> <ul style="list-style-type: none"> a. Perform two cardiac clinical competencies. b. Perform two brain clinical electives. c. Perform two gastrointestinal clinical competencies (digestive). d. Perform two hematopoietic/lymphatic clinical competencies. e. Perform two radioassay clinical electives. f. Perform one receptor imaging clinical competency. g. Perform one radionuclide therapy clinical competency (may be simulated). h. Perform three SPECT imaging procedures from various areas.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

R1	Interpret Graphic Information (forms, maps, reference sources)
R2	Words in Context (same and opposite meaning)
R3	Recall Information (details, sequence)
R4	Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
R5	Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
M1	Addition of Whole Numbers (no regrouping, regrouping)
M2	Subtraction of Whole Numbers (no regrouping, regrouping)
M3	Multiplication of Whole Numbers (no regrouping, regrouping)
M4	Division of Whole Numbers (no remainder, remainder)
M5	Decimals (addition, subtraction, multiplication, division)
M6	Fractions (addition, subtraction, multiplication, division)
M7	Integers (addition, subtraction, multiplication, division)

Postsecondary Nuclear Medicine Technology

- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Course Name: Clinical III

Course Abbreviation: NMT 2833

Classification: Vocational–Technical Core

Description: This course continues the integration of didactic learning into the practical setting. Record keeping and quality control results are an integral part of all procedures. (6 sch: 18-hr lecture)

Prerequisite: Clinical II (NMT 2826)

Competencies and Suggested Objectives	
1.	Summarize facility policies related to the nuclear medicine department and hospital. <ol style="list-style-type: none"> a. Locate the facility policy manual, the department procedure manual, and fire and emergency equipment. b. Perform fire safety, health emergency, and disaster procedures according to facility policies and procedures. c. Adhere to OSHA and state health department safety policies. d. Locate supplies within the department and obtain supplies, as necessary, from in-house sources. e. Schedule patients for nuclear medicine studies following facility procedures. f. Maintain patient and department records as required by state and federal regulations and facility policies.
2.	Summarize all aspects of patient care. <ol style="list-style-type: none"> a. Explain nuclear medicine procedures to patients and their families, and appropriately answer their questions concerning the procedures and the radiation involved. (The student should be able to explain frequently performed procedures without reference to notes. The student should be able to explain less frequently performed procedures after referring to the procedure manual.) b. Use communication techniques appropriate to the patient's age group, physical/mental/emotion state, and ability to communicate. c. Identify the patient using procedures established by regulation and/or facility protocols. d. Verify requisitions and assess the appropriateness of the indication for the test; determine if the patient can perform/tolerate the test; and take the appropriate action if the indication is questionable or if a diagnostic study may not be obtained. e. Transport and transfer the patient safely using proper body mechanics. f. Practice infection control in all circumstances. g. Prevent, and when necessary, control patient-related radionuclide contamination. h. Provide for the patient's basic needs, as appropriate for a nuclear medicine technologist. i. Monitor support equipment (such as IV pumps and oxygen supplies) for the patient while in the nuclear medicine department. j. Measure pulse, respiration, and blood pressure. k. Administer radioactive and nonradioactive drugs by the following routes, as allowed by federal and state regulations, and facility policy, using septic technique, universal

precautions, and required protocols:

- (1) Intravenous injection
- (2) Injection through an existing angiocatheter
- (3) Oral
- (4) Inhalation
- (5) Intramuscular injection
- (6) Subcutaneous injection
- (7) Urinary catheter

- l. Assist the physician with intrathecal and intracavitary injections.
- m. Assist the physician with administration of therapeutic radionuclides.
- n. Place in intravenous catheter, as allowed by state regulation and facility policy, using septic technique, universal precautions, and required protocols.

3. Display characteristics appropriate for the nuclear medicine professional.

- a. Demonstrate cooperation, and act as a team member at both the departmental and institutional level.
- b. Demonstrate professional etiquette in dealing with patients, families, visitors, other health care workers, support staff, and in communications with other facilities (such as physicians' offices).
- c. Demonstrate conflict prevention and resolution behaviors and techniques in the work setting.
- d. Demonstrate the ability to handle difficult people and work situations, such as an angry patient, using behaviors and techniques that diffuse or solve the problem or prevent the situation from worsening.
- e. Demonstrate professional behaviors including showing openness to learning; taking initiative and assuming responsibilities as appropriate to training; showing confidence as clinical skills are mastered; and maintaining personal hygiene and a professional appearance.
- f. Demonstrate calmness when the department is busy and multiple demands are made on the student.
- g. Perform two or more tasks simultaneously when training and skill level have reached an appropriate level.
- h. Recognize problems in the clinical setting and demonstrate a rational, step-wise process to analyze and attempt to solve the problem.
- i. Respect the patient's privacy, and maintain patient confidentiality.
- j. Obtain consent for a test from a patient or the appropriate person as required and/or allowed by regulation and/or facility policy.

4. Exhibit radiation protection practices.

- a. Use survey meters properly.
- b. Wear personal monitoring devices, and perform personal surveys as required by regulation and facility policy.
- c. Correctly read and evaluate radiation exposure reports.
- d. Utilize appropriate radiation safety precautions and procedures.
- e. Follow facility and regulatory guidelines when checking in packages containing radioactive materials and when preparing radioactive materials for shipment.
- f. Monitor waste and store radioactive waste according to facility and regulatory requirements.

<ul style="list-style-type: none"> g. Determine when radioactive waste can be disposed of as nonradioactive waste according to regulations. h. Perform surveys and wipe tests for radionuclidic contamination according to regulatory and facility requirements. i. Demonstrate correct procedures for cleanup when radionuclidic contamination is identified. j. Demonstrate correct procedures for containing and cleaning up a radioactive spill. k. Demonstrate preparation of an isolation room to be used for a patient who has received a high dose of I131, and demonstrate the procedure for surveying and cleaning the room prior to returning it to regular use.
<p>5. Complete procedures related to non-imaging instrumentation.</p> <ul style="list-style-type: none"> a. Check the functional status of a survey meter. b. Correctly employ a survey meter to detect radioactive contamination (or sources). c. Select parameters and correctly use a well counter for counting wipes and samples. d. Select parameters and correctly use an uptake probe to perform in vivo counting. e. Perform daily quality control checks on a well counter and/or uptake probe, such as background counts, constancy, and/or sensitivity. f. Perform a chi-square test on a well counter and/or uptake probe. g. Perform an energy resolution test on a well counter and/or uptake probe. h. Select parameters and correctly position radioactive materials in a dose calibrator for correct measurement. i. Perform daily quality control checks on a dose calibrator, including background check and constancy. j. Perform a linearity test on a dose calibrator. k. Perform an accuracy test on a dose calibrator. l. Perform geometric variation tests on a dose calibrator. m. Demonstrate proper use of manual and semiautomatic pipettes when measuring radioactive standards and/or samples.
<p>6. Complete procedures related to imaging instrumentation.</p> <ul style="list-style-type: none"> a. Select the appropriate camera and collimator for various nuclear medicine studies. b. Select appropriate camera and/or computer parameters for various nuclear medicine studies. c. Perform uniformity tests on a gamma camera. d. Perform linearity and resolution tests on a gamma camera. e. Perform uniformity correction map acquisition procedures. f. Perform the center of rotation test on a SPECT camera.
<p>7. Complete computer applications.</p> <ul style="list-style-type: none"> a. Use standard nuclear medicine computer programs to correctly draw regions of interest for various quantitative nuclear medicine studies. b. Perform cardiac axis orientation using standard cardiac myocardial perfusion processing programs. c. Use standard nuclear medicine computer programs to produce histograms or other graphs for various quantitative nuclear medicine studies. d. Select and apply filters to nuclear medicine studies as required. e. Prepare comparative displays of images on screen or on hard copy. f. Perform subtraction studies using standard nuclear medicine computer programs.

- | |
|--|
| <ul style="list-style-type: none">g. Adjust image contrast to provide maximum image enhancement without decreasing the accuracy of the study.h. Present computer generated data in appropriate forms for various nuclear medicine studies. |
| <p>8. Complete correct radiopharmacy techniques.</p> <ul style="list-style-type: none">a. Select and confirm the appropriate radiopharmaceutical for various nuclear medicine studies.b. Perform thin layer chromatography on radiopharmaceuticals.c. Check reconstituted kits and tagged blood cells for acceptable appearance.d. Test generator eluate for molybdenum content.e. Label syringes and vials containing radiopharmaceuticals as required by regulations and facility protocols.f. Prepare radiopharmaceuticals from freeze-dried kits, including calculating amount of eluate and saline to be added.g. Prepare radiopharmaceutical doses from bulk kits, including calculating volume to drawn.h. Adjust unit doses to provide doses different from that provided at the calibration time, including calculating volume to be discarded.i. Withdraw blood to be used for tagged blood cells.j. Tag red blood cells.k. Tag white blood cells (if state regulations and facility policy allows). |
| <p>9. Complete diagnostic procedures according to departmental procedure manual.</p> <ul style="list-style-type: none">a. Maintain patient safety throughout procedures.b. Acquire images at the appropriate times, according to protocol.c. Acquire images at the appropriate projections, according to protocol.d. Acquire additional views as needed, at the appropriate time and/or projection.e. Adapt standard techniques to accommodate patient needs and/or limitations.f. Process and print data according to protocol.g. Format and print images according to protocol.h. Evaluate images and/or data for artifacts and possible errors, and take appropriate actions if artifacts or errors are suspected.i. Label images and graphical data according to protocol.j. Complete all paperwork, and obtain previous studies, X-ray file folders, and so forth, and present completed imaging study to physician for review as required by protocol.k. Collect urine and/or blood samples at appropriate intervals and in correct containers.l. Prepare samples for counting according to protocol.m. Count samples and standards using appropriate settings and geometry.n. Prepare standards according to protocol.o. Use appropriate settings and geometry for in vivo counting.p. Process data from non-imaging studies according to protocol.q. Evaluate non-imaging data for possible errors, and take appropriate actions if errors are suspected.r. Complete all paperwork, and obtain previous studies, X-ray file folders, and so forth, and present completed non-imaging study to physician for review as required by protocol. |
| <p>10. Examine radionuclide therapy.</p> |

- a. Confirm patient identification.
- b. Confirm written directive.
- c. Calibrate therapy dose.
- d. Reiterate instructions given to patient by physician.

STANDARDS

ARRT Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

NMTCB Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

Related Academic Standards

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)
- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations
- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)

- A8 Estimation (rounding, estimation)
- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)
- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

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21st Century Skills

- CS1 Global Awareness
- CS2 Financial, Economic, and Business Literacy
- CS3 Civic Literacy
- CS4 Information and Communication Skills
- CS5 Thinking and Problem-Solving Skills
- CS6 Interpersonal and Self-Directional Skills

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Recommended Tools and Equipment

CAPITALIZED ITEMS

1. Equipment items for Nuclear Medicine Technology are provided at clinical sites.

NON-CAPITALIZED ITEMS

2. Other items for Nuclear Medicine Technology are provided at clinical sites.

RECOMMENDED INSTRUCTIONAL AIDS

It is recommended that instructors have access to the following items:

1. Computer
2. DVD player
3. Projector

Appendix A: Industry Standards¹

American Registry of Radiologic Technologists (ARRT) Content Specifications for the Examination in Nuclear Medicine Technology

ARRT1	Radiation Protection
ARRT2	Radionuclides and Radiopharmaceuticals
ARRT3	Instrumentation and Quality Control
ARRT4	Diagnostic and Therapeutic Procedures
ARRT5	Patient Care and Education

Nuclear Medicine Technology Certification Board (NMTCB) Components of Preparedness

NMTCB1	Radiation Safety
NMTCB2	Instrumentation
NMTCB3	Clinical Procedures
NMTCB4	Radiopharmacy

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Appendix B: Related Academic Standards²

Reading

- R1 Interpret Graphic Information (forms, maps, reference sources)
- R2 Words in Context (same and opposite meaning)
- R3 Recall Information (details, sequence)
- R4 Construct Meaning (main idea, summary/paraphrase, compare/contrast, cause–effect)
- R5 Evaluate/Extend Meaning (fact/opinion, predict outcomes, point of view)

Mathematics Computation

- M1 Addition of Whole Numbers (no regrouping, regrouping)
- M2 Subtraction of Whole Numbers (no regrouping, regrouping)
- M3 Multiplication of Whole Numbers (no regrouping, regrouping)
- M4 Division of Whole Numbers (no remainder, remainder)
- M5 Decimals (addition, subtraction, multiplication, division)
- M6 Fractions (addition, subtraction, multiplication, division)
- M7 Integers (addition, subtraction, multiplication, division)
- M8 Percents
- M9 Algebraic Operations

Applied Mathematics

- A1 Numeration (ordering, place value, scientific notation)
- A2 Number Theory (ratio, proportion)
- A3 Data Interpretation (graph, table, chart, diagram)
- A4 Pre-Algebra and Algebra (equations, inequality)
- A5 Measurement (money, time, temperature, length, area, volume)
- A6 Geometry (angles, Pythagorean theory)
- A7 Computation in Context (whole numbers, decimals, fractions, algebraic operations)
- A8 Estimation (rounding, estimation)

Language

- L1 Usage (pronoun, tense, subject–verb agreement, adjective, adverb)
- L2 Sentence Formation (fragments, run-on, clarity)
- L3 Paragraph Development (topic sentence, supporting sentence, sequence)
- L4 Capitalization (proper noun, titles)
- L5 Punctuation (comma, semicolon)
- L6 Writing Conventions (quotation marks, apostrophe, parts of a letter)

Spelling

- S1 Vowel (short, long)
- S2 Consonant (variant spelling, silent letter)
- S3 Structural Unit (root, suffix)

² CTB/McGraw-Hill LLC. (1994). *Tests of adult basic education, forms 7 and 8*. Monterey, CA: Author. Reproduced with permission of CTB/McGraw-Hill LLC. TABE is a registered trademark of The McGraw-Hill Companies, Inc. Copyright © 1994 by CTB/McGraw-Hill LLC. Reproduction of this material is permitted for educational purposes only.

Appendix C: 21st Century Skills³

CS1 Global Awareness

- Using 21st century skills to understand and address global issues
- Learning from and working collaboratively with individuals representing diverse cultures, religions, and lifestyles in a spirit of mutual respect and open dialogue in personal, work, and community contexts
- Promoting the study of non-English language as a tool for understanding other nations and cultures

CS2 Financial, Economic, and Business Literacy

- Knowing how to make appropriate personal economic choices
- Understanding the role of the economy and the role of business in the economy
- Applying appropriate 21st century skills to function as a productive contributor within an organizational setting
- Integrating oneself within and adapting continually to our nation's evolving economic and business environment

CS3 Civic Literacy

- Being an informed citizen to participate effectively in government
- Exercising the rights and obligations of citizenship at local, state, national, and global levels
- Understanding the local and global implications of civic decisions
- Applying 21st century skills to make intelligent choices as a citizen

CS4 Information and Communication Skills

- Information and media literacy skills: Analyzing, accessing, managing, integrating, evaluating, and creating information in a variety of forms and media; understanding the role of media in society
- Communication skills: Understanding, managing, and creating effective oral, written, and multimedia communication in a variety of forms and contexts

CS5 Thinking and Problem-Solving Skills

- Critical thinking and systems thinking: Exercising sound reasoning in understanding and making complex choices, understanding the interconnections among systems
- Problem identification, formulation, and solution: Ability to frame, analyze, and solve problems
- Creativity and intellectual curiosity: Developing, implementing, and communicating new ideas to others, staying open and responsive to new and diverse perspectives

CS6 Interpersonal and Self-Directional Skills

- Interpersonal and collaborative skills: Demonstrating teamwork and leadership, adapting to varied roles and responsibilities, working productively with others, exercising empathy, respecting diverse perspectives
- Self-direction: Monitoring one's own understanding and learning needs, locating appropriate resources, transferring learning from one domain to another
- Accountability and adaptability: Exercising personal responsibility and flexibility in personal, workplace, and community contexts; setting and meeting high standards and goals for one's self and others; tolerating ambiguity

³ *21st century skills*. (n.d.). Washington, DC: Partnership for 21st Century Skills.

- Social responsibility: Acting responsibly with the interests of the larger community in mind; demonstrating ethical behavior in personal, workplace, and community contexts