

Fluoroscopy

Radiation Safety and Risks

Objectives

- Regulations
- Basic Dosimetry
- Radiation Effects
- Factors that affect patient and staff radiation dose
- How to reduce radiation dose to patients and staff
- Learn about magnification, filtration, collimation and pulse fluoro
- How to use personal protective equipment

What is Fluoroscopy

- Fluoroscopy is a technique for generating x-ray images and presenting them continuously as visible images during a diagnostic or interventional procedure. It is usually used to track the movement of a contrast agent or an object through the body.
- A risk associated with fluoroscopy is radiation-induced injuries (burns) to the skin and underlying tissues.

Regulations

- Physicians and operators that use fluoroscopy units must have initial & biennial hospital approved radiation safety awareness with fluoroscopic machine safety training as required by applicable accreditation or regulatory agencies.
- The Joint Commission requires that physicians who use or operate fluoroscopic x-ray systems be properly credentialed. Clinical privileges are based on evidence of completion of this specific training.

Why is this important?

- Number of Fluoro injuries/adverse effects in physician, staff and patients is on the rise.
- Provide safety techniques to minimize exposure to patients and workers.
- Improves care quality to patients.

What's What?

- **Absorbed dose** is used to assess the potential for biochemical changes in specific tissues.
- **Equivalent dose** is used to assess how much biological damage is expected from the absorbed dose. Different types of radiation have different damaging properties.
- **Effective dose** is used to assess the potential for long-term effects that might occur in the future.

How is Radiation Dose Measured and what Does it Mean?

● Radiation Exposure

- Charge (ΔQ) produced by interaction of electromagnetic waves (x-ray) with mass of air (Δm).
- The unit of radiation exposure is the **roentgen (R)**

● Air Kerma:

- kinetic energy released in material by charge (ΔQ) produced by interaction of electromagnetic waves (x-ray) with mass of air (Δm).
- Expressed in **grays (Gy) or rads**

● Radiation Absorbed Dose (Rad)

- Energy (ΔE) deposited by ionizing radiation (x-rays) per unit mass of tissue (Δm).
- The unit of absorbed dose is the **gray (Gy)**.

How is Radiation Dose Measured and what Does it Mean?

Some units used in measuring ionizing radiation and radiation dose		
Unit	Description	Equivalent
Rem (roentgen equivalent man)	A unit of equivalent absorbed dose of radiation which takes into account the relative biological effectiveness of different forms of ionizing radiation, or the varying ways in which they transfer their energy to human tissue. The dose in rem equals the dose in rad multiplied by the quality factor (Q). For beta and gamma radiation, the quality factor is taken as one, that is, rem equals rad. For alpha radiation, the quality factor is taken as 20, that is, rems equal 20 times rads. Rem is essentially a measure of biological damage. For neutrons, Q is typically taken as 10.	$\text{rem} = \text{rad} \times Q$
Sievert (Sv)	A unit of equivalent absorbed dose equal to 100 rem.	$1 \text{ Sv} = 100 \text{ rem}$ $\text{Sv} = \text{Gy} \times Q$
Rad (radiation absorbed dose)	A unit of absorbed dose of radiation. Rad is a measure of the amount of energy deposited in tissue.	$1 \text{ rad} = 100 \text{ erg/gram}$
Gray (Gy)	A unit of absorbed radiation dose equal to 100 rad. Gray is a measure of deposition of energy in tissue.	$1 \text{ Gy} = 100 \text{ rad}$

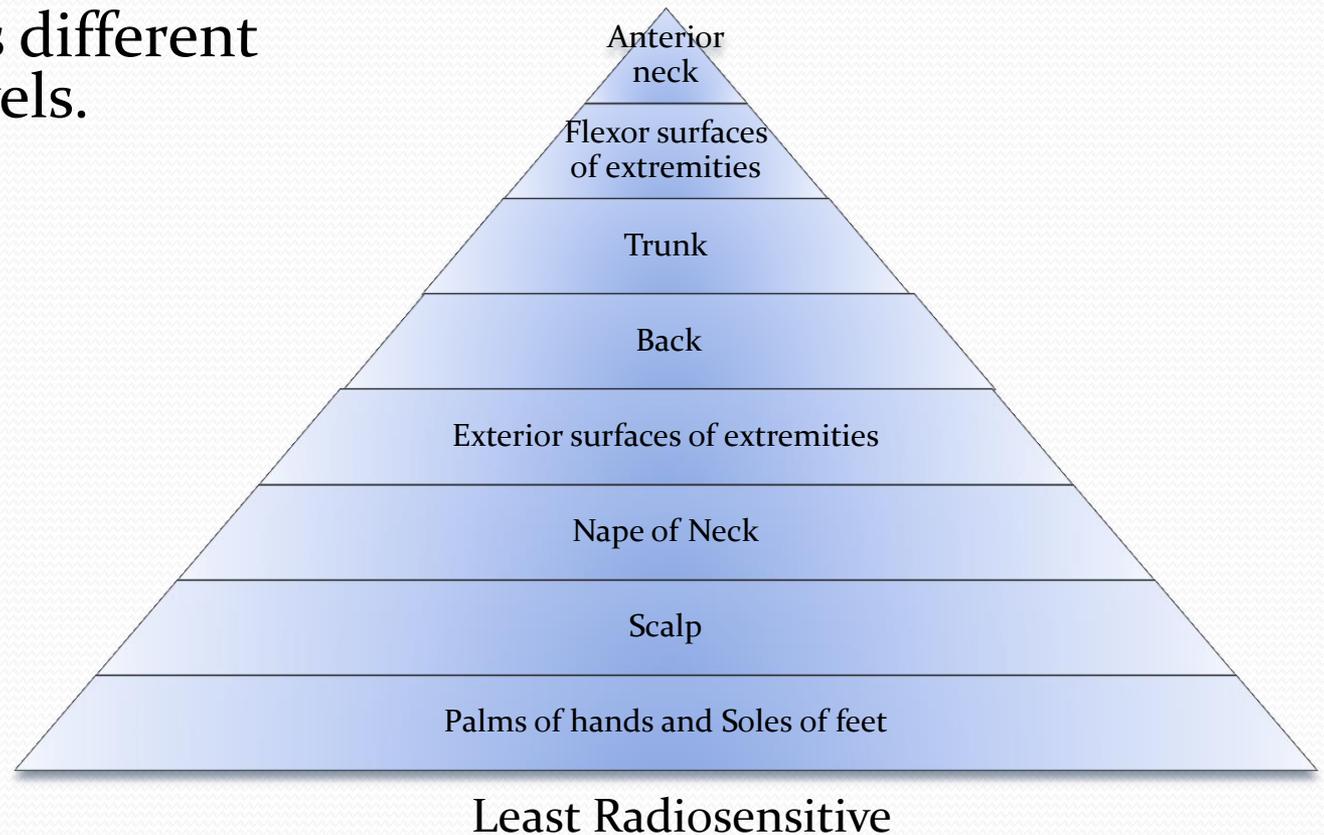
Effects of Radiation on Tissue

- Tissues at risk for radiation injury are skin, hair, subcutaneous tissue
- Fluoroscopy can induce mild skin reactions (2 to 5 Gray*) to severe subcutaneous fat and muscle reactions (greater than 5 Gray*)
- Previous radiation exposure to the same area of skin may have an effect on skin's response to additional radiation at a later time. Sometimes erythema (redness) presents immediately.
- Applicable follow-up is crucial after a patient is exposed to levels of radiation where there may be some indications of radiation injury.

*1 Gray is equal to 100,000 mRad and 1milliGray equals 100 mRad

Effects of Radiation to Skin

- The most commonly affected tissue is the skin. Skin has different sensitivity levels.



Radiation Effects

- Deterministic Effect – Dose Dependent
 - Severity of reaction depends on dose
 - Deterministic effects may have a threshold.
 - A threshold dose is the dose below which no injury is evident
 - Burns, hair loss, cataract induction
- Stochastic Effect – Not Dose Dependent
 - Risk of event occurring is dependent on dose
 - Severity is independent of dose
 - The results of winning a prize drawing is similar to a stochastic event: Buying more raffle tickets (higher dose) increases the chance of winning the prize but does not increase the prize.
 - There is “no threshold”
 - Cancer, genetic mutations

Radiation Effects



Cardiac Cath Lab – 2335 mGy (2.335 Gy)
Skin erythema as early as 2 hours post procedure

Radiation Effects



Cerebral Angio and CT – 2484 mGy (2.484 Gy)
Early transient erythema reaction within 2-24 hours

Radiation Effects

- Radiation risks are greater in Children
 - Tissues are more radiosensitive
 - Longer lifetime to manifest radiation induced injury (cancer, cataracts)
 - Each exam (therefore dose) is cumulative

Patient dose descriptors

- Radiography and fluoroscopy:
 - Reference Point Dose [mGy]
 - mGy is a milliGray
 - Entrance Dose [mGy]
 - calculated by tube output factors and exposure geometry
 - Dose Area Product (DAP) [$\text{Gy} \cdot \text{cm}^2$]
 - dose area product is a quantity used in assessing the radiation risk from diagnostic X-ray procedures
 - It is defined as the absorbed dose multiplied by the area irradiated
 - real-time measurement with DAP meter
 - absorbed dose can not be measured directly during a fluoroscopic procedure

Basic Dosimetry

Reference Dose
versus
Skin Dose

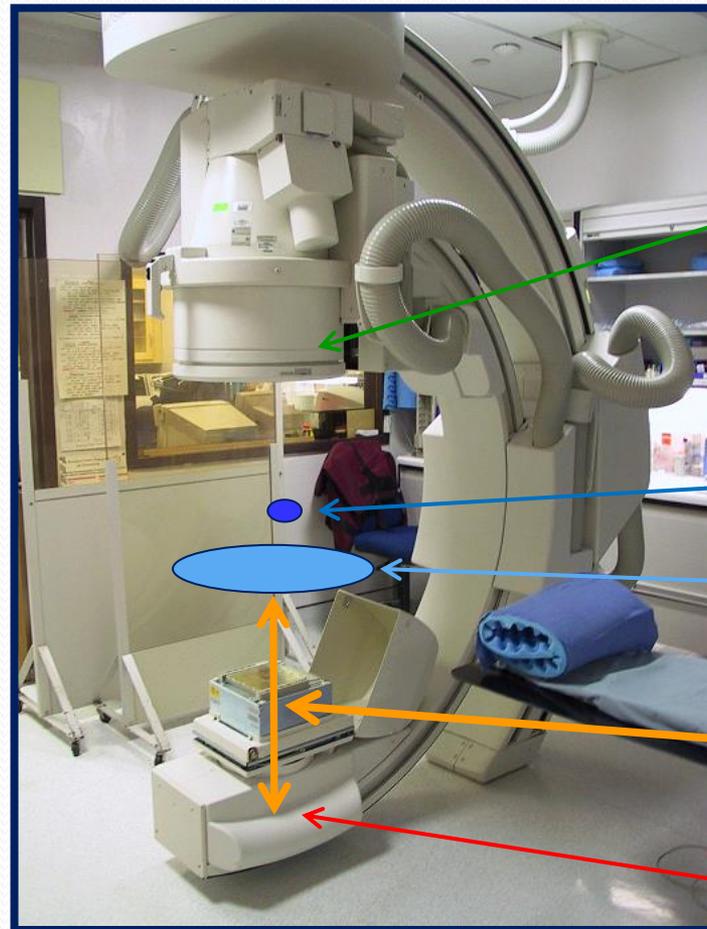


Image
Intensifier

Reference dose

Patient Skin
Entrance

****SSD****

X-ray Tube



So how can we work to
reduce radiation dose to
the patients and the
staff?

Principles of Radiation Protection

Optimization of protection by keeping exposure As Low As Reasonably Achievable (ALARA)



Patient Dose Reduction Techniques

- Use Fluoroscopic acquisition mode only when necessary.
 - Utilize Last Image Hold
 - Use pulsed fluoro instead of continuous
- Always acknowledge the exposure dose alerts every 5 minutes.
- Position tube and collimate with the fluoroscopy off
 - Collimation improves image quality, decreases scatter radiation to the user and reduces skin dose to the patient.
- Minimize the use of magnification.
 - Magnification will increase dose to the patient.
 - Only use to visualize smaller objects
- Move personnel away from the table during image acquisition.
- When lead shielding is used on a patient, make sure it is not in the primary beam as it can make the machine auto adjust for the lead, therefore increasing the output dose to penetrate the lead.
- Remember lowering patient radiation dose also decreases radiation exposure to the operators and personnel in the room.
- Entrance Dose (ED) rates on most machines are limited to less than 10 R/minute
 - At ED rates of 10 R/min, 30 minutes of fluoroscopy can deliver 300 R in skin dose (3 Gray*)

* Fluoroscopy can induce mild skin reactions at 2 to 5 Gray

Reduce the TIME that Fluoro is Active

- A signal audible to the fluoroscopist shall sound after every 5 minutes of irradiation time during a procedure.
- The signal shall sound until manually reset, or if automatically reset, for at least 2 seconds.
 - If no signal is available then the Radiology Technologist during fluoroscopy will verbalize each 5 minute warning during diagnostic procedures to a physician.
- When the high-level (boost) control is activated, special means of activation of high-level controls shall be required.
- The high-level control shall be operable only when continuous manual activation is provided by the operator. A continuous signal audible to the fluoroscopist shall indicate that the high-level control is being employed.

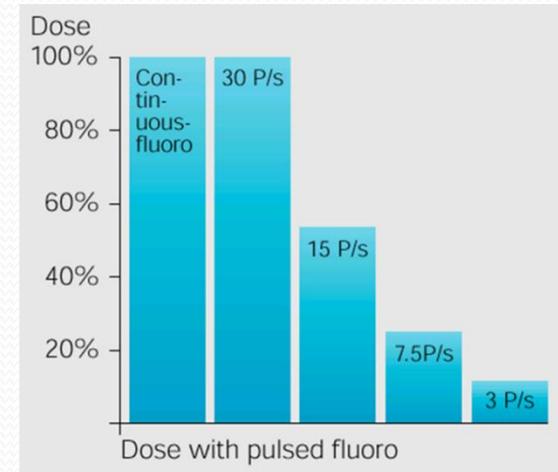


Pause AND Pulse to Fluoro - TIME

PAUSE to properly plan and prepare the procedure

- Activate equipment dose saving features
- No exposures unless necessary
- Depress last image hold and last image grab instead

PULSE at lowest possible rate



Place the patient's skin as close as possible to the image intensifier - DISTANCE

(GOOD Practice)

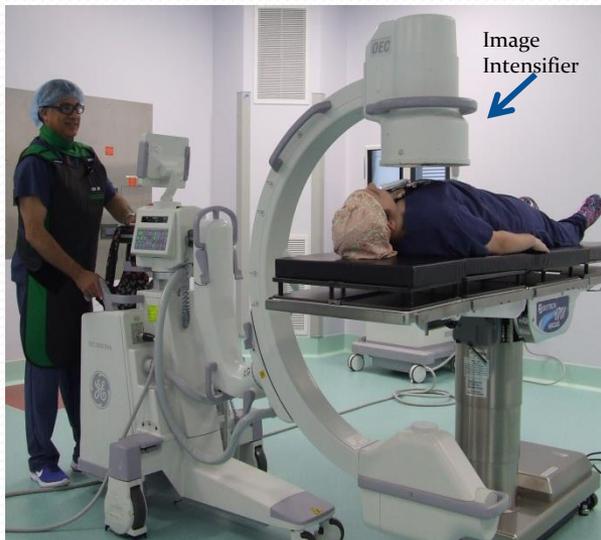


Image Intensifier close to patient, X ray tube far from patient

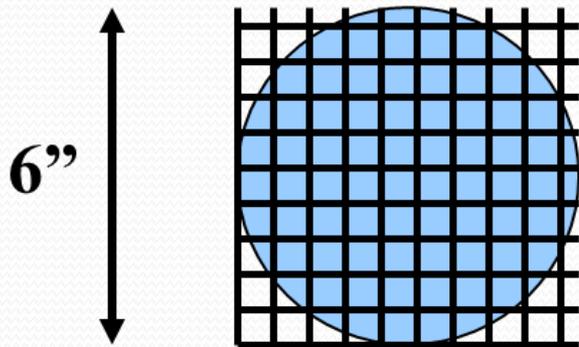
(BAD Practice)



Image Intensifier far from patient, X ray tube close to patient

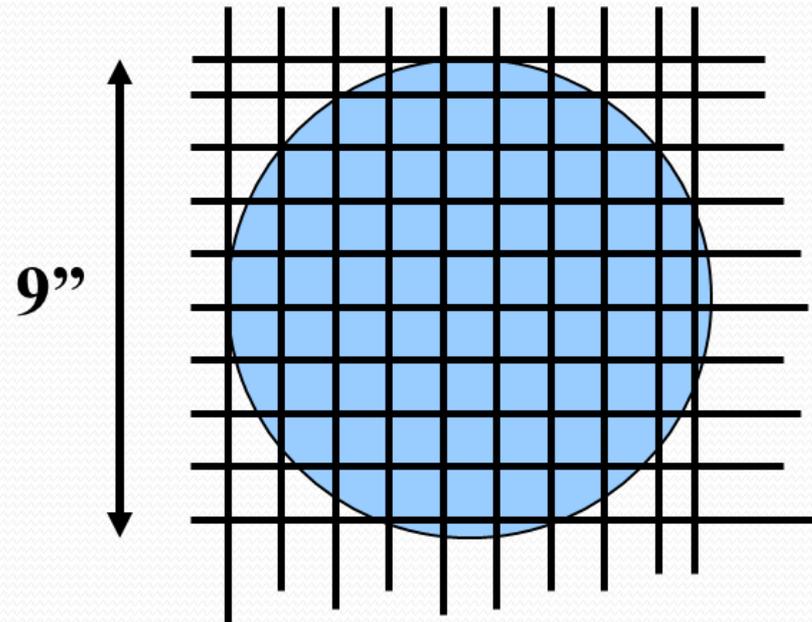
Magnification Reduction

Smaller Image Intensifier Mode (Magnification) has better resolution....



0.15 mm / pixel

vs.



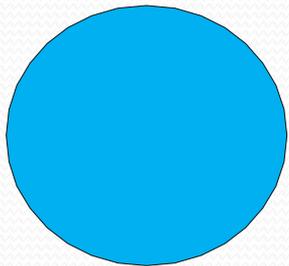
0.23 mm/pixel

....but higher exposure to patient and staff.

Magnification Reduction

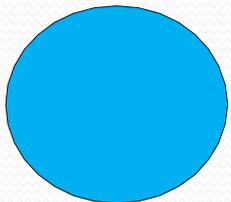
**Image Intensifier
Active Field of View (FOV)**

**Relative Patient Entrance
Dose Rate (mGy)**



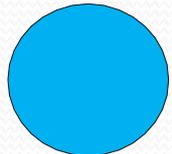
12" (32 cm)

100



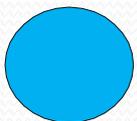
9" (22 cm)

177



6" (16 cm)

400



4.5" (11 cm)

711

If exposure settings are unchanged & just the magnification is increased, the patient dose increases.

Collimation

Collimation confines the X ray beam to an area of the user's choice.

- Reduces exposure to patient by reducing volume of tissue at risk
- Reduces scatter radiation at image receptor to improve image contrast
- Reduces scatter radiation to in-room personnel
- Reduces potential overlap of fields when beam is reoriented

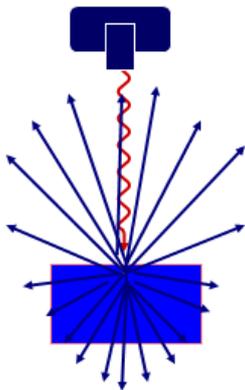


Patient Dose Optimization

- Deliver only the dose needed to make the diagnosis and no more.
- Choose the correct protocol for the patient.
- Only image the body part needed to make the diagnosis by using collimation
- A poor quality image that needs to be re-taken due to poor quality is a 100% wasted radiation dose.
- An image taken with too low of a dose risks a false-negative diagnosis thereby putting the patient at risk.

Factors affecting staff Dose - DISTANCE

- Staff should stand as far way from the intensifier as possible.
- More interactions and more scatter generates from the x-ray tube side of the body
- Over half of all scatter happens in the first 4 cm after the x-ray beam enters the patient,



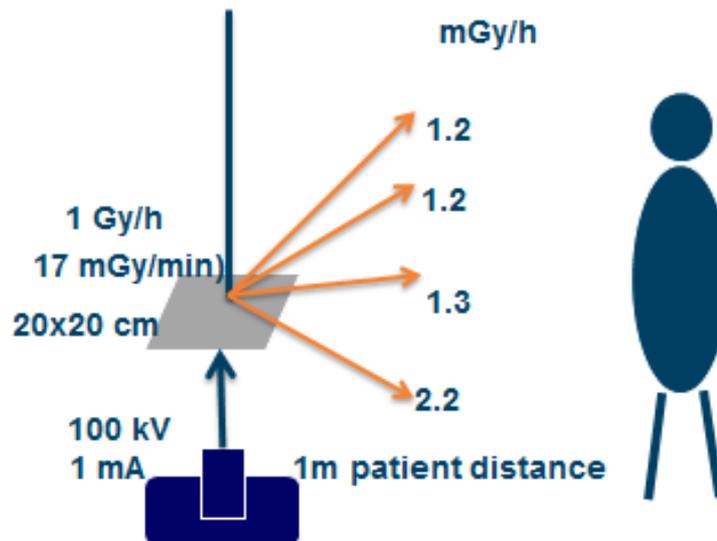
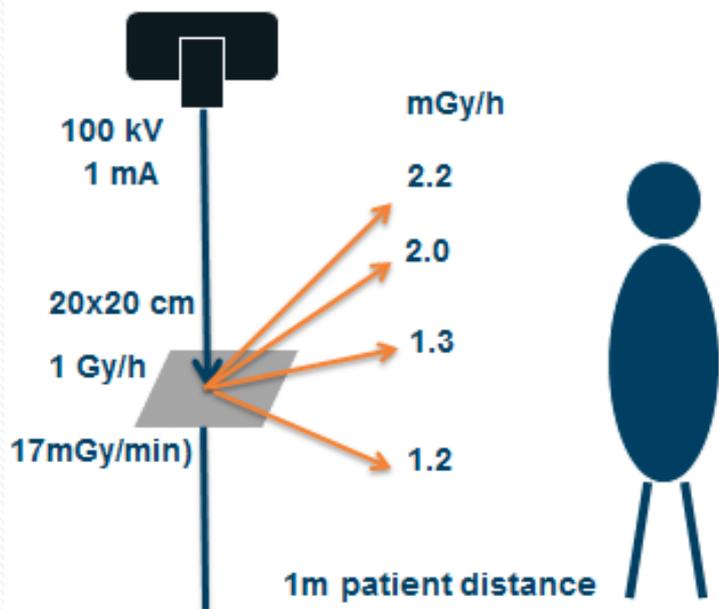
- Scattered dose rate is higher near the area into which the X-ray beam enters the patient
- The scattered radiation is not uniform around the patient.

Distance

Tube under-table position in fluoro reduces, in general, high dose rates to the specialist's eye lens

Over-table tube (higher dose)

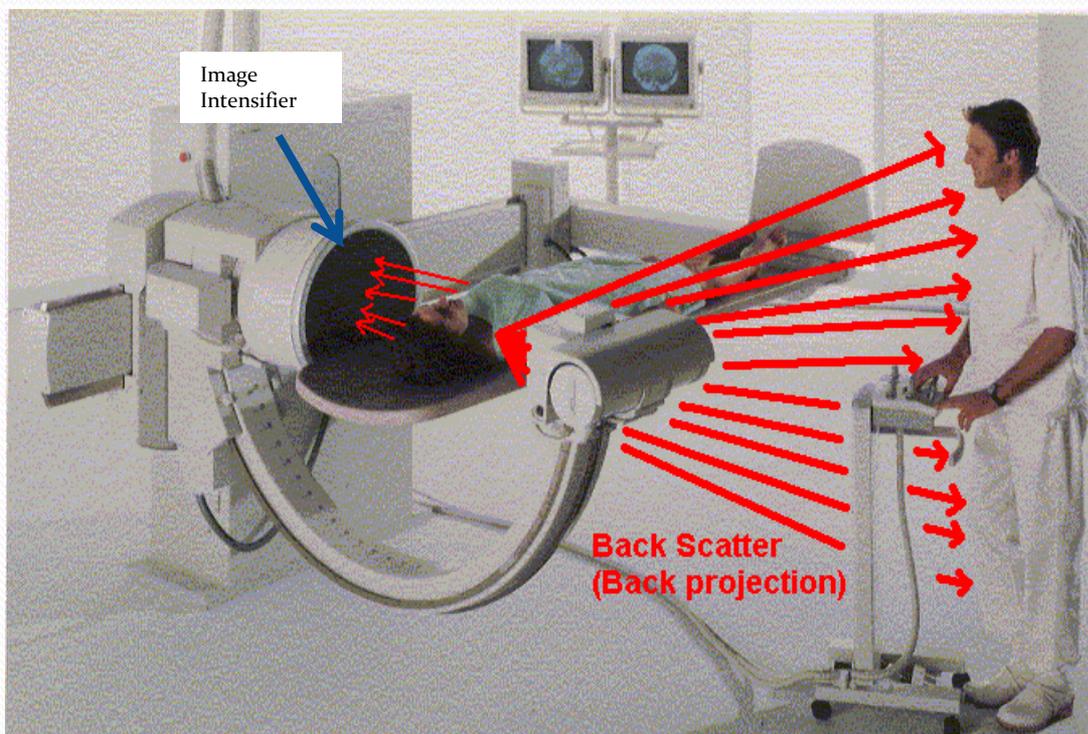
Under-table tube (lower dose)



Factors Affecting Staff Dose

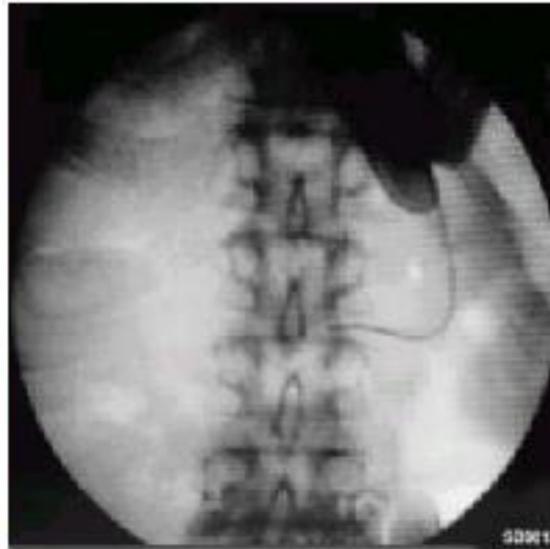
Operator should stand on Image Intensifier side if possible

AVOID this position if possible as it causes high scatter to operator



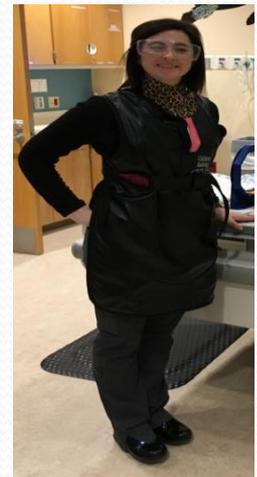
Radiation Protection of Hands

Best way to minimize dose to fingers and hands is to **keep your fingers and hands out of the beam!!!**



SHIELDING – Personal Protective Equipment

- The hospital provides personal protective equipment.
...But it is the responsibility of workers to use it!
- Everyone in the procedure room during fluoroscopy must wear a protective apron.
- Protective equipment includes full-length lead aprons, thyroid collar, and protective eye-wear.
- Aprons should be: **0.50 mm Pb equivalent**
- Always have Personal Protective equipment in place and secured before entering the room.
- If your duties require you to face away from the source of radiation then wear a two piece apron or one that wraps around the body.



Apron Integrity

- Lead aprons should be inspected annually at a minimum.
- CHMC lead aprons are imaged at least once per year.
 - If you have concerns about the integrity of a lead apron, reach out to your direct supervisor. S/he can coordinate investigation with radiology staff.
 - Do not fold the aprons when not in use.
 - Do not drape them over a chair or allow them to fall to the floor
- Lead apron integrity reports are saved on the Q Drive in the Radiation Safety Committee Folder



Practical advice for staff protection

- Increase distance from the patient.
- Minimize the use of magnification
- Use low dose pulse rate fluoroscopy modes.
- Acquire only the necessary number of images per series and limit the number of series.
- Collimate the X-ray beam to the area of interest.
- Stand on image intensifier side as far from patient as possible

****If image quality is inadequate, any radiation dose to the patient results in **needless radiation dose** to the patient!!**

Basic Dosimetry Exposure Limits

- General Public: 100 mRem/yr (1 mSv/yr)
- Occupational Users: Maximum is 5000 mRem/yr (50 mSv/yr)
 - Natural background radiation amounts to about 300 mRem/yr
 - ALARA: As Low As Reasonably Achievable
 - ALARA Goals: 10% of Maximum Permissible Dose Limits
 - Lifetime Total Effective Dose Equivalent (TEDE) in rem < Age
- Patients (Diagnostic, Therapy): No Limits
- Dose in unrestricted (shielding limits) area at 0.3 m from the wall: 2 mRem in any 1 hour (0.02 mSv/yr)

Dose Limits

- Here at Children's, our Radiation Safety Officer routinely checks employee exposures to ensure no limits are exceeded.
- We also have a Radiation Safety Committee which oversees patient and employee safety from radiation.



The graphic features the NRC logo in the top left corner, which includes an eagle and the text 'U.S. DEPARTMENT OF ENERGY' and 'NUCLEAR REGULATORY COMMISSION'. The title 'NRC Occupational Dose Limits' is displayed in orange text at the top right. A table with yellow text on a dark blue background lists various dose limits. A note at the bottom right states 'Note: 1,000 mrem = 1 rem'. The text 'Briefing for Media' is located at the bottom left of the graphic.

Whole Body (TEDE)	5,000 mrem/yr
Any Organ (TODE)	50,000 mrem/yr
Skin (SDE)	50,000 mrem/yr
Extremity (SDE)	50,000 mrem/yr
Lens of Eye (LDE)	15,000 mrem/yr
Embryo/Fetus of DPW	500 mrem/yr
Member of the Public	100 mrem/yr

Note: 1,000 mrem = 1 rem

Briefing for Media

Average Exposure from Background = 360mrem

Employee Dose Records

- **Terri Love, M.D.**

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- **Prestan Kiichler, BS, CNMT, NMTCB(RS), R.T. (R)(N)(CT)**

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Reporting Dose

- For all fluoroscopy cases, a low dose protocol including no grid, pulsed fluoroscopy & collimation is preferred unless the physician requests a higher dose protocol due to the body habitus size, urgent nature of the case or other factors deemed necessary by the physician.
- Procedures performed that have a single study radiation fluoroscopy time of > 8 minutes or >1000 Air Kerma require a technical notation in patient dose tracking record (NexoDose) to explain the reasons for the dose given to the patient. (i.e. Body habitus, Complexity of exam, Length of exam, other confounding variables, etc.)
- The modality supervisor/manager will review the notations. The reports will be forwarded to the Radiation Safety Officer who will in-turn report the matter to the Radiation Safety Committee.

Pregnancy and Radiation

- All females age 10 and older at CHMC will be screened for pregnancy prior to having an x-ray procedure. If it is determined that a pregnant patient must be imaged:
 - Shielding shall be used to shield the abdomen from radiation provided it does not interfere with the procedure.
 - Every attempt must be made to minimize direct exposure to the fetus.
- Medical emergency radiological procedures take precedence over pregnancy status.
- Pregnant workers can declare pregnancy in writing to the Radiation Safety Officer and receive a fetal monitor.
 - It is acceptable for pregnant workers to be in the room during fluoroscopy so long as they are wearing an appropriate lead apron.

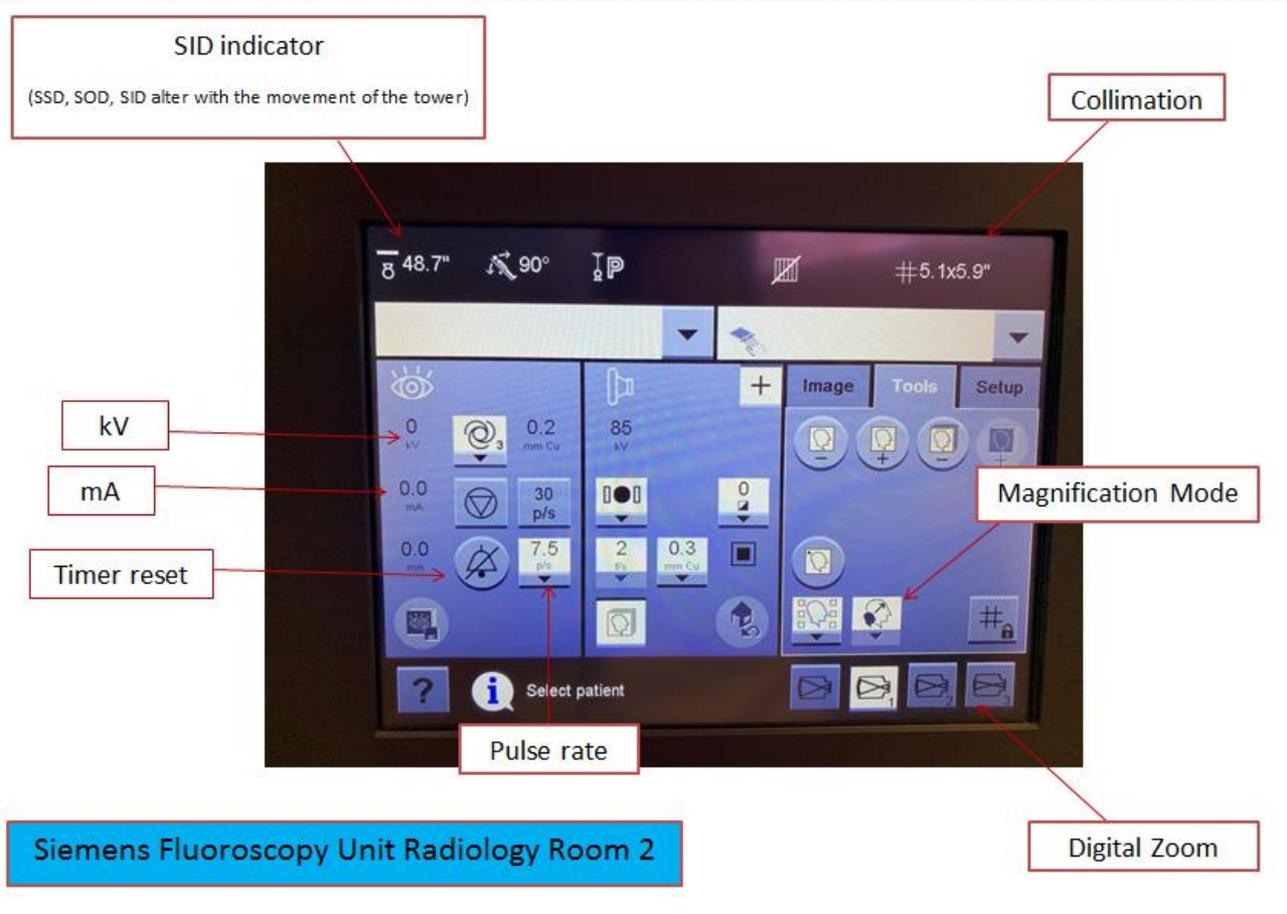
Responsibility of Radiation Workers

- Follow any applicable rules and procedures for protection and safety specified by the hospital.
- Use the monitoring devices and the protective equipment and clothing properly.
- Cooperate with the radiation safety officer with respect to wearing dosimeter badges and notify them if your badge is lost/damaged in any way.
- Abstain from any willful action that could put yourself or others in situations that contravene the requirements of the standard.
- Accept information, instruction and training concerning radiation protection and safety.

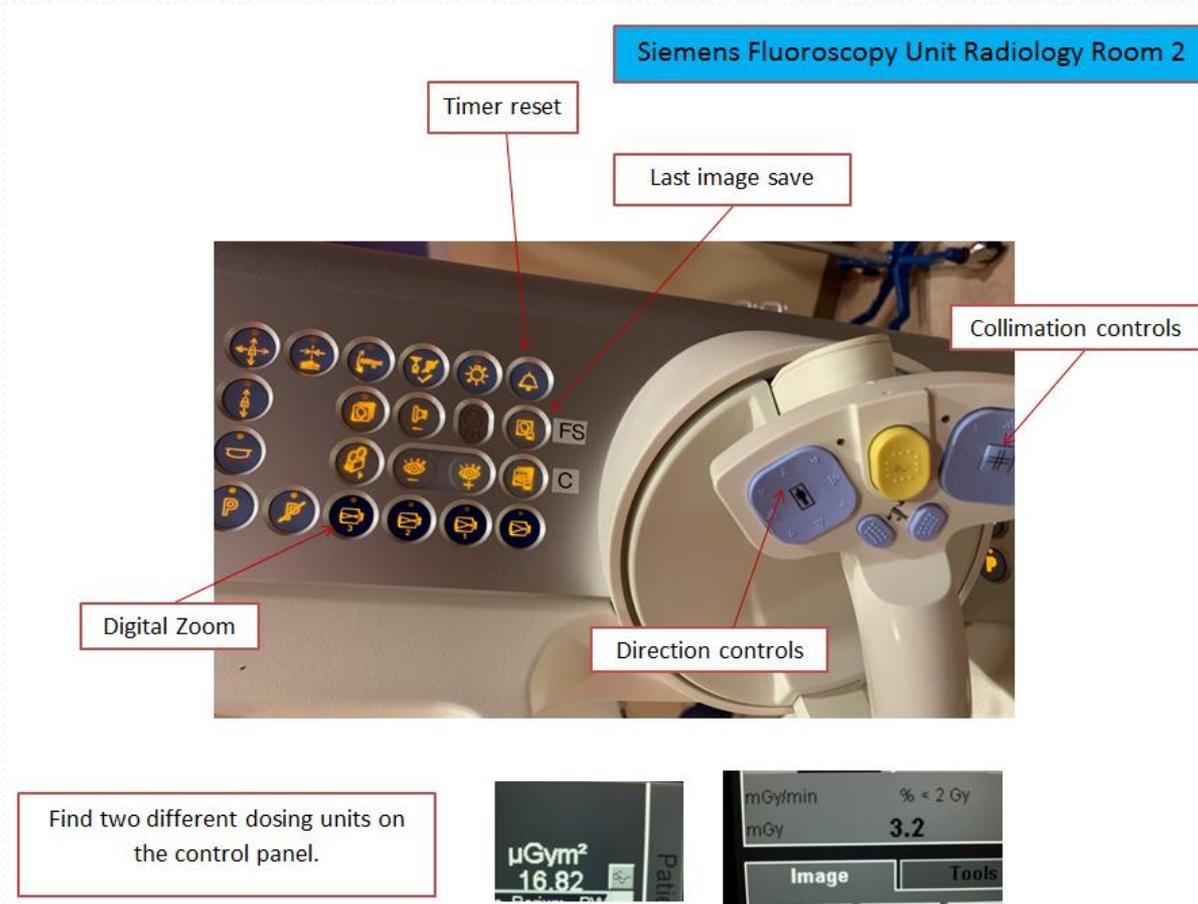
References

- <https://www.iaea.org/resources/rpop/health-professionals/radiology/fluoroscopy>
- <https://www.iaea.org/resources/rpop/health-professionals/interventional-procedures/radiation-protection-of-medical-staff-in-interventional-fluoroscopy>
- <https://www.iaea.org/resources/rpop>
- <https://radiologykey.com/9-radiation-effects-on-tissues-and-organs/>
- <https://ieer.org/resource/classroom/measuring-radiation-terminology/>
- <https://www.fda.gov/radiation-emitting-products/medical-x-ray-imaging/fluoroscopy>

CHMC Fluoro Equipment (Siemens Radiology Room 2)

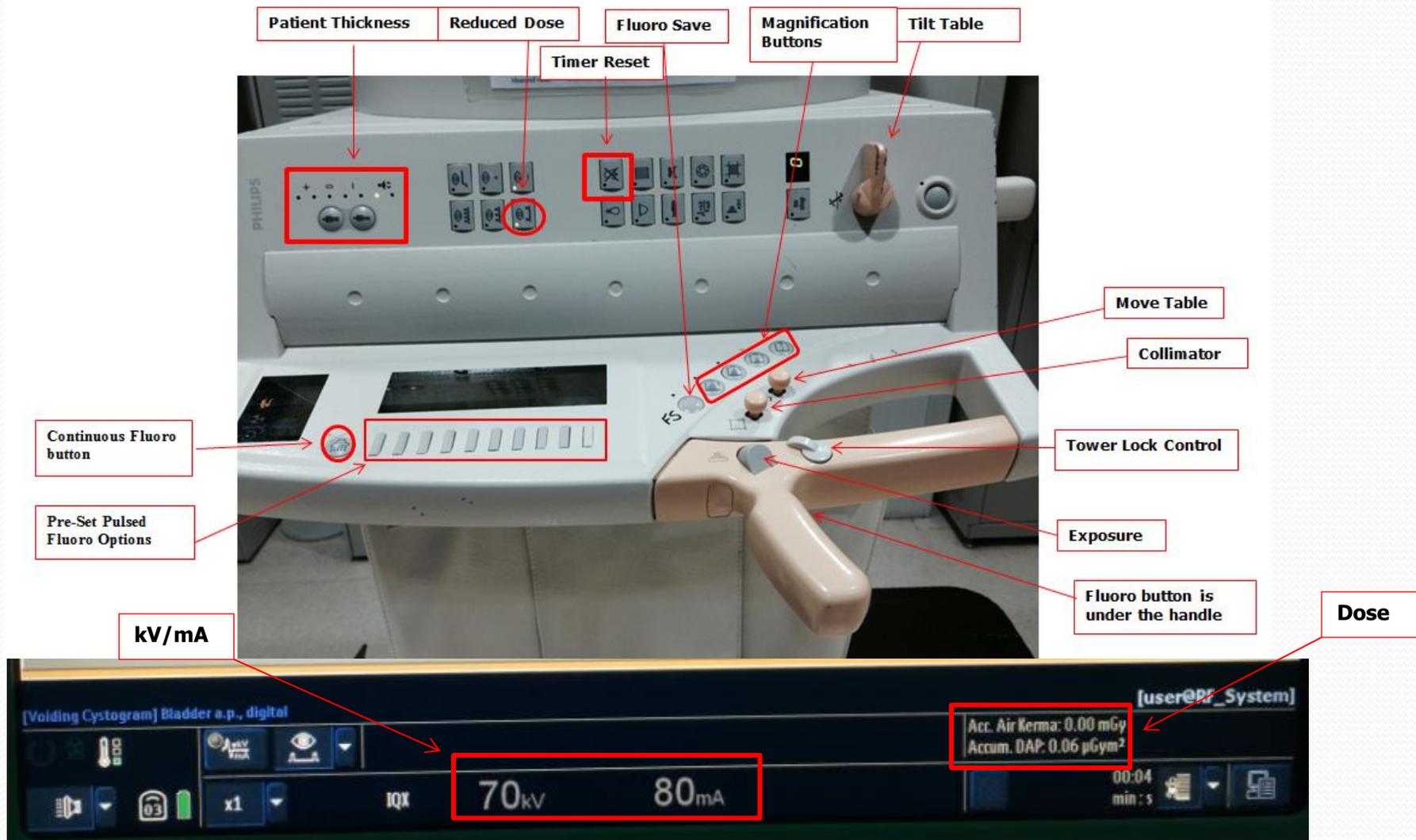


CHMC Fluoro Equipment (Siemens Radiology Room 2)



CHMC Fluoro Equipment (Philips Room 1)

Philips Fluoroscopy Room 1



CHMC Fluoro Equipment (Ortho Scan Mini C-Arm)



kV/mA

Collimators

Last Image Hold

Magnification

Time Reset



kV / mA

Image Rotate

Help

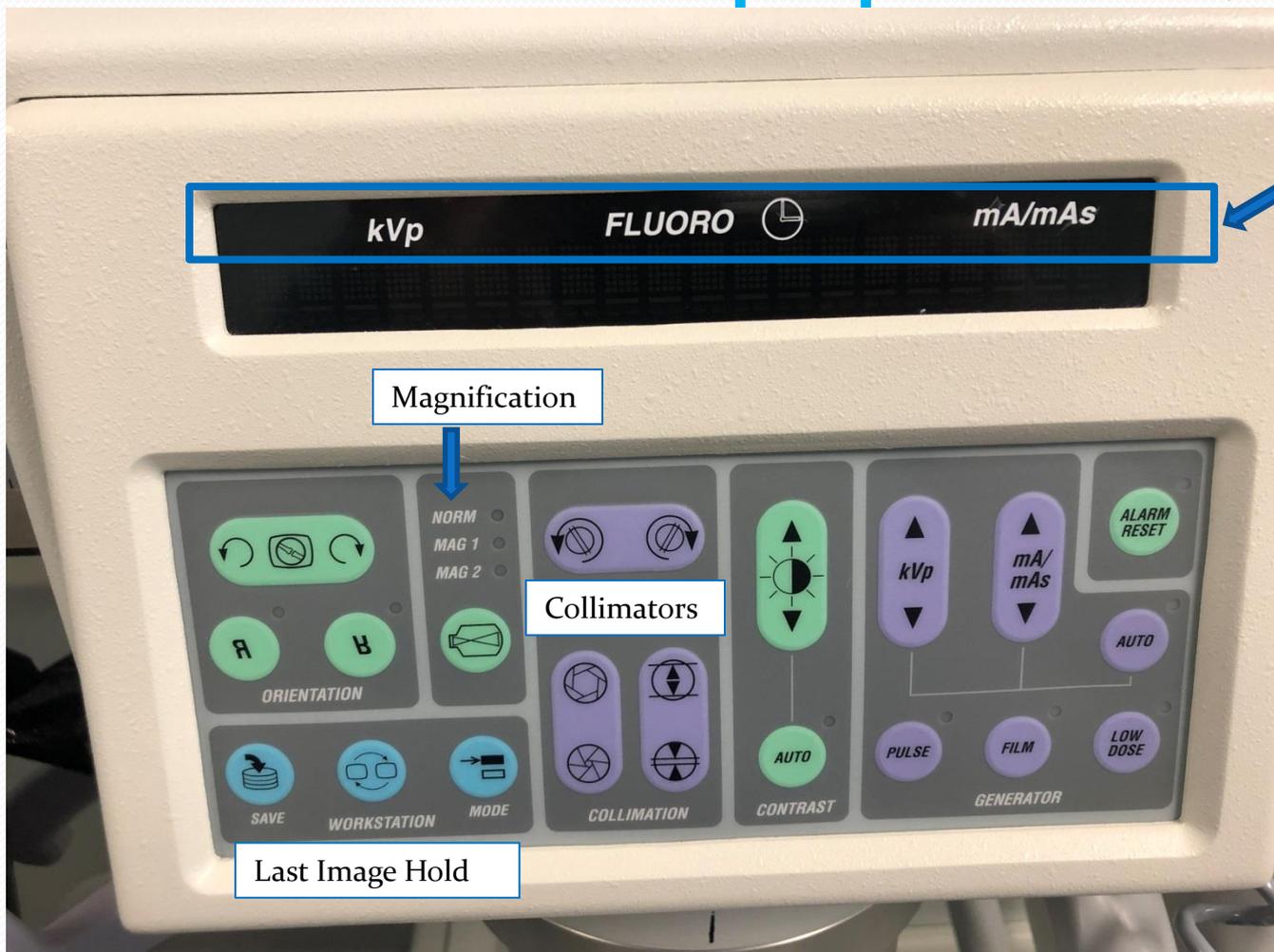
CHMC Fluoro Equipment (Philips C-Arm)

The image shows the control panel of a Philips C-Arm fluoroscopy system. The interface is dark-themed with various controls and readouts. Annotations with blue arrows point to specific features:

- Pulse Mode:** Points to the 'Fluoroscopy 15/s No Storage' button in the top left.
- Magnification/Digital Zoom:** Points to the 'Detector Zoom' button in the middle left.
- Manual kV Control:** Points to the 'kV Manual' button in the bottom left.
- Last Image Hold:** A white box with a blue arrow pointing to the 'Park' button in the top right.
- Collimators:** A bracket on the right side groups 'Couple Shutters', 'Reset Shutters and Collimator', and 'Automatic Shutter Pos.' buttons.
- Timer Reset:** Points to the 'Time' field in the bottom right status bar.

The central display shows two sets of coordinates: A (11:51) with 0°, 29°, 7.0 cm, 5.0 cm and Current Position with 43°, -22°, 6.2 cm, 5.0 cm. The bottom status bar displays: System status OK, Patient ID: 9000, Date of birth: 3-Mar-2014, and technical parameters: kV 70, mA 4.57, mAs 9.04, DAP Meter 0.202, and Time 0:04.

CHMC Fluoro Equipment (GE C-Arm)



kV/mA/Time
Display

Magnification

Collimators

Last Image Hold