STATE OF OHIO
DEPARTMENT OF HEALTH

GUIDANCE ON DEVELOPING AN ACCEPTABLE DIDACTIC SYLLABUS FOR THE GENERAL X-RAY MACHINE OPERATOR (GXMO) EDUCATIONAL PROGRAM

RTS-GXMO-700

Rev. 1

Effective Date: November 6, 2008

This consolidated guidance, along with the State of Ohio RTS Program, provides the applicants and reviewers with information concerning how to file a request, a listing of the applicable rules and industry standards policies affecting evaluation and registration certain administrative procedures to be followed, information on how to perform the review and write a license and the responsibilities of the licensee.

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1. INTRODUCTION

Consolidated guidance documents have been developed by the Ohio Department of Health's Bureau of Radiation Protection to provide guidance to licensees, registrants and applicants on implementing specific parts of the department's rules published in the Ohio Administrative Code (OAC); and guidance on the specific data and information needed, as a minimum, by the bureau in its review of applications for Department of Health licenses, registrations and educational program approvals.

These guides are not substitutes for rules, and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a license, registration or approval by the department.

This guide describes a didactic training syllabus that would be acceptable to the bureau's Radiologic Technology Section staff as part of a General X-ray Machine Operators (GXMO) educational program, meeting the curriculum requirements outlined in rule 3701-72-03 of the OAC. As mentioned above, it is not the intent of this guidance to constrain educational program providers from developing their own GXMO, didactic training syllabus and submitting it to the bureau for approval.

This consolidated guidance was issued by the bureau and is based the effort and input of the Radiological Advisory Council's Radiographic Equipment Committee. Comments and suggestions for improvements in any of the bureau's consolidated guidance documents are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or techniques, evolving technology and experience or lessons learned.

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2. PROGRAM GOALS

As permitted by Chapter 3701-72 of the Ohio Administrative Code, General X-ray Machine Operators (GXMO) will take radiographs using only predetermined techniques. A GXMO educational program should allow students to acquire and be able to demonstrate a basic knowledge and practical understanding of the fundamentals requisite for radiation safety and the daily operation of diagnostic X-ray equipment within the GXMO scope of limited practice. Therefore, at a minimum, the curriculum of the didactic training section of a GXMO training program shall include the following:

- Radiographic equipment and often-used terms and terminology;
- The nature of X-rays, their relative energy spectrum and their fundamental properties when traveling in space and interacting with matter;
- The components of the X-ray tube and their basic functions;
- How X-rays are produced by the X-ray machine;
- The essential factors controlling the quality and quantity of x-ray beam intensity, and specifically what kilovoltage peak (kVp) and milliamperes (mA) do to the X-ray beam;
- The functions of the X-ray tube, control panel, table and grid devices;
- The three potential interactions of X-rays with matter, how these combine to produce a useful image along with their potential negative effects on both the image clarity and radiation safety;

  Note: *The student is not required to conceptualize how these interactions occur using atomic models or their relative probabilities of interaction.*

- X-ray image formation and the different processing techniques for both film or screen and digital image receptor;
- Major factors that control and affect image quality forming the basis of technique chart development;
- The applicable units of measurement used in dosimetry, methods to monitor occupational exposure and when to do so;
- The acute biologic effects of radiation, with an emphasis on their limited relevance in diagnostic radiology;
- The long-term biologic effects of X-rays as a foundation to understanding the principles of safe practice;

- The cardinal rules of safety, along with standard safe practices in protecting both patients and operators from ionizing radiation;

- The initial clinical approach to the patient: identifying and verifying the correct patient, correct medical order, procedure, and patient confidentiality; and

- The proper patient assessment and patient care skills when performing radiographic procedures.

3. DIDACTIC TRAINING: COURSE SYLLABUS

3.1 Introduction to GXMO Licensure

A. X-rays used in medicine for more than 100 years

B. Ability to visualize internal anatomy has revolutionized medicine

C. Evolution of virtually every part of the X-ray unit and imaging systems to improve diagnostic quality and safety for both the patient and operator

D. Brief overview of course content

E. GXMO responsibilities

F. Ohio Department of Health rules

G. GXMO licensure process (See Table 3.1)

Table 3.1 GXMO Licensure Process

Process for Obtaining an Initial GXMO License

Step 1	Complete GXMO educational course OR complete first year of accredited radiologic technology program. Educators will supply student with exam registration form.
Step 2	Submit exam registration form to Cleveland Clinic 30 days prior to exam date.
Step 3	Complete at least one clinical module course approved by the ODH, specific to the type(s) of procedures to be performed when licensed, OR be a student enrolled in an accredited radiologic technology (RT) program. The program director will provide the student with a clinical course certificate, or if an RT student, the program director will provide the RT student with a clinical competency affidavit. This step may be completed at any time prior to applying for a license.
Step 4	Submit complete application to ODH. A complete application must include the following: • $65 application fee; • GXMO exam score certificate; • Didactic course certificate or college transcript; and • Clinical course certificate(s) or clinical course affidavit.

Process for Current GXMOs to Update Their License to Operate Digital Equipment

Step 1	Complete GXMO clinical educational course OR be a student enrolled in an accredited radiologic technology program. The educator will provide the student with a clinical course certificate, or if an RT student, the program director will provide the RT student with a clinical competency affidavit.
Step 2	Add clinical module(s) completed online at http://www.odh.ohio.gov/odhPrograms/rp/rlic/rlic1.aspx (Amend Personal Information link)
Step 3	Submit clinical course certificate or clinical competency affidavit to ODH by uploading online, or by mail or fax (614) 466-0381.
Step 4	ODH mails license approval letter upon receipt of clinical course certificate.

3.2 Introduction to Radiographic Equipment and Basic Terms

A. Collimator and the Light Field

B. Image Receptor (IR) System

- *Film-based cassette*
- *CR-based cassette*
- *DR*

C. Patient Positioning Aids

- *Sponges*
- *Immobilization devices*

D. Positioning of the X-ray Tube

- *Ceiling mount vs. tube hanger*
- *Tube motions: transverse, longitudinal, vertical, angle, tilt*
- *Detent*

E. Primary X-ray Beam

- *X-ray Source – tube*
- *Central ray*

F. Radiographic Table / Upright Cassette Holder

- *Table movement*
- *Trendelenburg position*
- *Under-table bucky (grid)*

G. Control Panel Component

- *Timer*
- *kVp*
- *AEC*
- *mA*

H. Remnant Radiation

I. Scatter Radiation

3.3 X-rays, Ionization and Matter

A. Atomic Structure

- *Atomic structure should be covered but can be very basic and discuss the fundamental particles and introduce the nomenclature*

B. Electromagnetic Spectrum

- *Energies and photons - no wavelength models; the emphasis should be on relative energies of X-rays vs. visible light*
- *Ionizing vs. non-ionizing radiation*

C. Fundamental X-ray Interactions with Matter

- *General information only, not at the atomic models*

  - Absorbed – radiopaque

  - Scattered – random "endpoint"

  - Passes through unaltered – radiolucent

D. Ionization

- *Definition*
- *Implications*
- *Cause of patient dose*
- *Cause of image formation*

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3.4 Basic X-ray Tube Designs and the Controlled Formation of X-rays

A. Tube Construction and Schematic

- *Protective housing*
- *Glass or metal enclosure*
- *Cathode and anode*
- *Port or window*
- *Added filtration*
- *Collimating shutters*
- *Positive beam limitation (PBL)*

B. Beam Limiting Devices

- *Fixed-Aperture*
- *Cylinder / Cones*
- *Collimator (variable aperture)*

C. X-ray Tube Components

- *Cathode filament(s)*
- *Focusing cup*
- *Anode target*
- *Rotating vs. stationary anodes*

D. Process of X-ray Production

- *Thermionic emission*
- *Kilovoltage*
- *Milliamperage and tube current*
- *Anode interactions – inefficient process: 99% heat/1% X-rays (No detailed atomic models; characteristic radiation should not be covered)*
- *Bremsstrahlung X-rays - "spectrum" of photon energies in beam*

E. Filtration

- *Tube filtration*
- *Compensating filters – trough and wedge*

3.5 The X-ray Beam

A. Definition of X-ray Beam Intensity

- *Units of output/beam intensity – roentgen or milliroentgen*

B. X-ray Beam Quantity

- *Definition*
- *Key factors affecting X-ray quantity:*
  - *mA*
  - *sec (time)*
  - *mAs*
  - *Distance: inverse square law*
  - *kVp*

C. X-ray Beam Quality

- *Definition*
- *Key factors affecting X-ray beam quality:*
  - *kVp*
  - *Half-value layer (HVL), definition*

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3.6 Primary Radiologic Image

A. Basic Interactions with Matter

- *Penetrate*
- *Absorb*
- *Scatter*

B. Differential Attenuation

- *Basis for subject contrast*

C. Intensity

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3.7 Film Image Receptors

A. Film Basics

- *Film construction*
- *X-ray exposure and "latent image" formation*
- *Inherent film characteristics:*
  - *Speed*
  - *Contrast*
  - *Spectral matching – see intensifying screens*
  - *Safelights – low-watt bulbs, safe at a distance*
- *Film handling and storage:*
  - *Definition of fog*
  - *Temperature/effects of heat*
  - *Humidity – static*
  - *Light*
  - *Radiation fog*
  - *Shelf life – age fog*
  - *Pressure*

B. Radiographic Intensifying screens

- *Fluorescence:*
  - *X-rays photons "captured" in light emitting crystals*
  - *Crystals give off many more photons of visible light (intensification)*
  - *Visible light exposes light sensitive film*
- *Advantage (dose reduction) and disadvantage (screen blur)*
- *Maintenance:*
  - *Cleaning, inspection*

C. Automatic Wet Film Processing

- *Developer*
- *Fixer*
- *Wash*
- *Dryer*
- *Components/systems:*
  - *Transport*
  - *Temperature*
  - *Circulation*
  - *Replenishment*
  - *Dryer*

D. Chemical Safety

- *Material safety data sheet (MSDS)*

E. Automatic Dry Film Processing

F. Processing Quality Control

- *Maintenance (daily, monthly, semiannually, annually)*
- *Daily monitoring, sensitometry*

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3.8 Digital Image Receptors

A. Digital Basics:

- *Analog signal "waveform" vs. digital signal "string" of binary numbers*
- *Matrix - pixels, pixel size, matrix size and spatial resolution*
- *Line pairs/mm selection and resolution*
- *The Digital Imaging and Communications in Medicine (DICOM) standard – definition and relative importance*

B. Digital Image Acquisition Technologies: Computed Radiography (CR)

- *Overview of CR (photostimulable phosphor) PSP imaging plates:*

  - Most common, least expensive, high quality images

  - Construction: cassette and PSP imaging plate

  - Barium fluorohalide (BF) crystal(s) – analogue to film screen phosphor

  - X-ray exposure interacts with BF crystals – "latent image" formed

  - Plate scanned by intense laser light, trapped energy released as light (and read) to produce a "manifest" image

B. Digital Image Acquisition Technologies: CR (Continued)

- *CR: PSP Plate Latent Image Formation and Reading*

  - X-ray energy trapped in europium-doped barium flourohalide (BaFBr[Eu] or BaFI[Eu]) in crystals is proportional to the X-ray exposure (no specifics of electron holes created in valence band, electrons in trap, etc.)

  - This information is extracted by a CR reader, comprised of a scanning monochromatic laser beam (typically red) and a photodetector (e.g. PMT)

  - Laser beam causes release of stored energy in the form of different colored light (blue-green or blue-purple)

  - The brightness of the stimulated light coming from any point on the plate is proportional to the amount of X-ray energy that had passed through the patient and been deposited there.

  - Data (analogue) then "digitized" (A/D conversion)

  - Exposure to plate by intense light "erases" any remaining trapped energy to ready plate to be used again

C. Digital Image Acquisition Technologies: Cassetteless

- *Indirect DR – X-rays converted to light prior to detection*

  - Employ flat panel detector (FPD) instead of traditional cassette

  - Intensifying screens convert X-rays to light (therefore indirect), but emitted light "read" directly by photodetector (CCD)

  - Phosphor "light spread" still present

  - FPDs must be directly connected to image processor

- *Direct DR – utilize crystals such as amorphous selenium which directly convert X-rays into a charge that is stored, ready to be read*

  - Cost increases with size; predominantly dental

D. Display Qualities

- *Human visual range vs. digital image detectors*
- *Window level – controls density*
- *Window width (gray scale compression or expansion) – controls contrast*
- *Inverse relationship between width and contrast*

E. Exposure Index	• *Definition* • *Vendor specific* • *Ethical and regulatory responsibility (As low as reasonably achievable (ALARA))*
F. Practical Considerations – Differences between Digital and Film	• *CR plates sensitivity to scatter radiation* • *Plates should be erased daily if not used* • *Latent image decay exponential* • *Exposure indices* • *Cost* • *Dose* • *Existing equipment* • *Resolution* • *Speed* • *Artifacts*

3.9 Optimal Techniques

A. Optimal Exposure Factors – Primary Effects on Contrast and Density

- *Kilovoltage (kVp)*
  - *(film/screen) – contrast and density*
  - *(digital) – adequate penetration*
- *Milliamperage (mA) – density*
  - *(film/screen) – density*
  - *(digital) – exposure index*
- *Time – density, detail*

B. Optimizing Image Detail - Geometric Factors

- *SID – definition and the effects on detail, distortion and magnification*
- *OID – definition and the effects on detail, distortion and magnification*
- *Distortion and positioning*
- *FSS – focal spot size*

C. Automatic Exposure Control (AEC) – Density

- *Definition*
- *Proper use*

D. Visibility of Structure

- *Optimization of image contrast*
- *Effect of scatter on image quality*
- *Motion*
  - *Types of motion*
  - *Common methods to reduce motion*

E. Radiographic Grids

- *Definition, and when it is needed*
- *Basic types*
- *Effects on contrast and density*
- *Effects on patient dose*
- *Focal distance*
- *Basic grid errors*

3.10 Image Evaluation

A. Proper Image Labeling and Documentation

- *Location*
- *Date*
- *Patient name*
- *Markers (left or right)*

B. Optimal Image Quality

- *Definition*

C. Film Fog

- *Common causes*
- *Over versus under-development; chemical fog*
- *Handling and storage*

D. Image Artifacts

- *Definition*
- *Motion*
- *Common film and CR image receptor artifacts*
- *Periodic cassette cleaning: required and documented*

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3.11 Radiation Safety Basics

A. Sources of Radiation

- *Sources of average annual dose*
  - *Natural sources*
  - *Man-made sources*
- *Average annual doses*
  - *General public*
  - *Operator*

B. Dosimetry – Units of Radiation Safety (Radiation Deposition In Matter)

- *Rad – gray (Absorbed dose)*
- *Rem – sievert (Equivalent dose)*

C. Basic Biologic Effects of Radiation Exposure

- *Human radiation response*
- *Law of Bergonie and Tribondeau*
  - *Relative radiosensitivity of cells*
- *Early effects - to show that high dose effects aren't relevant to diagnostic imaging*
- *Acute syndromes- dose and effect*
  - *Hematologic*
  - *Gastrointestinal*
  - *CNS*

C. Basic Biologic Effects of Radiation Exposure (Continued)

- *Local tissue effects*
- *Key biologic factors affecting radiosensitivity*
- *Age*
  - *Recovery (= intracellular repair + repopulation)*
- *Dose-response relationships*
  - *Linear, threshold model*
  - *Linear, non-threshold model*
  - *Non-linear models*
- *Direct effect vs. indirect effect*
- *Radiolysis of water*
  - *Indirect effect*
- *Irradiation of macromolecules*
  - *Direct effect*
  - *DNA is critical target*
  - *Somatic effects*
- *Radiation and pregnancy:*
  - *Fetal effects*
  - *Effects on fertility*
  - *Irradiation in utero – 1st trimester*
  - *First two weeks*
  - *Major organ formation period*

C. Basic Biologic Effects of Radiation Exposure (Continued)

- *Relative risk of childhood leukemia*

- *Late effects of radiation (background information should develop an understanding as to why certain shielding precautions are taken*

  - *Cataract formation*

  - *Radiation-induced malignancies – general concepts*

  - *Leukemia – latent and at-risk periods*

  - *Radiation induced malignancies – general – latent and at-risk periods*

  - *Thyroid*

  - *Total excess risk of malignancy - 8 cases per 10,000 persons irradiated with 1 rad*

- *Genetic effects*

  - *Linear, non-threshold – any dose confers some risk*

  - *Frequency of radiation-induced genetic mutations is extremely low*

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3.12 Methods of Patient Safety

A. General Safety Principles

- *As low as reasonable achievable (ALARA) Principle*
- *Cardinal principles – time, distance, shielding:*
  - *Minimize time – optimize mAs*
  - *Maximize distance – (Inverse-Square Law)*
  - *Maximize shielding – what's considered safe?*

B. Reduction of Unnecessary Patient Dose

- *Unnecessary examinations*
- *Avoiding repeat examinations*
- *Radiographic techniques*
- *Proper collimation*
- *Positioning*
- *Specific area shielding*

C. Kilovoltage

- *Optimal kVp – low mAs*

D. Scatter control

- *Collimation/ beam restriction: aperture, collimator and PBL*

E. Grids – Image "Scatter Reduction" (Contrast Improvement) vs. Patient Dose

- *Increases dose to patient*

G. The Pregnant Patient

- *Methods of screening*
- *Methods of documentation*
- *Risk vs. benefit*

  - Physician consultation before procedure

3.13 Methods of Operator Safety

A. Relative Safety of Radiologic Occupation

- ALARA
- Cardinal principles

B. Rule 3701:1-38-12 of the Ohio Administrative Code: "Occupational Dose Limits"

- *Annual dose limits*
  - *Whole body*
  - *Organ dose*
  - *Lens of eye*
  - *Skin of whole body*
  - *Skin of the extremities*
- *Prior occupational dose*
- *Embryo or fetal dose limits*

C. Rule 3701:1-38-13 of the Ohio Administrative Code: "Dose Limits for Individual Members of the Public"

- *Non-occupational dose limits*

D. Rule 3701:1-38-14 of the Ohio Administrative Code: "Survey and Monitoring Requirements"

- *Who should be monitored?*
- *Types of personnel dosimeters – sensitivity levels*
- *Wearing and handling of monitors*
- *Interpreting personnel dosimetry reports*

E. Personnel Shielding and Protective Barriers

- *Reduction of occupational exposure*
- *Primary radiation – definition*
- *Secondary radiation – definition*
- *Controlled work area - definition*
- *Uncontrolled work area - definition*

F. The Pregnant Worker

- *Effects on fertility*
- *Irradiation in utero*
- *Declaration of pregnancy*

3.14 Patient Assessment and Patient Care – Prelude to Clinical Training

A. Identifying the Correct Patient

- *Methods of correct patient identification: verbal name, date of birth and identification bracelet*
- *Patient communication regarding radiographic studies, explaining procedures to your patient*

B. Patient Clinical History

- *Verifying and taking a clinical history*
- *Importance of prior radiographic studies*

C. Confidentiality of Medical Information

- *Release of records*
- *Health Insurance Portability and Accountability Act, HIPAA*
- *Other institutional policies*

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