



OHIO DEPARTMENT OF HEALTH

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

RTS-GXMO-700

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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 is acceptable to the Bureau of Radiation Protection for a GXMO educational program meeting the curriculum requirements outlined in rule 3701-72-03 of the OAC.

This consolidated guidance was issued by the bureau and is based on the effort and input of the Radiation Advisory Council's Radiation-Generating 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.

2. PROGRAM GOALS

As permitted by Chapter 3701-72 of the Ohio Administrative Code, GXMOs will take radiographs using only predetermined techniques. A GXMO educational program should allow students to acquire and 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 how kilovoltage peak (kVp), milliamperes (mA), time, and source-to image receptor distance (SID) affect the X-ray beam;
- The functions of the X-ray tube, control panel, table and grid devices;

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- 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/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 long-term biologic effects of X-rays as a foundation to understanding the principles of safe practice; and the limited relevance of acute biologic effects.
- 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. Brief overview of course content**
- B. GXMO responsibilities**
- C. Ohio Department of Health rules**
- D. GXMO licensure process (See Table 3.1)**

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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 radiography program. Educators will supply students with exam registration form.
Step 2	Submit examination registration form to Diversified Technology an affiliate of RadEd LLC to schedule the exam.
Step 3	Complete one or as many approved clinical module course(s), specific to the procedures to be performed when licensed, OR be a student enrolled in an accredited radiography program. The GXMO program director will provide a clinical course certificate, OR for radiography students, the radiography program director will provided affidavit of clinical competency.
Step 4	Submit complete application to ODH via online or by mail. Complete Application Means: <ul style="list-style-type: none"> • \$65 application fee • GXMO exam score • GXMO course certificate or college transcript • Clinic course certificate(s) or clinical course affidavit On line: www.odh.ohio.gov/odhPrograms/rp/rlic/rlic1.aspx

3.2 Introduction to Radiographic Equipment and Basic Terms

- | | |
|--|--|
| A. Collimator and the Light Field | <ul style="list-style-type: none"> • <i>Definition and Purpose</i> |
| B. Image Receptor (IR) System | <ul style="list-style-type: none"> • <i>Film-based cassette</i> • <i>CR-based cassette</i> • <i>DR</i> |
| C. Patient Positioning Aids | <ul style="list-style-type: none"> • <i>Sponges</i> • <i>Immobilization devices</i> |
| D. Positioning of the X-ray Tube | <ul style="list-style-type: none"> • <i>Ceiling mount vs tube hanger</i> • <i>Tube motions: transverse, Longitudinal, vertical, angle, tilt</i> • <i>Detent</i> |
| E. Primary X-ray Beam | <ul style="list-style-type: none"> • <i>Definition</i> • <i>X-ray Source – tube</i> • <i>Central ray</i> • <i>Properties</i> |

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F. Radiographic Table / Upright Cassette Holder

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

G. Control Panel Components

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

H. Remnant Radiation

- *Definition*

I. Scatter Radiation

- *Definition*

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; 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 as the atomic models*
 - *Absorbed - radiopaque*
 - *Scatter – random “endpoint”*
 - *Passes through unaltered – radiolucent*

D. Ionization

- *Definition*
- *Implication*
- *Cause of patient dose*

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- *Cause of image formation*

3.4 Basic X-ray Tube Design 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 vs. 1% x-rays (No detailed atomic models; characteristic radiation should not be covered)*
- *Bremsstrahlung X-rays – “spectrum” of photon energies in Beam*

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E. Filtration

- *Tube filtration*
 - *Definition*
 - *Purpose*
 - *Types (inherent, added, total)*
- *Compensating filters - Definition*

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*
 - *kVp*
 - *Distance: inverse square law*

C. X-ray Beam Quality

- *Definition*
- *Key factors affecting X-ray beam quality*
 - *kVp*
 - *Half Value layer (HVL) – Definition*

3.6 Primary Radiologic Image

A. Basic Interactions with Matter

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

B. Differential Attenuation

- *Basis for subject contrast*
- *Effects on air, bone, muscle and fat (No Z-numbers)*

C. Intensity

- *Effects on intensity of the x-ray beam on the radiographic image*
- *Scale of contrast*

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3.7 Film/Screen Image Receptors

A. Film Basics

- *Film emulsion*
- *Definitions:*
 - *Cassette – Manifest Image*
 - *Speed*
 - *Latent image*
 - *Optical density*
 - *Detail/spatial resolution*
 - *Contrast resolution*
 - *Spectral matching*
- *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

- *Screen Phosphor*
- *Fluorescence – Definition and Purpose*
 - *Advantage – dose reduction*
 - *Disadvantage – Less resolution*
- *Maintenance*
 - *Cleaning, Inspection*
- *Spectral Matching*

C. Automatic Wet Film Processing

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

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- *Safelights – low watt bulbs, safe at a distance*

D. Chemical Safety

- *Safety Data Sheet (SDS)*
- *Protective Apparel*

E. Processing Quality Control

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

3.8 Digital Imaging

A. Digital Basics

- *Analog signal “waveform vs. digital signal “string” of binary numbers*
- *Analog to Digital Conversion (ADC)*
 - *Information sent to computer for processing*
- *Matrix – pixels, pixel size, matrix size and spatial resolution*
- *Line pairs/mm selections and resolution*
- *The Digital Imaging and Communications in Medicine (DICOM) standard – Definition and relative importance.*
- *Picture Archiving Communication Systems (PACS) – Definition and relative importance*

B. Computed Radiography (CR)

- *Overview of CR - Photostimulable Phosphor (PSP) image plates*
 - *Most common, least expensive*
 - *Construction – cassette and PSP imaging plate*
 - *X-ray exposure interacts with PSP “latent image” formed*

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- *Plate scanned by laser light, trapped energy released as light and read to produce a "manifest" image*
- *Exposure to plate by intense light "erases" any remaining trapped energy to ready plate to be used again.*
- *PSPs should be erased daily if not used.*

C. Direct Readout (DR)

- *Indirect conversion DR – converts X-rays to light prior to detection*
 - *Scintillators convert X-rays to light (therefore indirect) but emitted light "read" directly by photodetector (CCD)*
- *Direct Conversion DR – utilize crystals which directly converts 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*
- *Post processing*
 - *Window level – controls brightness*
 - *Edge enhancement*
 - *Smoothing*
 - *Image Reversal*
- *Define spatial and contrast resolution*
- *Window width – (gray scale compression or expansion) – controls contrast*
- *Inverse relationship between width and contrast*

E. Exposure Indicator

- *Definition*
- *Vendor specific*

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- *Ethical and regulatory responsibility – As Low As Reasonably Achievable (ALARA)*

F. Practical Considerations – Differences Between Digital and Film

- *CR plate sensitivity to scatter radiation*
- *Latent image decay exponential*
- *Exposure indices*
- *Cost*
- *Dose*
- *Existing equipment*
- *Higher contrast resolution*
- *Speed*

3.9 Optimal Techniques

A. Primary Factors Effecting Contrast Density and Exposure

- *Kilovoltage (kVp)*
 - *Film/screen – contrast and density*
 - *Digital – adequate penetration*
- *Milliamperage (mA)*
 - *Film/screen – density*
 - *Digital – exposure index*
- *Time – Density*
- *Beam Restriction*
 - *Contrast*
 - *Density and exposure*
 - *Scatter*
- *SID*
 - *Definition*
 - *Density and exposure*
- *Grid Ratio – effects on*
 - *Contrast*
 - *Density and exposure*

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- *Scatter and patient dose*

B. Image Detail – Geometric Factors (Spatial Resolution)

- *SID – definition and the effects on detail, distortion and magnification*
- *OID – definition and the effects on detail, distortion and magnification*
- *Distortion and positioning*
- *Focal Spot Size (FSS)*
- *Time – detail*

C. Automatic Exposure Control (AEC)

- *Definition*
- *Proper Use*

D. Visibility of Structure

- *Optimization of Image contrast (contrast resolution)*
- *Effects of scatter on image quality*
- *Motion*
 - *Types of motion*
 - *Common methods to reduce motion*

E. Radiographic Grids

- *Definition*
- *Scatter and patient dose*
- *Focal distance/tube alignment*

F. Technique Charts

- *Purpose*
- *Types*
- *Calipers - body part measurements*

3.10 Image Evaluation

A. Optimal Image Quality

- *Definition*

B. Image Artifacts

- *Definition*

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- *Motion*
- *Common film, CR image and DR Receptor artifacts*
- *Periodic cassette cleaning – required and documented*
- *Film fog*
 - *Common causes*
 - *Over vs. under development: chemical fog*
 - *Handling and storage*
- *Digital*
 - *Moire*
 - *Ghost or phantom*
- *Quantum mottle/noise*

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 – seivert (equivalent dose)*

C. Basic Biologic Effects of Radiation Exposure

- *Human radiation response*
- *Key biologic factors affecting Radiosensitivity*
- *Age*
- *Law of Bergonie and Tribondeau*
 - *Relative radiosensitivity of cells*
- *Early effects – to show that high dose effects aren't relevant to*

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diagnostic imaging

- *Erythema – definition*
- *Epilation - definition*

- *Late effects of radiation*
(background information should develop understanding as to why certain shielding precautions are taken)
 - *Cataract formation*
 - *Radiation-induced malignancies – general concepts*
 - *Thyroid*
- *Direct effect vs. indirect effect*
 - *Radiolysis of water (Indirect effect)*
 - *DNA is critical target (Direct effect)*
- *Somatic vs. genetic effects*
 - *Definitions*
- *Radiation and pregnancy*
 - *Effects on fertility*
 - *Irradiation in utero – 1st trimester – fetal effects*
 - *Relative risk of childhood leukemia*

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*
- *Proper collimation*

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- *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**
 - *Increase dose to patient*
- F. **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 3701:1-66-12 of the Ohio Administrative Code: “Occupational Dose Limits”**
 - *Annual dose limits*
 - *Whole body*
 - *Lens of eye*
 - *Skin, hands & feet*
 - *Cumulative 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*

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- *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, Clinical History, Confidentiality and Image Labeling

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*

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and Accountability Act, HIPAA

- *Other institutional policies*

D. Proper Image Labeling and documentation

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

4. Resources

Bontrager, Kenneth, *Textbook of Radiographic Positioning and Related Anatomy*, 8th edition, 2013

Bushong, S, *Radiologic Science for Technologists*, 10th edition, Elsevier-Mosby, 2014

Campeau, F, Fleitz, J, *Limited Radiography*, 3rd edition, Thompson-Delmar, 2010

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Long, B, Frank, E, Ehrlich, RA, *Radiography Essentials for Limited Practice*, 4th edition, Elsevier-Saunders, 2013

Statkiewicz, Sherer, *Radiation Protection in Medical Radiography*, 7th edition, 2014