Certification

NMTCB Certification Examination Validation Report

The Nuclear Medicine Technology Certification Board

In 1977 the Directors of the Nuclear Medicine Technology Certification Board (NMTCB) set a goal to develop a true criterion-referenced examination to assess the mastery level of the individual technologist. To meet its goal, the NMTCB used an examination development methodology associated with criterion-referenced examination development. In criterion-referenced examinations the questions are written with the intent of testing job-related knowledge and skills essential for competent practice. In this way, an examinee's performance is reliably compared to a job-related base of knowledge and not with the performance of fellow examinees. To ensure job relatedness, the NMTCB derived a task analysis with input from practicing technologists across the country. The examination content has been and continues to be based upon the tasks enumerated and the implied skill and knowledge necessary to perform those tasks. This Task Analysis was printed in the June 1979 issue of the *Journal of Nuclear Medicine Technology*.

Since the Task Analysis is used to develop the NMTCB exam, it is crucial that it be validated. In 1981 the NMTCB initiated validation of the Task Analysis to verify that all significant tasks were representative of the job of a nuclear medicine technologist and that the weights assigned to each content area on the exam reflected the relative emphasis given each topic in learning and application of knowledge. This validation study was conducted in collaboration with the Vocational Technical Education Consortium of States, a component of the Commission on Occupational Institutions, Southern Association of Colleges and Schools.

One hundred and sixty-two full-time nuclear medicine technologists across the country received a background information questionnaire, a 93-item equipment list, and a list of tasks organized under duty areas as performed by nuclear medicine technologists. Survey participants were asked to identify equipment used and the tasks performed on the job in each duty area. To assess the relative time spent on the job performing a validated set of tasks, respondents rated tasks within a duty area using a 7-point, time-spent scale.

All information was analyzed using computer programs from the Statistical Package for Social Sciences. The analysis routines included basic descriptive statistics on each task and piece of equipment, and frequency data on each respondent's hospital size, technical area, department size, and certification board(s). Cross-tabulations among all parameters were performed. Frequency data on each task in relationship to the 7-point, time-spent scale were also generated.

The Board developed criteria for task validity, which included the percentage of respondents performing a task, the relative time spent in task performance, and the degree of a task's criticality. Based on the validation procedure, the Task Analysis and Examination Content Specifications Outline were revised. The Task Analysis major group titles were reorganized for clarity as the following: Group I—Radiation Protection, Radiopharmacy, and Therapy, Group II—Instrumentation, Group III—Imaging Procedures, and Group IV—Nonimaging Procedures including both radiobioassay and radioimmunoassay. Groups were numbered so that the associated tasks, which may not have been defined by previous arbitrary titles, could be included. Additionally, the validation study supported the inclusion of computers under Groups II and III and greater emphasis on patient care in Group III. Teaching radiobiology concepts to other hospital personnel was deleted because this was not validated as a career entry task.

Content Guidelines were written to define the knowledge necessary to perform the job functions outlined in the Task Analysis. The 1983 NMTCB exam as well as subsequent exams will reflect this validated data. As new technologies enter routine nuclear medicine practice, the Task Analysis, Content Guidelines, and Content Specifications Outline will be revised accordingly.

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NMTCB Task Analysis of Nuclear Medicine Technology

I. Group I

A. Maintain local, state or federal license and assure compliance with Nuclear Regulatory Commission (NRC), Food and Drug Administration (FDA), and Joint Commission on Accreditation of Hospitals (JCAH) regulations and standards:
   1. Notify appropriate authority when change in radiation safety program occurs.
   2. Amend radioactive materials license when necessary.
   3. Review regulations periodically.
   4. Maintain required radiation records.
   5. Post appropriate signs in designated areas.
   6. Design program to follow regulations regarding receipt and disposition of all radiopharmaceuticals.
   7. Design and initiate program to comply with regulations regarding therapeutic radiopharmaceuticals and follow-up data.
   8. Recommend purchase of radiation protection equipment to comply with regulations.
   9. Package radioactive material according to regulations and maintain accurate written records of transfer.

B. Follow appropriate protection procedures:
   1. Employ patient and personnel monitoring devices—
      a. review monthly personnel exposure records in regard to maximum permissable radiation dose limits;
      b. take appropriate measures to reduce radiation exposure when necessary;
      c. keep exposure as low as is reasonably achievable using appropriate protection parameters continuously;
      d. notify NRC of excessive radiation exposure or misadministration when appropriate.
   2. Select and use proper shielding to reduce radiation exposure from radioactive materials, i.e., employ inverse square law and half-value layers.
   3. Use proper methods for storage of radioactive drugs.
   4. Identify and use proper procedures for radioactive drugs that pose special hazards.
   5. Instruct patient, family, and hospital staff in radiation safety precautions after administration of diagnostic and therapeutic radiopharmaceuticals.
   6. Provide instruction on proper radiation emergency procedures to be followed until radiation personnel arrive.

C. Perform radiation surveys:
   1. Perform quality control on survey instruments.
   2. Set frequency and locations for surveys and follow schedule.
   3. Use proper survey meters for each type and level of activity.
   4. Follow regulations regarding personnel surveys and interpret results.
   5. Perform wipe tests where applicable.
   6. Survey hospitalized patients who have received radioactive therapy.
   7. Perform leak tests on sealed sources when appropriate.
   8. Record data in some standard format.

D. Maintain radiopharmaceutical laboratory:
   1. Initiate purchase orders for radiopharmaceuticals and other supplies.
   2. Perform wipe tests of exterior package on radioactive shipments.
   3. Log receipt and wipe test results of radioactive materials.
   4. Monitor all packaging materials and deface radiation symbol on boxes before discarding.
   5. Store radioactive materials and nonradioactive kits in appropriate areas.
   6. Determine necessity for reorder of radiopharmaceuticals and kits to prevent patient study delays.

E. Obtain generator eluate:
   1. Assemble generator and position behind lead barriers.
   2. Elute generator using aseptic technique.
   3. Assay eluate using dose calibrator or whole-vial assay.
   4. Record assay results and time in log book.
   5. Check eluate for radionuclidic and chemical contamination and record results.

F. Compound radiopharmaceuticals:
   1. Review daily work schedule and prepare appropriate radiopharmaceutical compounds using [^{99m}Tc] pertechnetate to include sulfur colloid, microspheres or macroaggregated albumin, phosphates, DTPA, etc.
   2. Determine total radioactivity to be added to radiopharmaceutical kit and record volume of generator eluate used. Be aware of any activity limits in preparation of kits.
   3. Prepare radiopharmaceutical assay form for each lot of material.
   4. Check total activity in reaction vials with dose calibrator.
   5. Calculate concentration of radioactivity in the radioactive compound and label vial as to date and time of preparation, lot number, concentration, and volume.
   6. Check all preparations for proper pH, color, clarity, and particle size if appropriate and record on radiopharmaceutical assay form.
   7. Determine radiochemical purity of compound by chromatography or electrophoresis.
   8. Perform sterility and apyrogenicity testing when appropriate.

G. Dispense radiopharmaceuticals:
   1. Quantitate activity of radiopharmaceutical—
      a. verify information on radiopharmaceutical vial including concentration, specific activity, total activity, lot number, assay time, and date;
      b. determine elapsed time between initial and required assay;
      c. calculate activity using appropriate decay factor for time elapsed;
      d. calculate activity to be administered for diagnostic

and therapeutic procedures;
e. determine volume or number of capsules of the radiopharmaceutical required for diagnostic and therapeutic procedures.

2. Prepare activity to be administered—
   a. dispense liquid preparation—
      1) draw up correct volume of radiopharmaceutical into syringe using aseptic technique and observing proper radiation safety precautions;
      2) verify (using dose calibrator) the activity to be administered;
      3) verify that radionuclidic impurity limits are not exceeded;
      4) record patient name, examination, radiopharmaceutical activity, volume, lot number, time, date, and prescription number, if appropriate.
   b. dispense gaseous preparation—
      1) calibrate and dispense radioactive gas from bulk load system or unit dose system;
      2) load radioactive gas into administration machine if appropriate;
      3) maintain appropriate records.
   c. dispense capsule preparation—
      1) verify (using a dose calibrator) activity to be administered;
      2) verify that radionuclidic impurity limits are not exceeded;
      3) record patient name, examination, radiopharmaceutical activity, volume, lot number, time, date, and prescription number, if appropriate.

H. Administer the radiopharmaceutical (diagnostic and therapeutic):
   1. Determine proper method and route of administration.
   2. Assemble proper materials for intravenous, gaseous, or oral administration.
   3. Reassure patient and try to relieve any apprehension.
   4. Administer the radioactive drug using proper technique.
   5. Observe patient for possible reactions.
   6. Discard contaminated materials in appropriate waste containers.

I. Dispose of radioactive waste:
   1. Monitor all radioactive materials and determine if acceptable to discard.
   2. Monitor alumina columns from generators to determine if acceptable to discard.
   3. Maintain long-term storage area to allow for decay of radioactivity.
   4. Dispose of all contaminated material when appropriate.
   5. Maintain log of radiopharmaceutical disposal.

J. Decontaminate area:
   1. Notify persons in the area that a spill has occurred.
   2. Cover spill with absorbent paper to prevent spread.
   3. Check area around spill, hands, and clothing for contamination.
   4. Clean area of the spill.
   5. Survey area to determine if contamination has been removed.
   6. Report the incident to the Radiation Control Officer.
   7. Record details of spill and corrective action in laboratory survey logbook.

II. Group II

A. Evaluate scintillation counter performance:
   1. Perform energy linearity check at installation.
   2. Perform volumetric standardization at time of installation.
   3. Calibrate with Cs-137.
   4. Determine percent full width at half maximum (FWHM) energy resolution.
   5. Conduct sensitivity checks.
   6. Check background and determine cause for higher-than-normal background.
   7. Take 60-cycle test count if possible.
   8. Conduct a chi-square testing analysis.
   9. Maintain records of these procedures as required.

B. Perform routine imaging system quality control:
   1. Scintillation cameras—
      a. Perform field uniformity check—
         1) select radionuclide source of appropriate activity and energy;
         2) check pulse height analyzer (PHA) photopeak adjustment:
         3) obtain uniformity images using identical standardized imaging parameters, i.e., counts, information density (I.D.), intensity, etc.
      b. Analyze field uniformity images—
         1) compare with previous uniformity image and identify any nonuniformities;
         2) differentiate source of nonuniformities using proper procedures, i.e., check collimator, pulse height analyzer peaking, detector, cathode ray tube, lenses, etc.
         3) obtain service if indicated.
      c. Perform detector linearity check—
         1) position radioactive source and parallel line phantom for linearity check;
         2) obtain two images oriented 90° to each other using standardized imaging parameters;
         3) identify any line distortion on image;
         4) determine source of nonlinearity, i.e., camera system components, detector-source geometry, and arrange for service if nonlinearity is present.
      d. Perform spatial resolution checks—
         1) use uniformity check source;
         2) utilize a high resolution phantom compatible with the specified resolution of the camera;
         3) obtain resolution images oriented 90° to each other using standardized imaging parameters;
         4) compare with prior resolution images;
         5) obtain service if resolution degradation is observed.

e. Conduct sensitivity checks—
   1) position radioactive source with an appropriate half-life;
   2) assure that identical geometry and measurement parameters are used each time.
f. Check image recording equipment—
   1) perform lens focus check;
   2) check and adjust cathode ray tube dot focus and shape;
   3) assess integrity of cathode ray tube phosphor.
g. Maintain required records for quality control checks.

2. Rectilinear scanners—
   a. Assess performance of NaI(Tl) scintillation spectrometer—
      1) calibrate with Cs-137.
      2) determine percent FWHM energy resolution;
      3) conduct a sensitivity check;
      4) perform a 60-cycle test count if available.
   b. Check calibration of photorecorder—
      1) compare three film exposures taken at three different information densities to determine equal film density;
      2) assess operation of contrast enhancement and background erase using a transmission gray wedge;
      3) compare with previous results to determine any changes in system operation.
   c. Maintain required records for quality control procedures.

C. Operate gas-filled detectors:
   1. Survey meters (G-M tubes)—
      a. calibrate according to NRC specifications;
      b. perform reference check source test and compare with previous results;
      c. maintain records as required.
   2. Dose calibrator (ionization chamber)—
      a. ascertain linearity over entire range of radionuclide activity to be measured;
      b. test for significant geometrical variation in activity measured as a function of sample volume or configuration and determine correction factors;
      c. test accuracy for commonly used radionuclides that have adequate reference standards available;
      d. check for constancy using a long-lived radionuclide standard;
      e. maintain records of procedures as required.

D. Identify proper computer operation:
   1. Perform basic operations and recognize "normal" operating modes.
   2. Identify general problem areas and notify appropriate personnel when required.
   3. Check for gray scale image reproduction.
   4. Maintain temperature and humidity levels for proper computer operation.
   5. Maintain data storage media, i.e., magnetic tape, disk, diskette.
   6. Maintain set of updated manuals with software documentation of protocols.

III. Group III

A. Perform administrative procedures:
   1. Maintain adequate supplies of radiopharmaceuticals and all other materials including film to ensure that patient studies are performed in a timely fashion.
   2. Schedule patient studies, ensuring appropriateness. Interact with hospital staff to effect proper and timely arrangements for patient study.
   3. Determine most appropriate sequence for multiple procedures.
   4. Maintain appropriate records of radiopharmaceutical dosages, quality control procedures, patient reports, and other required records.
   5. Maintain an updated procedure manual on a regular periodic basis.

B. Provide patient care:
   1. Receive patient and provide proper nursing care during imaging procedure.
   2. Provide patient comfort, before, during, and after the procedure.
   3. Maintain good communication with patient, explain procedure, answer questions, and listen to patient's comments.
   4. Provide functionally safe and sanitary conditions for patient.
   5. Recognize emergency conditions—
      a. determine vital signs when necessary, including pulse rate, respiratory rate, temperature, and blood pressure;
      b. administer cardiopulmonary resuscitation when necessary;
      c. maintain intravenous fluids, oxygen, and other life-support equipment;
      d. administer first aid.
   6. Maintain emergency tray.

C. Prepare patient:
   1. Verify patient identification and written orders for study.
   2. Check procedural contraindications and obtain pertinent patient history.
   3. Obtain informed consent when necessary.
   4. Check patient, clothing, and linen for objects, scars, inflamed areas, etc., that may attenuate and contaminate.
   5. Prepare patient with premedications, i.e., Lugol's, perchlorate, and instruct patient to void, etc. Include any necessary preparation required for imaging procedure.
   6. Transfer patient from wheelchair/stretcher to imaging table.
   7. Administer appropriate radiopharmaceutical to patient by appropriate route.
   8. Wait appropriate length of time after administration of radiopharmaceutical to begin imaging procedure.

D. Perform imaging procedures:
   1. Select imaging parameters—
      a. select proper instrument and auxiliary equipment necessary to perform imaging procedure;
      b. prepare instrument for procedure, i.e., select proper collimator, imaging parameters, etc.;
      c. select appropriate parameters for data acquisition using a computer;
      d. monitor performance of film processor system and maintain processor quality control.
   2. Position patient and obtain images—
      a. select appropriate positions for procedure;
      b. place patient in correct position using supportive materials and immobilizers to obtain scintigrams for each view;
      c. place electrocardiogram leads in proper position for multigated acquisition studies;
      d. determine correct detector-to-patient distance;
      e. indicate appropriate anatomic landmarks for each view of a procedure;
      f. perform imaging procedure and collect specimens if applicable;
      g. recognize differences in image appearance and make adjustments if appropriate.
   3. Perform data processing—
      a. retrieve patient study;
      b. perform any necessary data manipulations including using a computer to achieve desired endproduct;
      c. process film according to manufacturer's specifications and film processor optimum operation;
      d. review study to assure correct information is supplied and any special views required have been obtained;
      e. analyze data acquired for physician interpretation.
   4. Maintain quality control in all aspects of imaging procedure.
   5. Recognize artifacts caused by instrumentation malfunction, the radiopharmaceutical, the patient, or technologist error.

Note: The aforementioned tasks apply to imaging procedures for the central nervous, endocrine, respiratory, cardiovascular, gastrointestinal, genitourinary, skeletal, hematopoietic, etc. body systems.

IV. Group IV

A. Perform administrative procedures:
   1. Schedule patient procedures.
   2. Determine most appropriate sequence for multiple procedures.
   3. Maintain adequate supplies, including radiopharmaceuticals and kits.
   4. Maintain appropriate records of radiopharmaceutical dosages, quality control procedures, patient reports, and other required records.
   5. Maintain an updated procedure manual.

B Prepare patient:
   1. Verify patient identification and written orders for study.
   2. Instruct patient and nursing staff of appropriate standing and special orders to include medications.
   3. Check procedural contraindications and obtain pertinent patient history.
   4. Obtain informed consent when necessary.

C. Operate laboratory equipment:
   1. Check accuracy and operation of pipetting devices.
   2. Maintain constant temperature of water bath and refrigerators.
   3. Compute relative centrifugal force, operate centrifuge, and maintain routine tachometer checks.
   4. Calibrate and operate pH meters.
   5. Calibrate and use laboratory scales and balances.
   6. Operate vortex mixers and shakers maintaining constant conditions.
   7. Maintain quality control records on all laboratory equipment.

D. Collect proper specimen for procedure:
   1. Collect blood samples—
      a. select proper equipment (needles, syringes, etc.);
      b. choose proper anticoagulant or preservative for specific procedure;
      c. perform venipuncture at appropriate time intervals and verify proper labeling;
      d. add hemolyzing compounds when necessary;
      e. place blood on ice as required;
      f. centrifuge blood and separate blood components as required; determine hematocrit;
      g. store aliquot of patient sample as directed by protocol.
   2. Collect urine samples—
      a. choose appropriate container;
      b. add a small amount of preservative to container;
      c. instruct patient and nursing staff about the method and length of collection;
      d. aliquot urine sample and measure total urine volume;
      e. measure specific gravity of urine if required;
      f. collect additional urine if volume collected is insufficient.

E. Prepare standards and controls:
   1. Label cells with a radioactive drug according to protocol.
   2. Choose appropriate volumetric glassware for dilution of the standard.
   3. Add portion of solvent to glassware and a solution to prevent sticking.
   4. Add an amount of activity similar to that given to the patient and dilute up to the calibration mark.
   5. Dilute capsule in appropriate solvent if necessary for standard.

F. Perform assay:
   1. Check expiration date.

2. Determine if volume and activity of reagents are adequate.
3. Allow assay components and patient specimens to equilibrate at room temperature.
4. Prepare assay reagents.
5. Add radioassay components according to protocol.
6. Incubate standards and samples in appropriate environment for required time.
7. Separate bound from free radioactivity using necessary laboratory equipment.

G. Operate counting equipment:
1. Set pulse height analyzer on scintillation detector and center the photopeak within analyzer settings chosen for procedure.
2. Count samples, standards, and room background for a statistically significant number of counts, making corrections for geometrical differences if necessary.
3. Outline organs to be counted externally if applicable.
4. Choose correct detector-to-patient distance and count for a statistically significant number of counts.

H. Perform calculations:
1. Reduce data to net counts by subtracting room background and nonspecific binding counts.
2. Calculate the desired fraction (bound/total, bound/free, free/total, etc.) for generation of standard curve or apply appropriate formulas, including conversion and dilution factors.
3. Plot above fractions obtained for standards on appropriate graph paper or if necessary plot graph, determine the half-time, and extrapolate to zero time.
4. Determine data for all patients and controls from derived standard curve.
5. Transfer assay results to laboratory data record and to patient's request form.
6. Calculate organ ratios if applicable.
7. Report both patient's calculated values and normal range of the specific procedure used.

I. Maintain assay quality control:
1. Develop and maintain quality control procedures for all assays, using appropriate control sera.
2. Record daily results of all controls on quality control charts.
3. Periodically perform appropriate control sera checks.
4. Maintain records of antibody binding for each assay to note any reagent deterioration.
5. Recognize a significant shift in assay control and take appropriate action.
6. Compare another laboratory's results with your own.

J. Evaluate assay performance:
1. Perform all tasks necessary to assess the accuracy, precision, sensitivity, and specificity of assay.
2. Develop a normal range for each assay.
3. Test biological validity of the assay.
4. Choose kit with best overall performance.

Note: The aforementioned tasks apply to the following nonimaging procedures and assays: blood volumes (Cr-51 and RISA), red cell survival and sequestration, ferrokinetic studies, thyroid uptake, Schilling test, glomerular filtration rate, etc. and hepatitis, vitamin B_{12}, folate, ferritin, hormone assays, carcinoembryonic antigen, drug screening, gonadotropin, calcitonin, thyroid-binding globulin, myoglobin assays, etc.

NMTCB Content Guidelines

I. Group I

A. Properties of nuclear radiation:
1. Units of radiation
2. Types of radiation
3. Interaction of radiation with matter
4. Radiation production

B. Regulatory requirements:
1. NRC
   a. Title 10, Code of Federal Regulations
      1) Part 19
      2) Part 20
      3) Part 35
   b. regulatory guides
   c. agreement state requirements
   d. nonagreement state requirements
2. Food and Drug Administration regulations
3. Department of Transportation regulations
   a. transportation groups
   b. transportation index
   c. packaging types
4. Occupational Safety and Health Administration safety standards

C. Radiation protection
1. Patient and personnel monitoring
   a. absorbed dose units
   b. maximum permissible radiation doses
      1) occupational and nonoccupational
      2) whole body and extremities
   c. radiation protection techniques
      1) time, distance, and shielding
      2) contamination control
   d. "as low as reasonably achievable" (ALARA) concept
   e. Part 20–Reports of Overexposure
2. Shielding
   a. units of exposure
   b. half-value layers
   c. shielding formula
   d. exposure rate constant (Γ)
   e. shielding devices

D. Radiation surveys:
1. Survey meters (i.e., Geiger-Muller, cutie pie)
   a. rationale for use
   b. meter calibration requirements
   c. type and frequency of surveys
2. Area monitoring
   a. exposure rate limits
   b. surface contamination surveys
   c. air sampling

d. sealed source leak tests
e. written records

3. Patient monitoring
   a. exposure limits for hospitalized patients undergoing radiopharmaceutical therapy
   b. written records

E. Radiopharmacy:
1. Radiopharmaceutical receipt and storage
   a. package survey requirements
   b. records of receipt and package survey
   c. storage requirements of radiopharmaceuticals
   d. temperature, light, humidity, and ventilation
2. Radiopharmaceuticals*
   a. physical characteristics, i.e., decay schemes
   b. biologic behavior
3. Generators†
   a. decay scheme of parent radionuclide
   b. transient versus secular equilibrium
   c. operation
      1) assembly
      2) elution
         a) chromatographic separation
         b) aseptic technique
   d. eluate assay
      1) dose calibrator operation
      2) activity measurements
      3) assay records
      4) possible contaminants
         a) methods of eluate testing
         b) allowable limits—radionuclidic and chemical
4. Radiopharmaceutical preparation‡
   a. general chemical reaction
   b. kit contents
   c. method of preparation
   d. FDA-approved radiopharmaceuticals
   e. activity and chemical limits in kit preparation
   f. dose calibrator operation
   g. records
   h. specific quality control testing
   i. specific compounding pitfalls, and radionuclidic and chemical contaminant limits
5. Radiopharmaceutical quality control‡
   a. radionuclidic purity testing
      1) method of testing
      2) commonly detected impurities and their limitations
   b. radiochemical purity testing
      1) principle of paper chromatography
      2) principle of thin layer chromatography
   c. radiopharmaceutical purity testing
      1) methods of testing
      2) influencing factors, i.e. pH, particle sizing, etc.
   d. sterility testing
      1) method of testing
      2) United States Pharmacopeia requirements
   e. pyrogen testing
      1) United States Pharmacopeia test
      2) limulus amoebocyte lysate test
6. Radiopharmaceutical activity calculation and unit preparation
   a. quantitation
      1) acceptable activity range for diagnostic and therapeutic procedures
      2) acceptable dosage of adjunct medications, i.e., potassium perchlorate, nonradioactive vitamin-B_{12}, etc.
      3) acceptable limits of impurites
      4) calculations
         a) units of activity
         b) determination of elapsed time
         c) decay equation
         d) volume or capsule determination
   b. preparation of unit radiopharmaceuticals
      1) aseptic technique
      2) method of activity verification
      3) required records

F. Administration of radiopharmaceuticals (diagnostic or therapeutic)
1. Procedure for venipuncture
   a. venous anatomy
   b. materials needed
   c. bolus injection technique
2. Procedure for dispensing gaseous preparation
3. Procedure for oral administration
4. Procedure for other routes of administration
   a. intramuscular
   b. intrathecal
   c. intrapleural
   d. intra-abdominal
   e. intracatheter
5. Complications and reactions
6. Written records
   a. informed consent
   b. misadministration

G. Radiation decontamination and disposal procedures:
1. Decontamination procedures
   a. patient and personnel decontamination
   b. equipment and area decontamination
      1) procedure for major spill

*This outline refers to the following radioactive drugs: Co-57 and Co-58 labeled vitamin B_{12}, Cr-51 (sodium chromate), Fe-59 (ferrous citrate), Ga-67 citrate, I-123 (sodium iodide), I-125 (sodium iodide), I-125 fibrinogen, I-125 human serum albumin, I-131 (sodium iodide), I-131 human serum albumin, I-131 sodium orthoiodohippurate, In-111 oxine, In-111 DTPA, P-32 (sodium phosphate), P-32 (chromic phosphate), Se-75 (selenomethionine), Tl-201 (thallous chloride), Xe-133, and Sr-90 in applicator form.

†This outline refers to the following generators: Mo-99/Tc-99m and Ru-81/Kr-81m.

‡This outline refers to [^{99m}Tc] pertechnetate and kit preparation of the following Tc-99m labeled compounds: antimony sulfide colloid, bone imaging agents, DMSA, DTPA, glucoheptonate, hepatobiliary agents, human serum albumin, macroaggregated albumin, microspheres, pyrophosphate, and sulfur colloid.

2) procedure for minor spill
2. Disposal of radioactive waste
a. NRC regulations
1) liquids
a) storage for decay
b) limits released to sanitary sewage system
2) solids
a) storage for decay
b) incineration
c) burials
d) transfer to commercial disposal service or site
3) gases
a) storage for decay, i.e., xenon traps
b) release to atmosphere

II. Group II

A. Scintillation counters:
1. Basic electronic nomenclature
2. Detector system components
a. inorganic and organic scintillators
1) types
2) theory of light emission
b. photomultiplier tube(s)
1) structure
2) high voltage power supply
c. preamplifier
d. amplifier
e. pulse height analyzer (single channel and multichannel)
1) theory of operation
2) calibration
3) pulse height selection
f. scalers and other readout devices
3. Detector characteristics
a. efficiency
b. linearity
c. geometry
d. resolution
e. deadtime
4. Quality control
a. chi-square testing
b. background determination
c. written records

B. Scintillation camera:
1. Components
a. crystal size
b. photomultiplier tube number and arrangement
c. electronics
1) pulse positioning circuitry
2) energy discrimination
2. Collimators
a. types
b. performance characteristics
1) image size
2) sensitivity
3) resolution
3. Image display
a. oscilloscopes (cathode ray tubes)
b. multiformat devices
c. photographic
1) Polaroid
2) transparency
4. Quality control
a. field uniformity check
1) material needs
2) procedure
3) nonuniformity identification
b. detector linearity check
1) available bar phantoms
2) procedure
3) types of nonlinearity
c. spatial resolution
1) materials needed
2) procedure
3) full width at half maximum
4) modulation transfer function
d. sensitivity check
e. image recording
1) cathode ray tube
a) focus
b) astigmatism
2) film/developer quality control

C. Tomographic systems:
1. Principles of operation
2. Component parts

D. Rectilinear scanners:
1. Components
a. detector systems
b. photomultiplier tube
c. preamplifier and amplifier
d. pulse height analyzer
e. display
1) dot tapper
2) photorecorder
2. Collimators
a. types and construction
b. collimator characteristics
1) resolution
a) line spread function
b) full width at half maximum
c) modulation transfer function
2) sensitivity
3) efficiency versus resolution
4) isoresponse curves
3. Scanner operation
a. calculation of scanning parameters
b. scanning artifacts
4. Quality control
a. sensitivity
b. resolution
1) energy
2) spatial
c. film density

d. contrast scale

E. Gas-filled detectors:
   1. Ionization chamber
      a. component parts
      b. theory of gas ionization and types
   2. Survey meters
      a. Geiger-Müller counters
      b. cutie pie
   3. Dose calibrator
      a. principles of operation
      b. quality control
         1) required procedures
         2) allowable limits
         3) written records

F. Computers:
   1. Binary number system
      a. accuracy
      b. magnitude
      c. word length
   2. System hardware
      a. acquisition
         1) analog-to-digital converters
            a) speed
            b) accuracy
         2) acquisition modes
            a) frame
            b) list
            c) multigated
         3) matrix types and sizes
      b. storage
         1) internal
            a) organization of data
            b) size
         2) external (tape,disks, floppy disks)
            a) types
            b) advantages and disadvantages
      c. processing (central processing unit)
      d. display
         1) cathode ray tube
         2) video
         3) hard copy
   3. Software principles
      a. language type
      b. acquisition programs
         1) manual
         2) predefined
      c. programs for image enhancement and display
      d. data analysis programs

III. Group III

A. Administrative procedures:
   1. Written records
      a. patient radiopharmaceutical administration
      b. instrumentation quality control records
      c. radioparmaceutical dispensing log
      d. NRC, FDA, and JCAH; state records retention requirements
      e. legal requirements
      f. nuclear medicine procedure manual requirements
   2. Patient scheduling
      a. effective half-life
      b. energy ranges
      c. interfering procedures
   3. Sequence of procedures
   4. Supplies and storage
      a. inventory control
      b. storage conditions
         1) film
         2) chemicals
         3) medications
   5. Miscellaneous safety requirements
      a. municipal codes or ordinances
         1) fire
         2) electrical
         3) building
      b. OSHA requirements

B. Principles of patient care:
   1. Patient communications
   2. Nursing procedures
      a. body mechanics
      b. vital signs
      c. first aid
      d. infection control precautions
      e. cardiopulmonary resuscitation
         1) emergency cart
         2) life-support equipment
   3. Medical-legal aspects

C. Patient preparation:
   1. Premedication and sedation
      a. mechanisms of drug action
      b. drug dosage
   2. Radiopharmaceutical administration
      a. new drug application
      b. investigational new drug
      c. approved routes of administration
      d. informed consent
   3. Pediatric activity determination
      a. body weight
      b. body surface area
      c. organ volume
   4. Injection techniques
      a. aseptic method
      b. bolus technique principles
      c. temporal relationship to other medications
   5. Radiopharmacology
      a. mechanisms of localization
      b. biological and effective half-life
      c. contraindications

1) pregnancy
2) allergies
d. target organ
e. blood clearance rates
6. Radiobiology
a. effects
1) cellular
a) direct
b) indirect
2) molecular
b. sensitivity
1) LD_{50}
2) somatic syndromes
7. Dosimetry
a. whole body
b. target organ
c. other vital organs
8. Radiation safety practices
a. patient precautions
b. personnel precautions

D. Imaging procedures:
1. Imaging parameters
a. information density
b. dead time
c. collimators
1) effect
2) procedure requirements
3) distance
4) artifacts
d. window width selection
e. counting statistics
1) dynamic
2) static
f. computer acquisition parameters
1) mode
2) frame rate
2. Patient positioning
a. normal and abnormal anatomy
b. normal and abnormal physiology
c. imaging views
1) positioning terminology
2) anatomic position
d. immobilization
e. anatomical markers
f. electrocardiogram principles
1) theory of operation
2) lead placement
3. Special data acquisition
a. tomographic principles
b. multiple gated principles
c. first pass principles
4. Data processing
a. data manipulation techniques
1) regions of interest
2) subtraction
3) histogram curve generation
4) dilution formula calculation
5) image addition
6) image filtering
7) curve smoothing
b. film types and properties
1) emulsions
2) film base
3) speed
c. film processing
1) theory
2) processor operation
3) quality control
4) film labeling
5. Procedure quality control
a. instrumentation malfunction
b. radiopharmaceutical
c. patient
d. technologist error

Note: This content applies to the following body systems imaging procedures: central nervous, endocrine, respiratory, cardiovascular, gastrointestinal, genitourinary, skeletal, hematopoietic, etc.

IV. Group IV

A. Administrative procedures:
1. Scheduling
a. effective half-life
b. energy ranges
c. interfering procedures
2. Sequence of procedures
3. Radiopharmaceutical and/or kit supplies
4. NRC, FDA, JCAH; state records retention requirements
5. Legal requirements
6. Nuclear medicine procedure manual requirements

B. Patient preparation:
1. Instructions to patient and nursing staff
2. Administration or discontinuance of medication
3. Dietary restrictions

C. Laboratory equipment:
1. Pipets
a. types
b. operation, i.e., to deliver (TD) and to contain (TC)
c. quality control
1) precision
a) methods of measuring
b) coefficient of variation
c) acceptable limits
d) frequency of determination
2) accuracy
a) methods of measuring
b) acceptable limits
c) frequency of determination

2. Centrifuge
   a. components
   b. operation
   c. relative centrifugal force calculation
   d. quality control records
3. Laboratory weight balances and pH meters
   a. calibration
   b. operation
   c. quality control
4. Other auxiliary equipment, i.e., vortex mixers, shakers, water baths, refrigerators

D. Specimen collection:
1. Instructions to patient and nursing staff
2. Timing of samples, i.e., blood, urine, etc.
3. Procedure for venipuncture
   a. necessary equipment and supplies
   b. aseptic technique
4. Sample type, i.e., serum, plasma
5. Appropriate anticoagulant
6. Sample stability
7. Hematocrit determination

E. Standard and control preparation:
1. Labeling procedure of specimen
2. Laboratory glassware preparation
3. Activity calculations
4. Dilution factors

F. Assay performance:
1. Physiology of assay ligands
2. Assay types
   a. radioimmunoassay
   b. competitive protein binding
   c. radioenzymatic
   d. radioreceptor
3. Assay reagents
4. Basic reaction
   a. competitive equilibrium
   b. sequential saturation
5. Separation of bound from free fraction
   a. methods
      1) solid phase
      2) immunoprecipitation
      3) chemical precipitation
      4) gel filtration
   b. sources of error
6. procedure pitfalls

G. Sample counting:
1. Operation of scintillation counter
2. Operation of liquid scintillation counter
3. Quality control
   a. geometry
   b. statistics
4. Sample counting and external organ counting

H. Calculation of results:
1. Determination of nonspecific binding
2. Calculation of % bound/total, % free/total, % bound/free
3. Other nonimaging formulas
4. Standard curve plot
   a. graph paper type
      1) linear
      2) semi-log
      3) log-logit
   b. graphing data
   c. determination of sample concentration
5. Organ ratios
6. Normal ranges

I. Assay quality control and evaluation:
1. Control serum
   a. pooled serum controls
   b. commercial serum controls
2. Percent binding of zero standard
3. Precision
   a. intra-assay
   b. interassay
   c. Levy-Jennings plot
4. Accuracy
   a. methods of measuring
   b. acceptable limits
5. Sensitivity
6. Specificity
7. Normal range determination

Note: This content applies to the following nonimaging procedures and assays: blood volumes, red cell survival and sequestration, ferrokinetic studies, thyroid uptake, Schilling test, glomerular filtration, etc. and hepatitis, vitamin B_{12}, folate, ferritin, hormone assays, carcinoembryonic antigen, drug screening, gonadotropin assays, calcitonin, thyroid binding globulin, myoglobin, etc.

NMTCB Examination Content Specifications Outline

Percentage of questions within the total test

I. Group I (30%) 60 items

A. Properties of nuclear radiation:
1. Units of radiation
2. Types of radiation
3. Interaction of radiation with matter
4. Radiation production

B. Regulatory requirements:
1. Nuclear Regulatory Commission
2. Food and Drug Administration
3. Department of Transportation

4. Occupational Safety and Health Administration safety standards

C. Radiation protection:
   1. Patient and personnel monitoring
   2. Shielding

D. Radiation surveys:
   1. Survey meters
   2. Area monitoring
   3. Patient monitoring

E. Radiopharmacy:
   1. Radiopharmaceutical receipt and storage
   2. Radiopharmaceuticals
   3. Generators
   4. Radiopharmaceutical preparation
   5. Radiopharmaceutical quality control
   6. Radiopharmaceutical activity calculation and unit preparation

F. Administration of radiopharmaceuticals:
   1. Procedure for venipuncture
   2. Procedure for dispensing gaseous preparation
   3. Procedure for oral administration
   4. Procedure for other routes of administration
   5. Complications and reactions
   6. Written records

G. Radiation decontamination and disposal procedures:
   1. Decontamination procedures
   2. Disposal of radioactive waste

II. Group II (25%) 50 items

A. Scintillation counters:
   1. Basic electronic nomenclature
   2. Components of detector system
   3. Detector characteristics
   4. Quality control

B. Scintillation cameras:
   1. Components
   2. Collimators
   3. Image display
   4. Quality control

C. Tomographic systems:
   1. Principles of operation
   2. Component parts

D. Rectilinear scanners:
   1. Components
   2. Collimators
   3. Scanner operation
   4. Quality control

E. Gas-filled detectors:
   1. Ionization chamber
   2. System hardware
   3. Dose calibrator

F. Computers:
   1. Binary number system
   2. System hardware
   3. Software principles

III. Group III (25%) 50 items

A. Administrative procedures:
   1. Writtten records
   2. Patient scheduling
   3. Sequence of procedures
   4. Supplies and storage
   5. Miscellaneous safety requirements

B. Principles of patient care:
   1. Patient communications
   2. Nursing procedures
   3. Medical-legal aspects

C. Patient preparation:
   1. Premedication and sedation
   2. Radiopharmaceutical administration
   3. Pediatric activity determination
   4. Injection techniques
   5. Radiopharmacology
   6. Radiobiology
   7. Dosimetry
   8. Radiation safety practices

D. Imaging procedures:
   1. Imaging parameters
   2. Patient positioning
   3. Data acquisition and processing including computers
   4. Procedure quality control

IV. Group IV (20%) 40 items

A. Administrative procedures:
   1. Scheduling
   2. Sequence of procedures
   3. Radiopharmaceutical and kit supplies
   4. Nuclear Regulatory Commission/Food and Drug Administration/Joint Commission on Accreditation of Hospitals
   5. Legal requirements
   6. Nuclear medicine procedure manual

B. Patient preparation:
   1. Procedural instructions
   2. Premedication
   3. Dietary restrictions

C. Laboratory equipment:
   1. Pipets
   2. Centrifuges
   3. Laboratory weight balances and pH meters
   4. Auxiliary laboratory equipment

D. Specimen collection:
   1. Collection instructions
   2. Sample timing
   3. Anticoagulants/preservatives/hemolyzing agents
   4. Separation of blood components
   5. Specimen storage
   6. Hematocrit determination

E. Standard and control preparation:
   1. Glassware types and preparation
   2. Dilution factors

F. Assay performance:
   1. Physiology of assay ligands
   2. Assay types
   3. Assay reagents
   4. Basic reaction
   5. Sample separation
   6. Procedure pitfalls
G. Sample counting:
   1. Operation of solid and liquid scintillation counters
   2. Quality control
   3. External organ counting
H. Calculation of results:
   1. Nonspecific binding
   2. Calculation of percent bound or free
   3. Nonimaging formulas
   4. Standard curve plot
   5. Organ ratios
   6. Normal ranges
I. Assay quality control and evaluation
   1. Control sera
   2. Percent binding of zero standard
   3. Precision
   4. Accuracy
   5. Sensitivity
   6. Specificity
   7. Normal range determination