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Radiation Safety in Endoscopy

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Disclosures

None

Introduction

- Medical radiation accounts for half of the radiation exposure in the United States
- It is estimated that 2% of cancers are related to radiation from CT Scan exposure
- Within the field of radiology there has been a push to be mindful of radiation exposure
- Several gastroenterology procedures involve fluoroscopy, and yet, there is no standardized technology or education among physicians and endoscopy staff in the United States

Sethi S et al. Dig Dis and Sci. 2019
Kwok K et al. GIE. 2021

Introduction

- The states of NY, NJ and CT do not require certification for physicians to perform procedures with fluoroscopy

- Concerns regarding radiation exposure influence whether physicians choose subspecialities with fluoroscopy.

- Education of physicians can reduce subsequent radiation exposure for patients and staff during ERCPs

Kwok K et al. GIE. 2021
Krueger KJ et al. Gastro. 1992
David YN et al. Gastro. 2021
Barakat MT et al. Clin Gastro and Hep. 2018

Outline

- Define radiation and its effects
- Understanding fluoroscopy equipment
- ALARA and dosimetry
- Changes to mitigate radiation
- Special considerations for pregnant staff
- Looking forward

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- **Define radiation and its effects**
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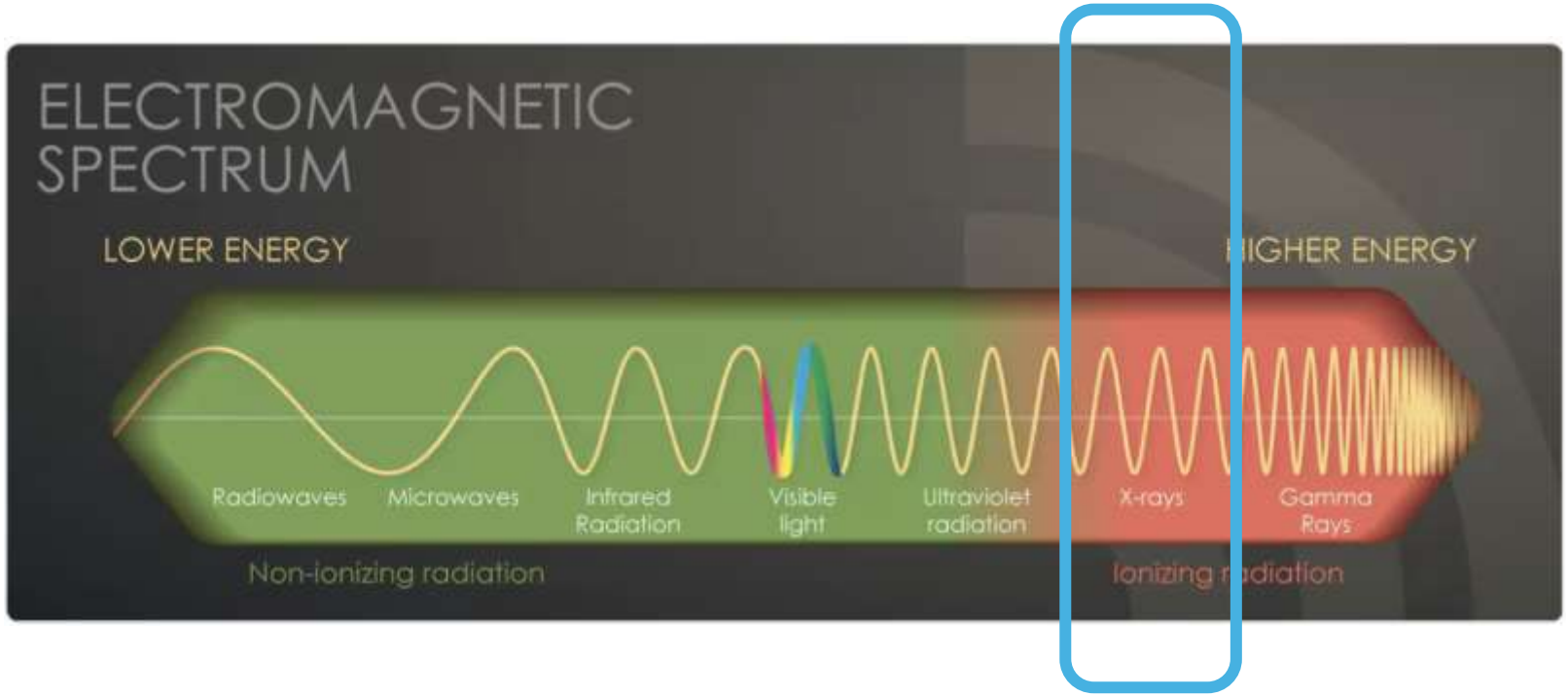
What is radiation?



Radiation and your health CDC 2024
Kwok K et al. GIE. 2021

Ionizing radiation can cause damage to DNA

Stochastic Effects

- Can occur at any radiation dose
  - Probability of occurrence increases with increased dose
- Ex:
  - Cancer, genetic defects that can be inherited.

Deterministic Effects

- Occur once a radiation dose threshold is reached
  - Severity increases with dose exposure
- Ex:
  - Birth defects, cataracts, hair loss, skin injury

Kwok K et al. GIE. 2021
Bang J et al. Am. J Gastro. 2019
Calo NC et al. CGH. 2022

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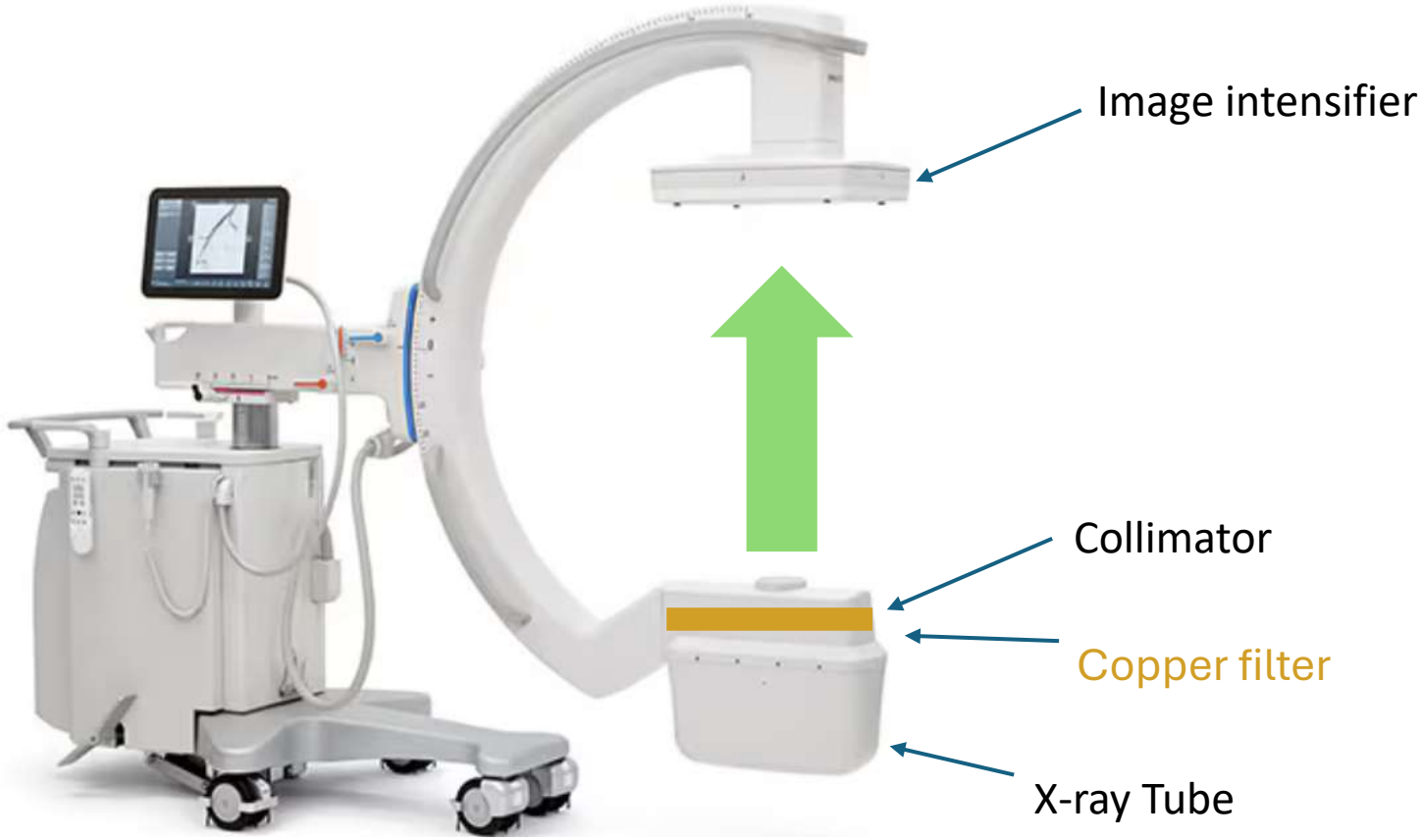
Components of a fluoroscopy unit



Dumonceau JM et al. Endoscopy. 2012

Fixed vs. Mobile

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Muniraj et al. Am J Gastro. 2015

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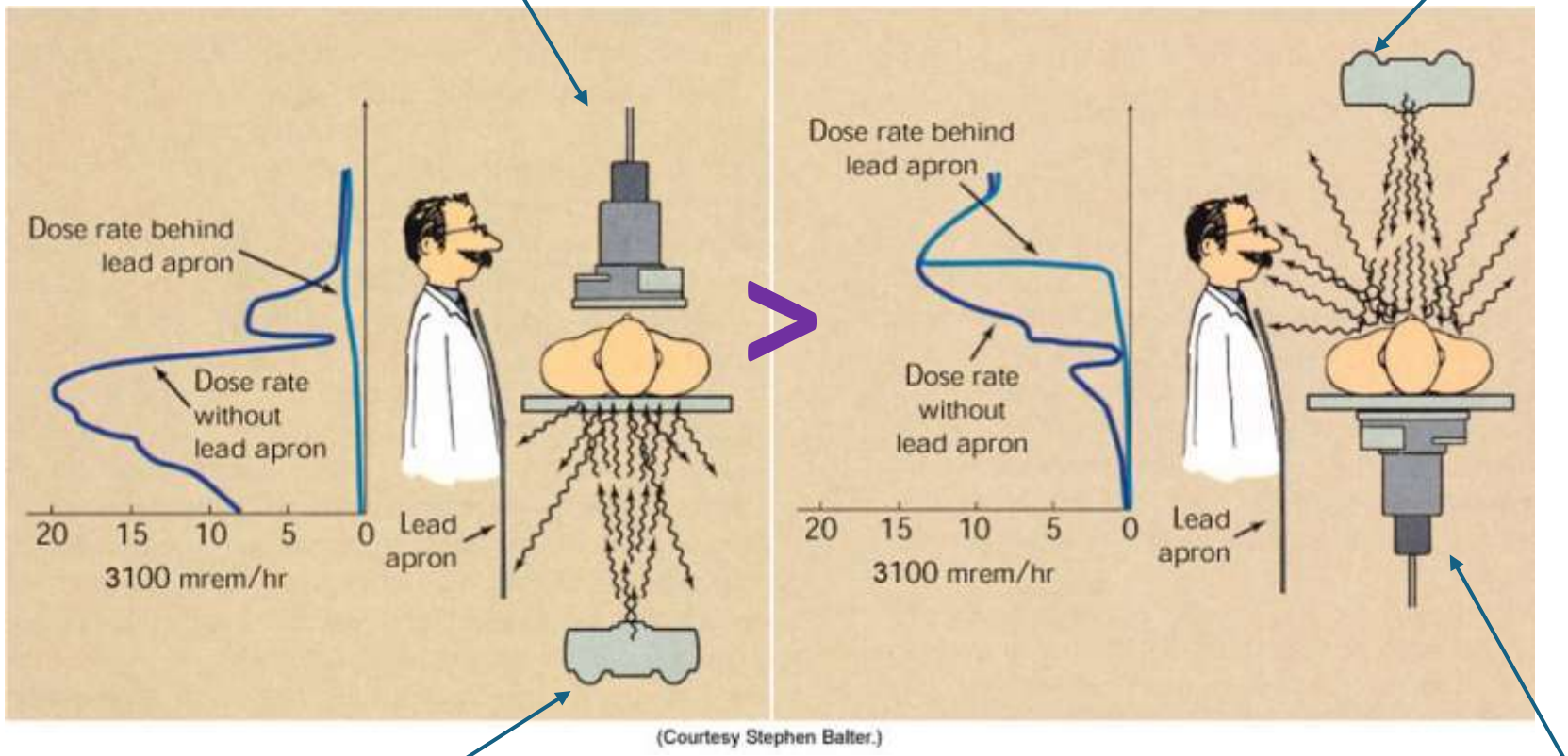
Undercouch vs. Overcouch



(Courtesy Stephen Balter.)

Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed.,
Kwok K et al. GIE. 2021
Muniraj et al. Am J Gastro. 2015

Notable machine settings

- **Automatic Brightness Control**
  - Maintains a constant brightness for images
  - Downregulates or upregulates x-ray production
- **Magnification**
  - The higher the magnification the greater the radiation dose
  - Ideally use magnification at lowest possible setting
- **Collimation**
  - Radiopaque shutters to focus the x-ray beam on an area of interest
  - Less tissue irradiated leading to less scatter and less exposure to staff/patient
- **Gantry Angle**
  - Angle at which x-ray beam is projected
  - Oblique and steep views--> x-ray must penetrate more tissue to obtain an image--> overall more radiation gets used

Kwok K et al. GIE. 2021

Variability among equipment

- No industry standard or uniformity for controls across machines

- In 2006 FDA established safety standards for ionizing radiation emitting products
  - Source- to-skin distance standards
  - Radiation output values
  - Alarm at 5 minutes fluoroscopy time (FT)

Figure 1. Representative control panels from 4 different fluoroscopy manufacturers. Note the lack of standardization of key controls. Clockwise from upper left: Philips (Amsterdam, Netherlands), Siemens Healthineers (Erlangen, Germany), GE Healthcare (Chicago, Illinois), Omega Medical Imaging (Sanford, Fla, USA).

Kwok K et al. GIE. 2021

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ALARA

"As low as reasonably achievable"

- Minimize exposure to patients and staff
- Emphasis on TIME, DISTANCE, and SHIELDING
- Limits are set by the International Commission on Radiological Protection and National Council for Radiation Protection

TABLE 2. Annual occupational dose limits

	Dose limit	Notes
International Atomic Energy Agency[98]		
Total body	20 mSv	Per year averaged over 5 y
	50 mSv	In 1 y
Lens of eye	20 mSv	Per year averaged over 5 y
	50 mSv	In 1 single year
Extremity (hands, feet, or skin)	500 mSv/y	
NCRP[99]		
Total body effective dose	50 mSv	Per year
Lens of eye	50 mGy	Lowered limits based on NCRP Commentary No. 26
Extremity (hands, feet, or skin)	500 mSv/y	

NCRP, National Council of Radiation Protection.

Kwok K et al. GIE. 2021

How do we measure radiation?

- **Absorbed Dose:**
  - Amount of energy absorbed in 1 gram of matter
  - Fluoroscopy time
  - Entrance skin dose (mGy)
  - Kerma air product
  - Deterministic effects for the patient

TABLE 1. Absorbed dose (D) vs dose equivalent (H)

	SI	Non-SI (USA)
Absorbed dose (D)	1 Gray (Gy)	100 rad
Equivalent dose (H)	1 Sievert (Sv)	100 rem
	1 milliSievert (mSv)	100 mrem

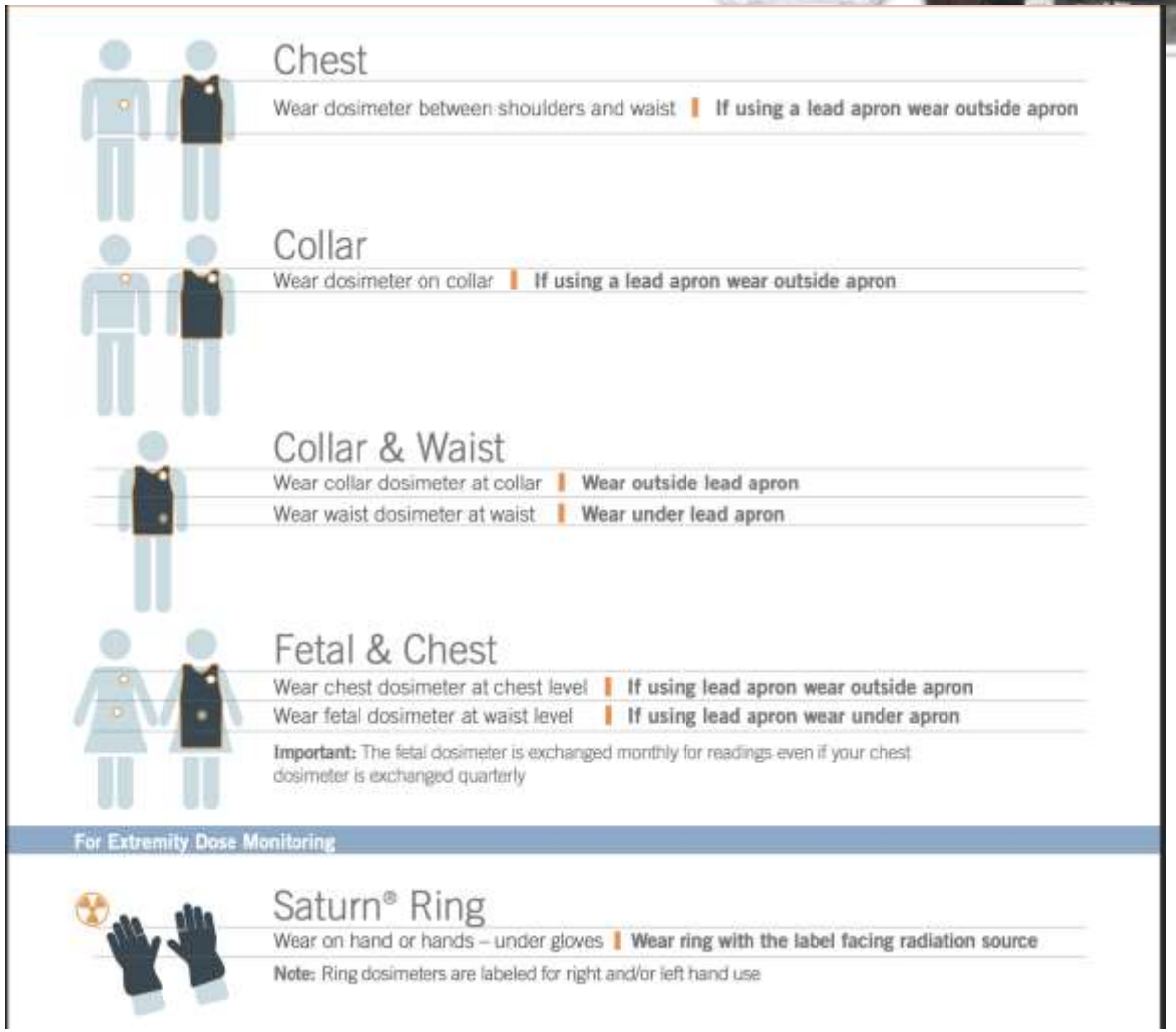
SI, Système international.

- **Dose Equivalent:**
  - Absorbed dose modified by the ability of the radiation to cause biological damage
  - Effective Dose (mSv)
  - Stochastic effects for staff

Kwok K et al. GIE. 2021

Dosimeters


Account No.
Serial No.
Account No.
Contact your RSO for the Account No. associated with your Saturn™ Ring
Serial No.
Account No.


Chest
Wear dosimeter between shoulders and waist | If using a lead apron wear outside apron
Collar
Wear dosimeter on collar | If using a lead apron wear outside apron
Collar & Waist
Wear collar dosimeter at collar | Wear outside lead apron
Wear waist dosimeter at waist | Wear under lead apron
Fetal & Chest
Wear chest dosimeter at chest level | If using lead apron wear outside apron
Wear fetal dosimeter at waist level | If using lead apron wear under apron
Important: The fetal dosimeter is exchanged monthly for readings even if your chest dosimeter is exchanged quarterly
For Extremity Dose Monitoring
Saturn® Ring
Wear on hand or hands – under gloves | Wear ring with the label facing radiation source
Note: Ring dosimeters are labeled for right and/or left hand use

Interpreting a report

Begin wear date	End wear date	Dosimeter Type	Dosimeter Location	Total DDE	Total LDE	Total SDE
2023/09/06	2023/09/30	Pa	Fetal	1		
2023/09/01	2023/09/30	Pa	Collar	54	54	52

This serves as notification that your radiation exposure for the monitoring period noted below exceeds our institutional ALARA I action levels. The following actual readings are reported by Landauer our dosimeter provider.

Monitoring Period	**Quarter**	2		2023

Your personal exposures for the quarter	**Dose Received (mRem)**
Whole body: head and trunk; active blood forming organs (DDE)	120
Lens of the eyes (LDE)	399
Skin of any portion of the whole body (SDE)	384
Hands and forearms; feet and ankles (Extremity)	

Listed below are established ALARA I and ALARA II action levels set by our institution, corresponding to 10% and 30% of the regulatory levels, respectively. All action levels are quarterly values and are in mrem:

Institutional ALARA I and ALARA II action levels	ALARA I	ALARA II
Whole body; head and trunk; Active blood forming organs (DDE)	125	375
Lens of the eyes (LDE)	375	1125
Skin of any portion of the whole body (SDE)	1250	3750
Hands and forearms; feet and ankles (Extremity)	1250	3750

Dose assessment	DDE (mrem)	LDE (mrem)	SDE (mrem)	EXT (mrem)
EDE2	M	M	M	–
EDE2	M	1	2	–
EDE2	M	1	1	–

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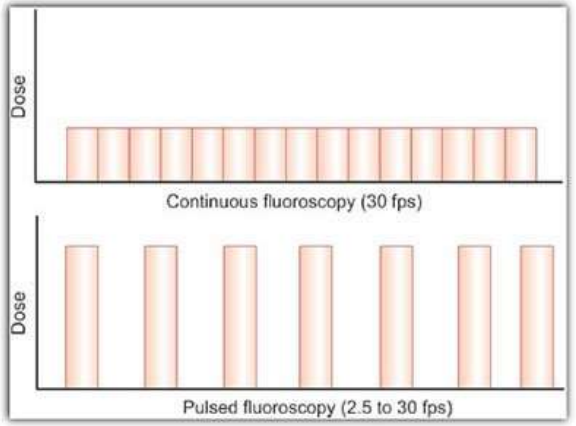
Decreasing Time



- **Pulsed Image**
  - X-ray beam produced at a lower frame rate compared to continuous
- **Last Image Hold**
  - Keeps last fluoroscopy image on the screen
  - Shown to decrease fluoroscopy time by 50-80%
- **Limit use of spot image**
  - each image is equivalent to 3 seconds of fluoroscopy time
- **Pair endoscopy and fluoroscopy image together**
  - associated with 1.4 minutes less of FT
- **Endoscopist control** of fluoroscopy foot pedal
- **Endoscopist's experience**
  - Case fluoroscopy time is inversely proportional to annual volume of the proceduralist
  - One study showed that every 10 years of independent practice was associated with 21% decrease in FT
  - Data are mixed on whether involving an advanced fellow increases fluoroscopy time

Kwok K et al. GIE. 2021
Kakodkar S et al. Cureus 2021
Calo NC et al. CGH. 2022
Jorgensen JE. GIE. 2010
Kim E,et al. GIE. 2010
Jowhari F et al. Endosc Int Open 2017

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Distance

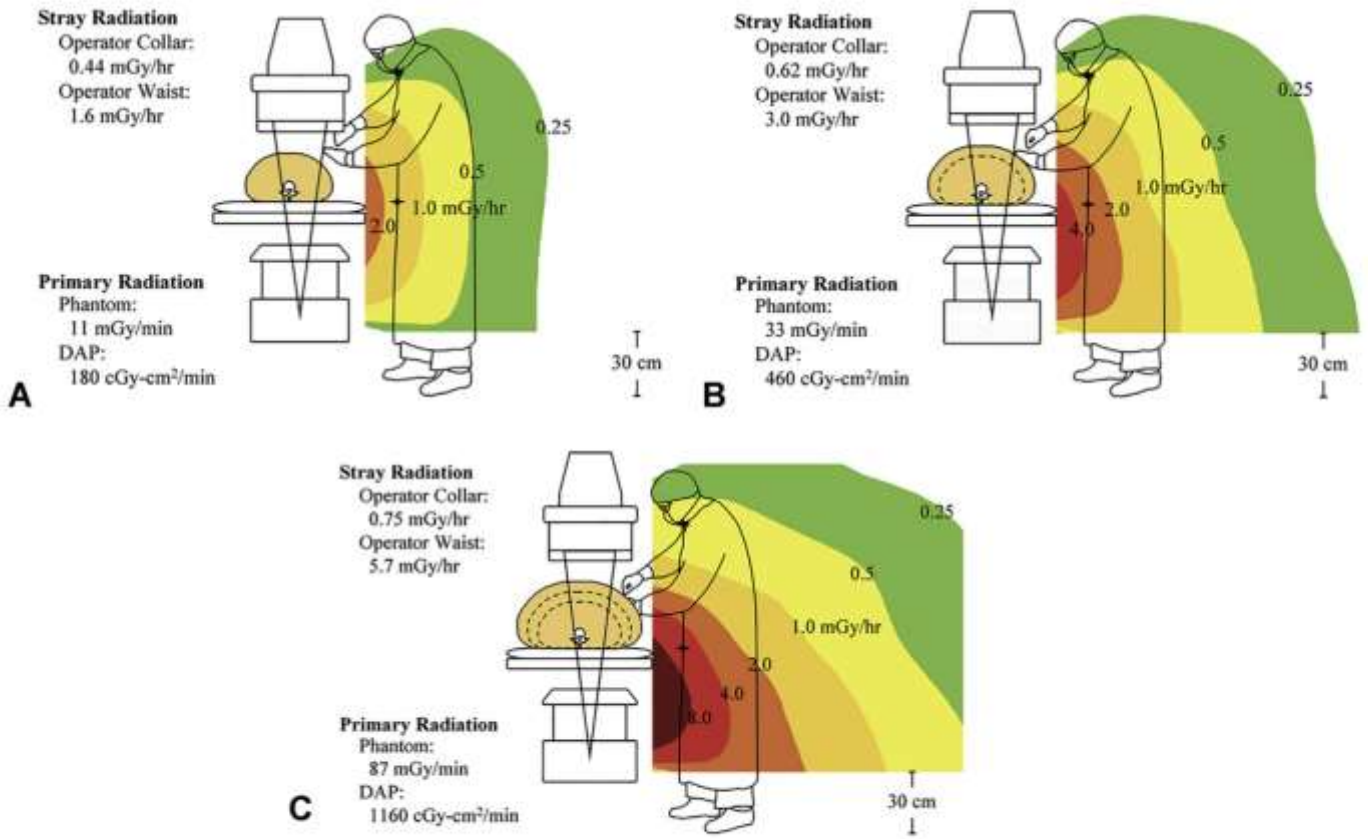

Figure 2. The effect of increasing patient abdominal thickness on operator exposure, at abdominal thicknesses of 24 cm (**A**), 29 cm (**B**), and 34 cm (**C**). (Reproduced with permission from Schueler BA, Vireze TJ, Bjarnason H, et al. An investigation of operator exposure in interventional radiology. RadioGraphics 2006;26:1533-41.)

- The greatest source of radiation for staff is scatter from the patient
- The larger the patient the greater the scatter
- Exposure is inversely proportional to the square distance from the source
- Staff should stand as far as possible

Kwok K et al. GIE. 2021

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Personal Shielding

Lead

- Made in 3 types of thicknesses
  - **0.25mm lead blocks >90% of scatter**
  - 0.5 and 1mm lead provides minimal extra protection at the cost of heaviness
- **Two-piece** lead is generally more ergonomic
- Wrap-around lead provides protection when staff is placed tangential from x-ray
- Ensure a good fit, unnecessary gaps in arm holes can expose breast tissue

Thyroid Shield

- Existing studies have underestimated risks of thyroid cancer
- Recommended to have 0.5mm thickness

Eye Protection

- Risk for cataracts across interventional specialties, especially with overcouch systems.
- Can decrease risk for cataracts by 3-8 fold.
- Some data suggest that endoscopists may not meet the lifetime threshold for this to be a risk
- **0.5mm goggles recommended by ASGE guidelines for endoscopists**

Kwok K et al. GIE. 2021
Chou LB et al. J Bone Joint Surg Am 2010
Sethi S et al. Dig Dis and Sci. 2019
Mekaroonkamol. Am J Gastro. 2017 .

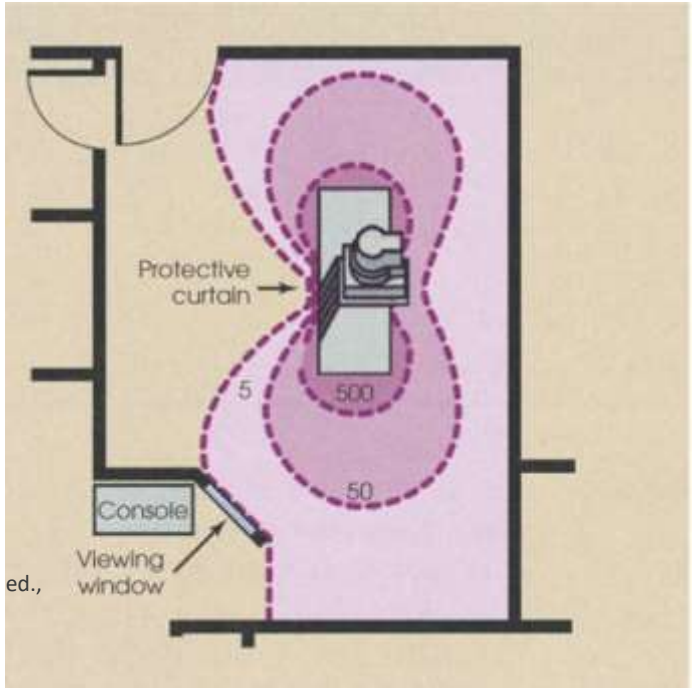
Protecting Lead

- Ideally should be hung
- Folding lead can produce cracks
- Institutions should inspect lead annually with radiographs to identify cracks

Kwok K et al. GIE. 2021

Additional Shielding

- An RCT showed that lead-equivalent drape around the image intensifier resulted in > 90% reduction in scatter to proceduralist and nurses eyes and neck



c.f. Bushberg, et al. The Essential Physics of Medical Imaging, 2nd ed.,
Muniraj T et al. Am J Gastro 2015
Dumonceau JM et al. Endoscopy. 2012

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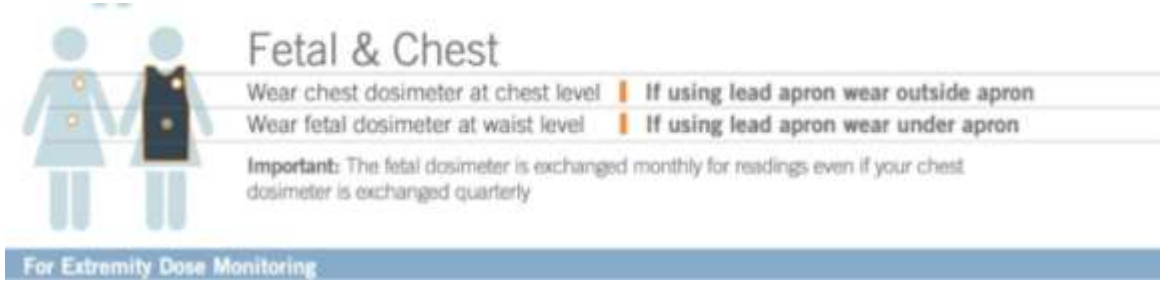
Recommended limits of exposure in pregnancy

- Pregnant health care workers can continue to work with a lower recommended dose limit than non-pregnant workers
- **No consensus of dose limits** for pregnant or child-bearing aged personnel
  - US National Council on Radiation (NRCP) recommends **no more than 5 mSv for an entire pregnancy or 1mSv/month after pregnancy is declared**
  - International Commission on Radiological Protection recommends a **maximum of 1 mSv for the duration of the pregnancy** after it is declared
- Most fetal risks are deterministic
- Suggestion is to limit or reduce radiation exposure

Table 1. Potential Effects of Radiation Exposure to the Developing Fetus According to Pregnancy Stage and Radiation Dose

Potential effect	Weeks of gestation	Radiation dose, mSv	Approximaate number of ERCPs required for level of exposure[a]
Loss of pregnancy	<4	100–200	50,000–100,000
Growth retardation	<8	200–500	100,000–250,000
Malformations	<8	250–500	125,000–250,000
Developmental delay	8–15 >16	60–500 >1500	30,000–250,000 750,000
Microcephaly	<15	>20,000	10 million
Decrease in intelligence quotient	>16	>100	50,000

ERCP, Endoscopic retrograde cholangiopancreatography.
[a]Calculations based on the effective radiation dose of 0.002 mSv per ERCP for endoscopists, assuming proper shielding practices are followed.[24]



Calo NC et al. CGH. 2022

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Ideal practices for women in fluoroscopy

- Data does not justify preventing pregnant staff from involvement in fluoroscopy-guided procedures at any point in pregnancy if appropriate protective measures are taken
- Total dose during pregnancy should not exceed > 5mSv and ideally no more than 0.5mSv/month
- Pregnant staff should wear two dosimeters
    - One at the collar over lead apron
    - One at the waist under lead apron
- Using a dosimeter at the waist prior to pregnancy could help estimate radiation dose at endoscopists current caseload and help with planning for pregnancy
- Pregnant staff should work with radiation safety and physicist for guidance on protection and optimal room set up
- Adjust lead apron sizing as pregnancy advances
- Units should have a plan in place to re-distribute the caseload for pregnant staff as needed/desired based on dosimeter readings

Calo NC et al. CGH. 2022

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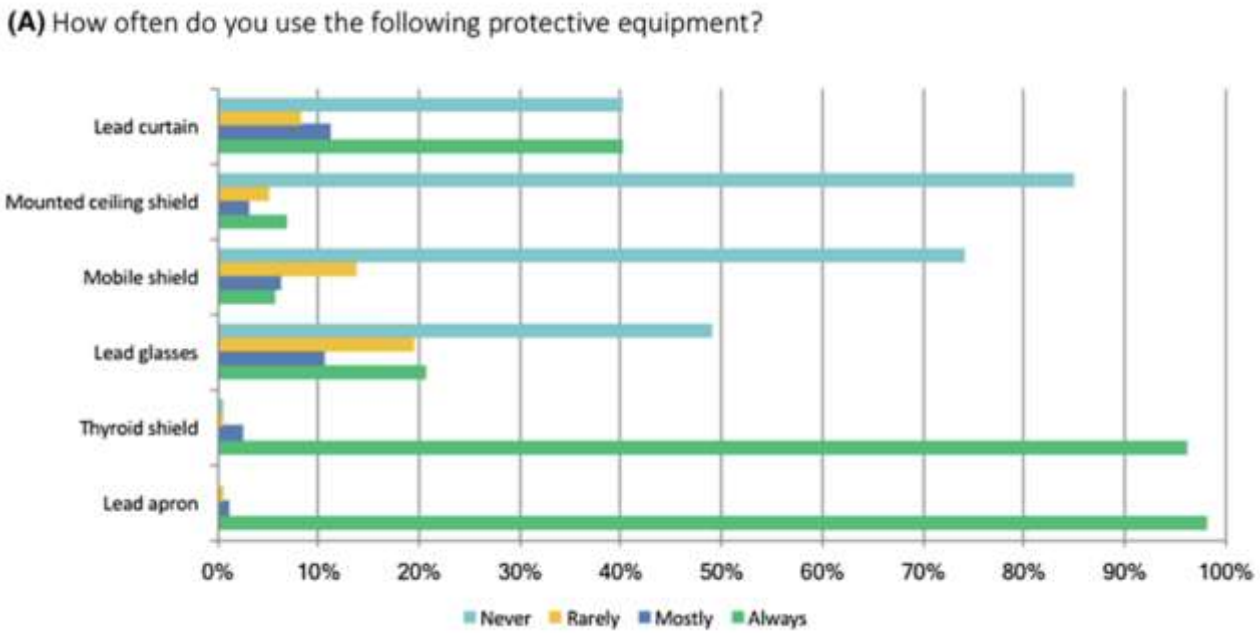
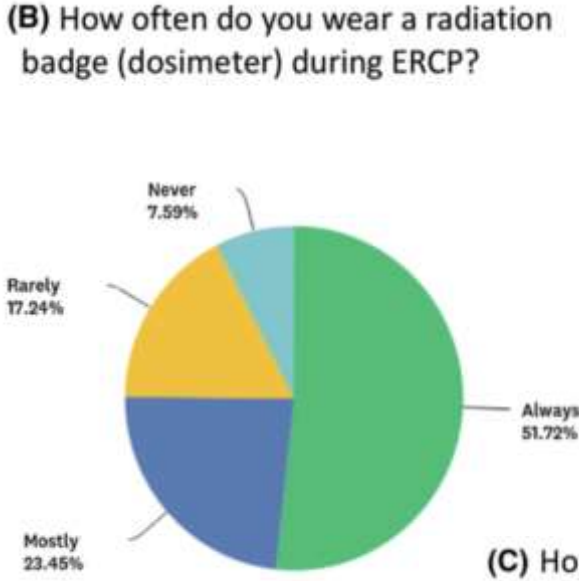
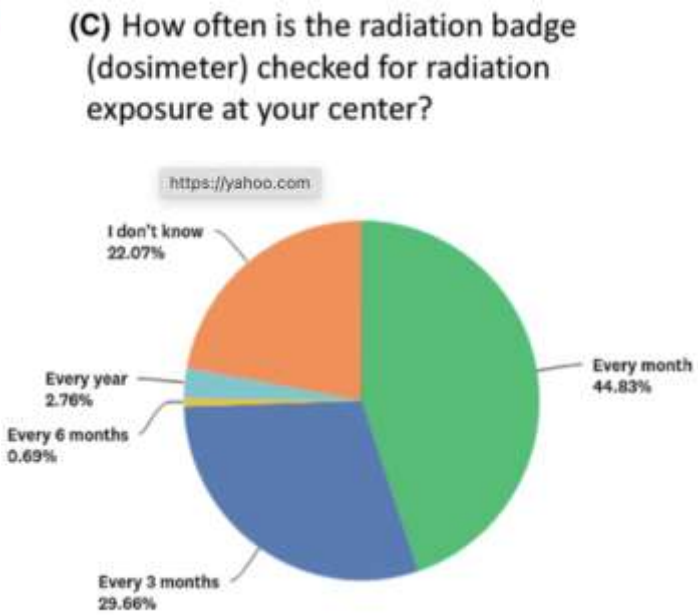
What do we need to improve radiation safety in endoscopy?







Sethi S et al. Dig Dis and Sci. 2019

Education

PANCREAS, BILIARY TRACT, AND LIVER

Effects of a Brief Educational Program on Optimization of Fluoroscopy to Minimize Radiation Exposure During Endoscopic Retrograde Cholangiopancreatography

Monique T. Barakat,[a] Nirav C. Thosani,[a] Robert J. Huang, Abhishek Choudhary, Rajan Kochar, Shivangi Kothari, and Subhas Banerjee

Division of Gastroenterology and Hepatology, Stanford University Medical Center, Stanford, California

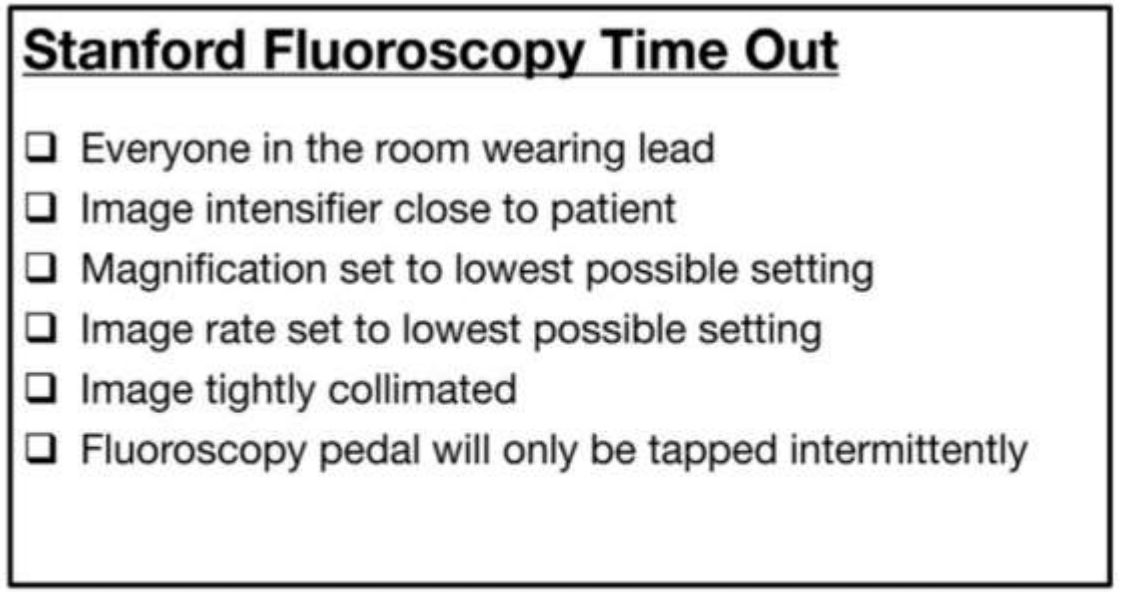


Figure 1. Stanford fluoroscopy time-out placard posted on fluoroscopy machine. Each statement is verbalized prior to initiation of endoscopic retrograde cholangiopancreatography.

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Education at Stony Brook

- Presentation on radiation safety administered to General GI fellows
- 10 GI fellows were included in the study
  - 80% male, 30% first year fellows, 30% second year fellows, 40% third year fellows
- All participants took both the pre- and post-intervention tests, with only 1 participant taking the post-test at 3 weeks due to a personal illness
- **None of the participants endorsed any formal radiation safety training prior to the study,** yet 50% stated that concerns regarding radiation had influenced their decision whether or not to pursue a career in interventional gastroenterology
- **Mean test scores significantly improved from 53% to 74% post-intervention (p = 0.0059).**
- Prior to the intervention only 60% of trainees stated they felt comfortable modifying behaviors to limit their own radiation exposure during cases; **this improved to 90% post-intervention**
- **Education does help everyone!**

In Summary

- Radiation is all around us
- Ionizing radiation is used in healthcare imaging. Unfortunately, it can place patients and staff at risk for DNA damage
- Using undercounch fixed fluoro units result in the least scatter and radiation risk for patients and staff
- Settings such as low magnification, collimation, pulsed imaging, last image hold, limited spot images, and pairing fluoro and endo images together can decrease amount of radiation used per case

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In Summary

- Distance and shielding further mitigate radiation exposure for staff
- Monitoring is essential for understanding individual risk
- Pregnant staff can continue to work in fluoroscopy-based cases
- Use of two dosimeters prior to pregnancy can help woman understand their radiation exposure and aid with family planning
- Education leads to better practices to reduce exposure

Thank you

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Salvatore Nania R.T.

Jason Philips R.T.

Bianca Di Coco MD

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