Reducing Radiation Risk For You and Your Patient

74th Annual Meeting
Quebec, 2019
Saturday June 29th

Mitchell R. Humphreys, MD
Chair and Professor, Dept of Urology
Dean MCSCPD
Mayo Clinic

Terminology

- Ionizing radiation involves the detachment of electrons from subatomic particles and is a known carcinogen
  - Deterministic effects
    - Occur above a threshold
    - Dose-related increasing risk and severity
    - Classically: radiation-induced dermatitis
  - Stochastic effects
    - Caused by mutation or permanent change, cell remains viable
    - Absence of a threshold dose
    - Increased levels of exposure do not affect the type or *severity* of the effect, but do increase the *probability* of an effect

Skin threshold dose is 2Gy

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Terminology

- Absorbed dose – amount of radiation in the tissue
  - Measured in Gray (Gy)
- Exposure = number of ions produced by x-rays per kilogram of air
  - Measured in Roentgen (R)
- Equivalent dose – dose in a specific organ or tissue
- Effective dose – reflects whole body exposure
  - Measured in rem or Sievert (Sv)
- Dose area product (DAP) – radiation dose to air multiplied by area of the x-ray field
  - Measured in Gy cm^2

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Thresholds

- European Union
  - Effective dose limit is 100mSv over 5 yrs
  - No more than 50mSv in any one year
- United States
  - Effective dose limit of 50mSv in one year
  - Lifetime limit of 10mSv x age(yrs)
- International Commission on Radiological Protection
  - No more than 20mSv/yr over 5 years
  - No more than 50mSv in one year

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Background

- Up to 50% of radiation dose received by the United States population is attributable to medically related imaging

- Annual per capita radiation exposure from medical sources in the U.S. 0.54 mSv in 1980 → 3.0 mSv in 2006
  - 600% increase
  - Attributed to increased use of CT

5 million in 1980

62 million in 2006

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Risks in Stone Patients

- Stone pts at risk for significant radiation exposure
  - Ranging from 1.18 to 37.66 mSv
- Acute stone episode pts undergo 4 radiographic studies in the 1-year period after stone event.
  - 1.2 KUB, 1.7 NCCT, 1 IVP
- Obesity increased FT by 36%, and mean ED by 177%
  - BMI 30-39.9 kb/m2 = twofold increase in ED
  - BMI 40 kg/m2 = threefold increase in ED

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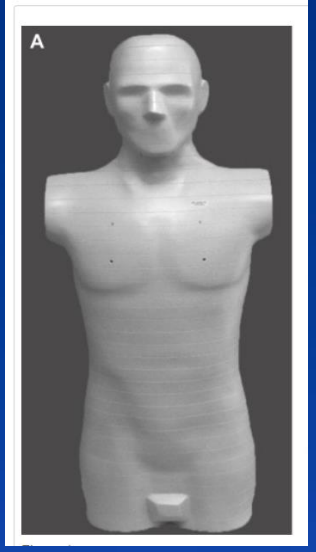
Chen TT, et al. J Urol, 194:878; 2015.

Stone Patients



- Surgical management – Ureteroscopy
  - Nonobese males are exposed to a median 1.13 mSv
    - Median fluoroscopy time 46.95 seconds
    - Median stone burden 5 mm
    - Skin entrance exposed to the highest absorbed dose rate
    - Small intestine → gallbladder
- Surgical management – PCNL
  - Mean ED for R PCNL 7.63 mSv
  - Mean ED for L PCNL 8.11 mSv
  - Risks for increased exposure:
    - high BMI, increased stone burden, increased # of access tracts
- Surgical management – ESWL
  - Mean total ED in males 1.71 mSv, females 1.82 mSv (less for distal stones)

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Preminger et al. J Urology. March 2012.
Lipkin et al. J Urol 2015; 194: 878-885

Exposure from Imaging

Modality	Exposure
Conventional NCCT	10-20 mSv
Stone protocol NCCT	3.04 mSv
Low dose CT	1.40-1.97 mSv
Ultralow dose CT	< 1 mSv
KUB	0.63-1.1 mSv
KUB with 3 tomograms	3.93 mSv
IVP	3.0 mSv
Digital tomosynthesis	0.83 mSv

LDCT for BMI < 30kg/m^2

NCCT for BMI > 30kg/m^2

MET FU = KUB and US

After URS or SWL = US alone or with KUB

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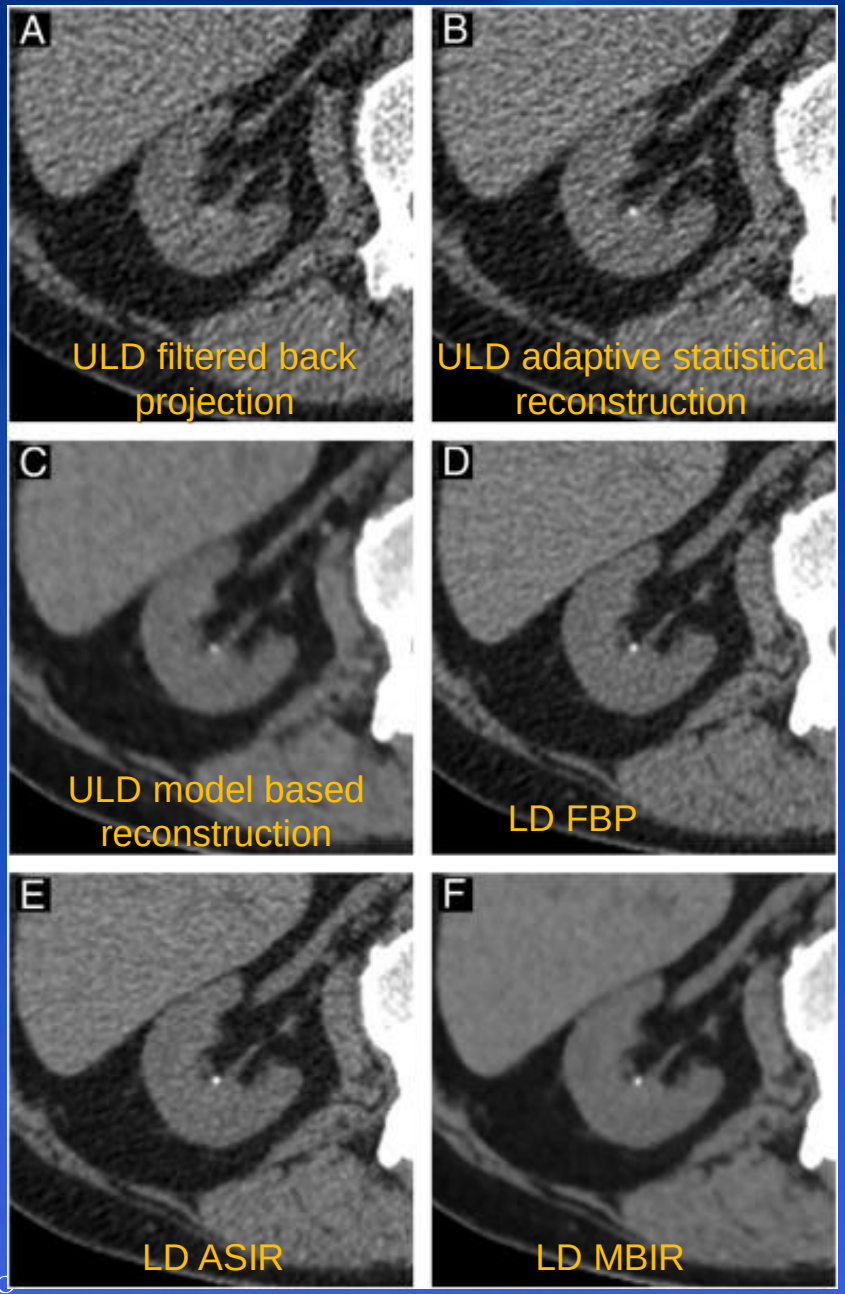

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Feasibility of ultra-low radiation dose reduction for renal stone CT using model-based iterative reconstruction: prospective pilot study☆,☆☆,★

J. Scott Kriegshauser [a,*], Sailen G. Naidu [a], Robert G. Paden [a], Miao He [d], Qing Wu [c], Amy K. Hara [b]

[a] Department of Radiology, Mayo Clinic Hospital, Phoenix, AZ
[b] Department of Radiology, Mayo Clinic, Scottsdale, AZ
[c] Division of Health Sciences Research, Mayo Clinic, Scottsdale, AZ
[d] Department of Industrial Engineering, Arizona State University, Tempe, AZ

- CT dose index was 61% less for ULD
- Noise was 50% less with ULD MBIR than LD ASIR.
- ULD MBIR is comparable to standard of care (LD ASIR)

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Risks to the Urologist

Multiple tracts

Higher BMI

Stone burden

- Radiation exposure: arises due to scatter from the beam, patient and operating table
- Lens of the eye is most radiosensitive
- 50 URS procedures/yr = 0.12% of max dose
- 50 PCNL/yr = 1.67% of max dose
- 10mSv of exposure increases lifetime risk of fatal cancer by 3%
- 20mSv during a year increases risk of fatal cancer to between 1:1,000 and 1:10,000
  - Risk of fatal malignancy in gen pop is 1:5

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Hanna L, et al. J Endo, 29: 526; 2015.

- 278 patient records analyzed
- Endpoints:
  - Fluoroscopy time & radiation exposure by different procedure types
  - Fluoroscopy time & radiation exposure by different consultants
  - For PCNL – radiation dose & time by Urology vs IR

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Procedure Specific Doses

	Fluoroscopy time (sec)	Range (sec)	Fluoroscopy Dose (mSv)	Range (sec)
Stent placement	63	0-582	1.5	0-39.5
Stent exchange	48.5	6-346	1.2	0-19.6
Diagnostic URS	64		1.7	
Stone URS	56		1.4	
Total	48	0.0-1140	0.0012	0-0.0645

Left PCNL = 8.11mSv

Right PCNL = 7.63 mSv

PCNL Access

	Fluoroscopy Time (sec)	Fluoroscopy Dose (mSv)
Urologist	45.5	1.5
IR	255	35.7

PCNL Procedure

	Fluoroscopy Time (sec)	Fluoroscopy Dose (mSv)
Urologist	67	1.4
Urologist 1/ IR	255	21.7
Urologist 2/ IR	337	28.5

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What you can do

- ALARA
- Protect yourself
- Know your equipment
- Procedural control
- Alternative imaging
- Adjunctive techniques

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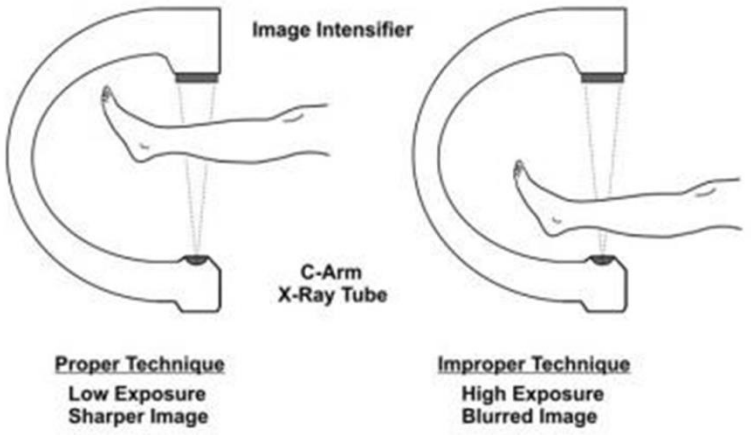
ALARA

- Reduce radiation exposure
  - Time – minimize “beam-on” time
  - Distance – double the distance from the source, exposure dose is 1/4th
  - Shielding – disposable, lightweight sterile radioprotective drape
- Scatter – affected by pt size, position, settings, shielding, filtration, angulation.



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½ meter scatter
UROSKOP Omnia
451
220 mR/h
VICTOREEN
220 mR/hour


1 meter scatter
UROSKOP Omnia
55 mR/hour


2 meters scatter
12.8 mR/hour

Protections

- Standard lead requires 0.35mm thickness which reduces transmission by 100-fold
  - 0.25mm allow 10% of radiation transmission
  - 0.5mm allows 2% of radiation transmission
- Leaded eyewear
- Leaded gloves
- Wear dosimeters

Hellawell G, et al. J Urol 174, 948; 2005.

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Know your equipment

- Low dose rate setting – lowest pulse/sec
- Minimize use of cine mode
- Collimate the beam
- Use magnification as little as possible
- Keep field clean of radiodense objects
  - Automatic voltage increase to maintain image quality
- Image intensifier as close to pt as possible

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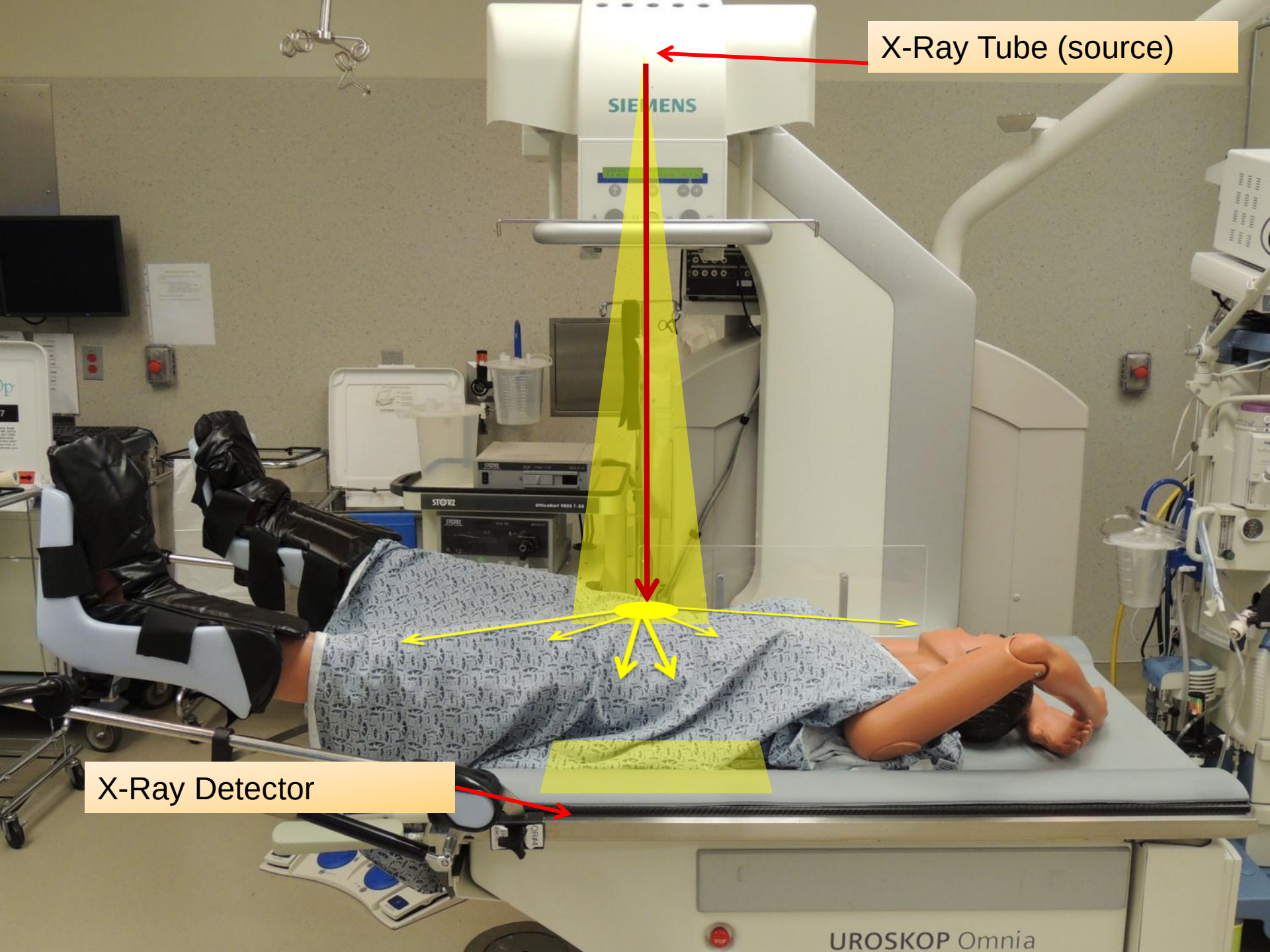
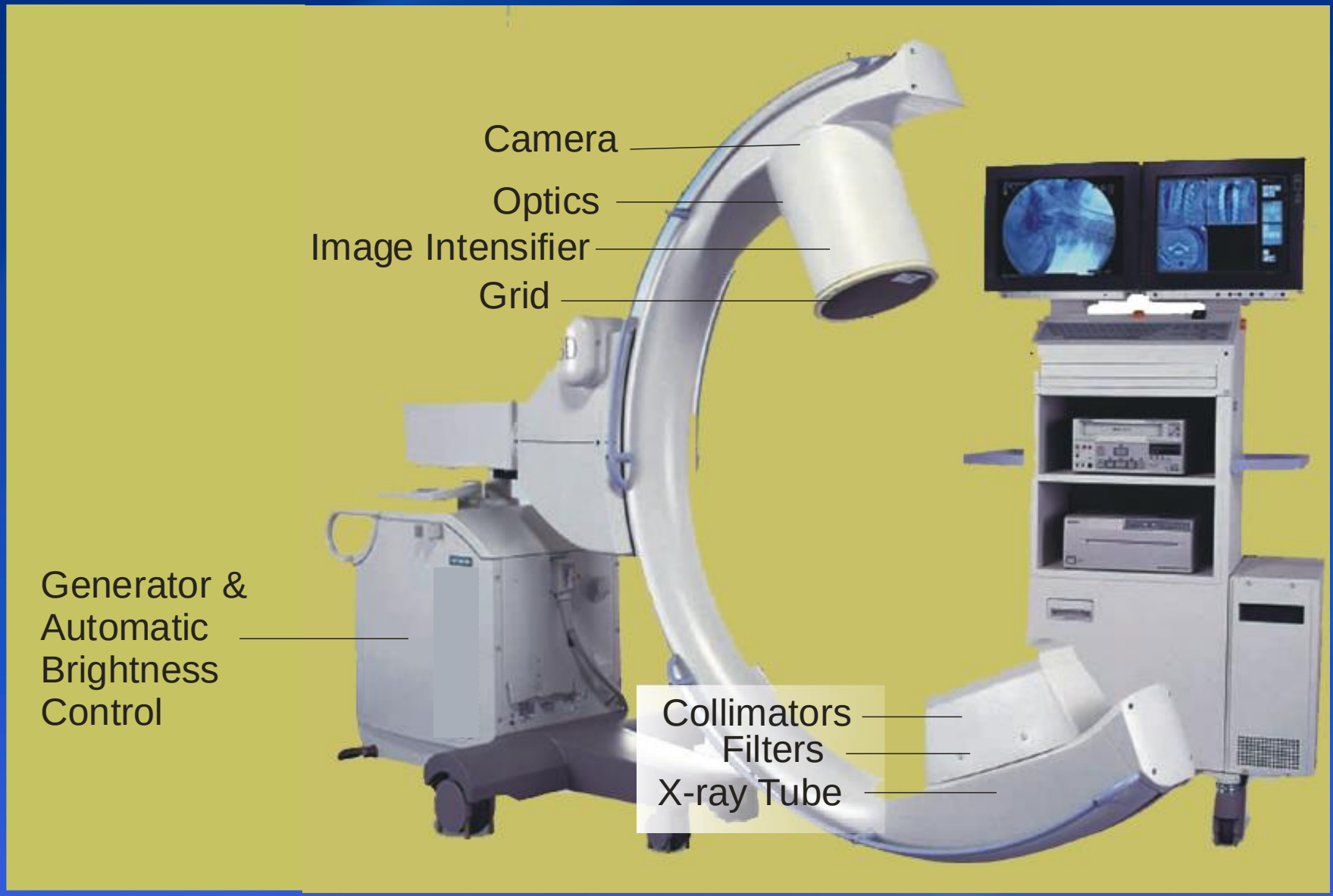
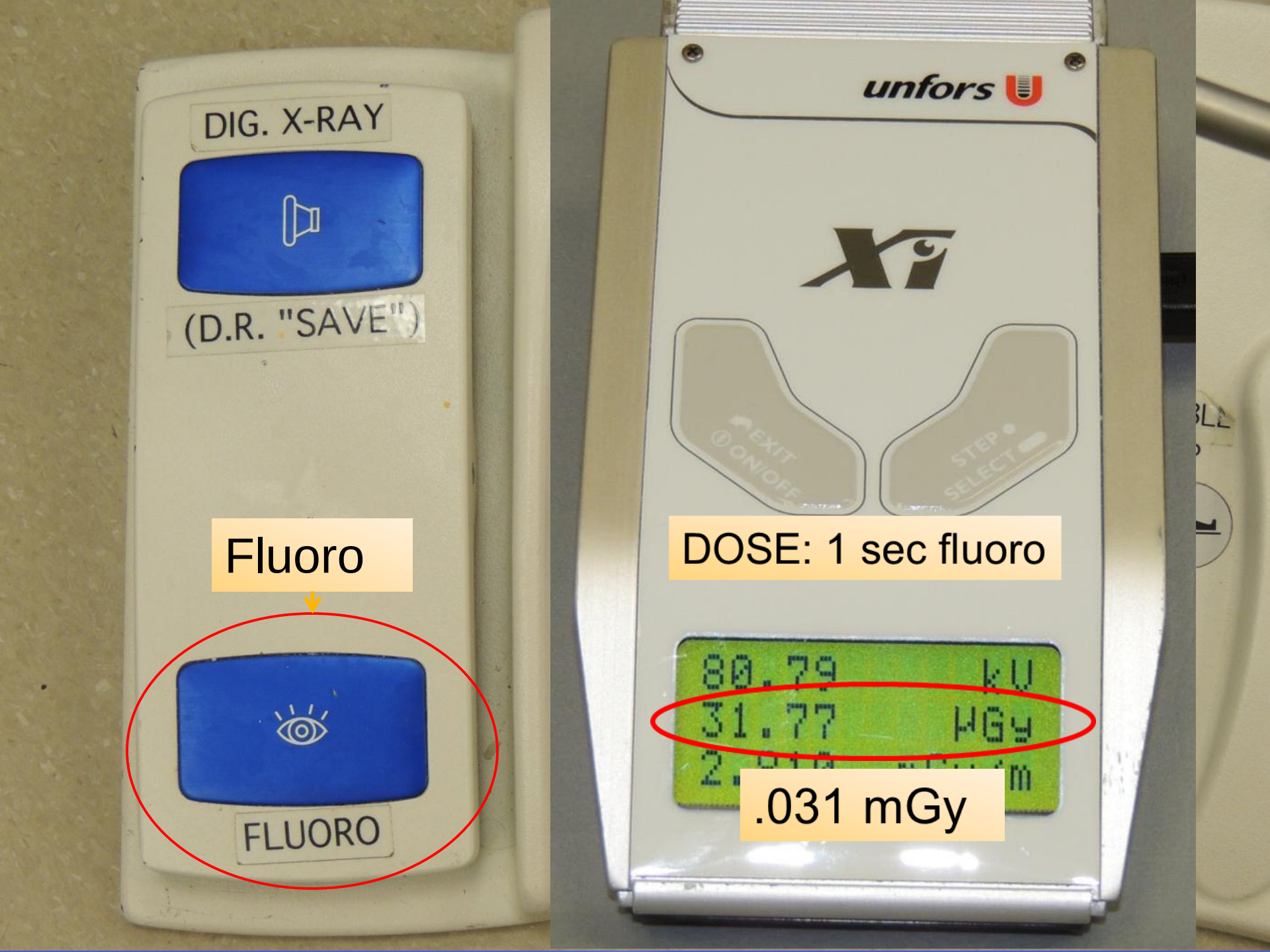
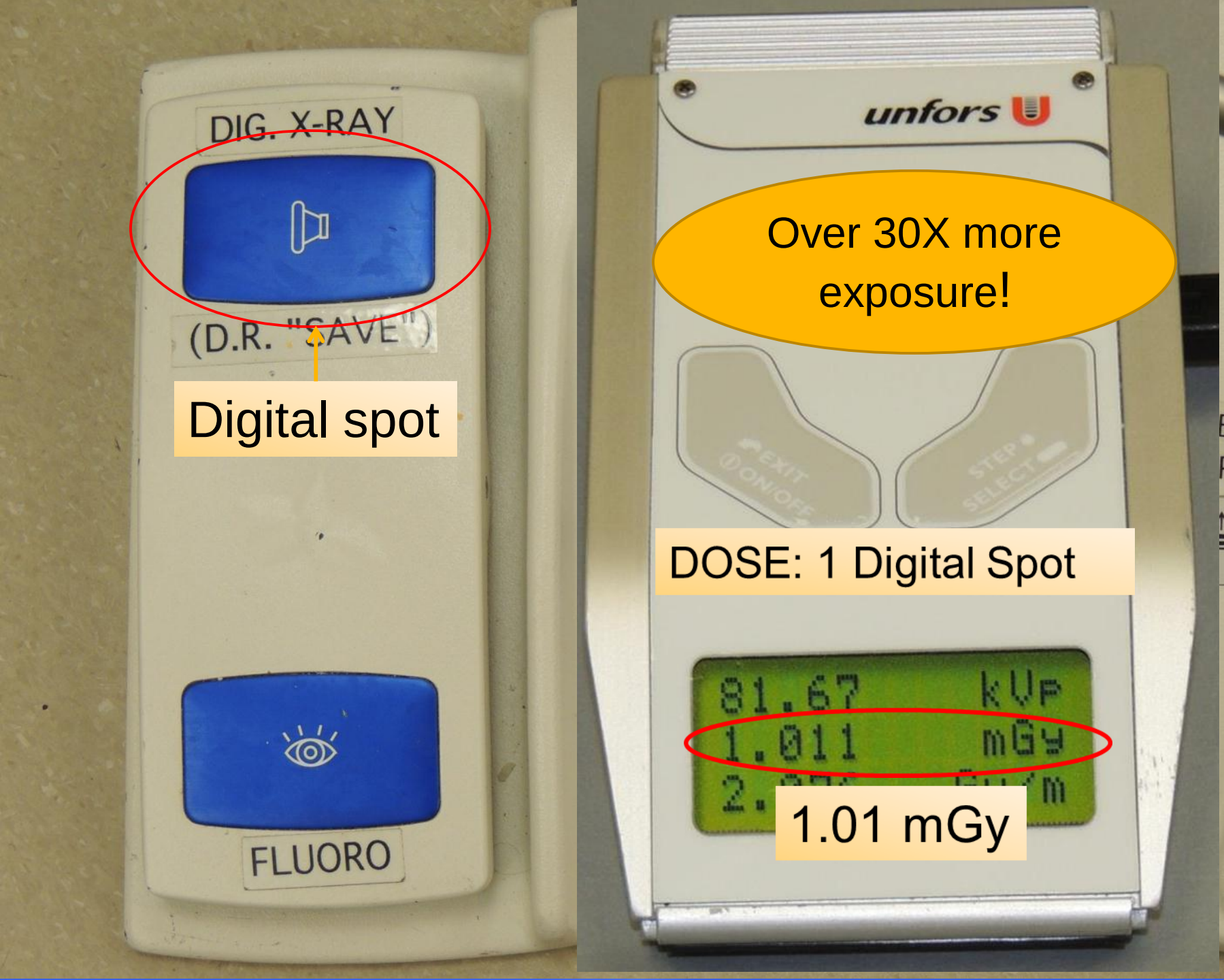
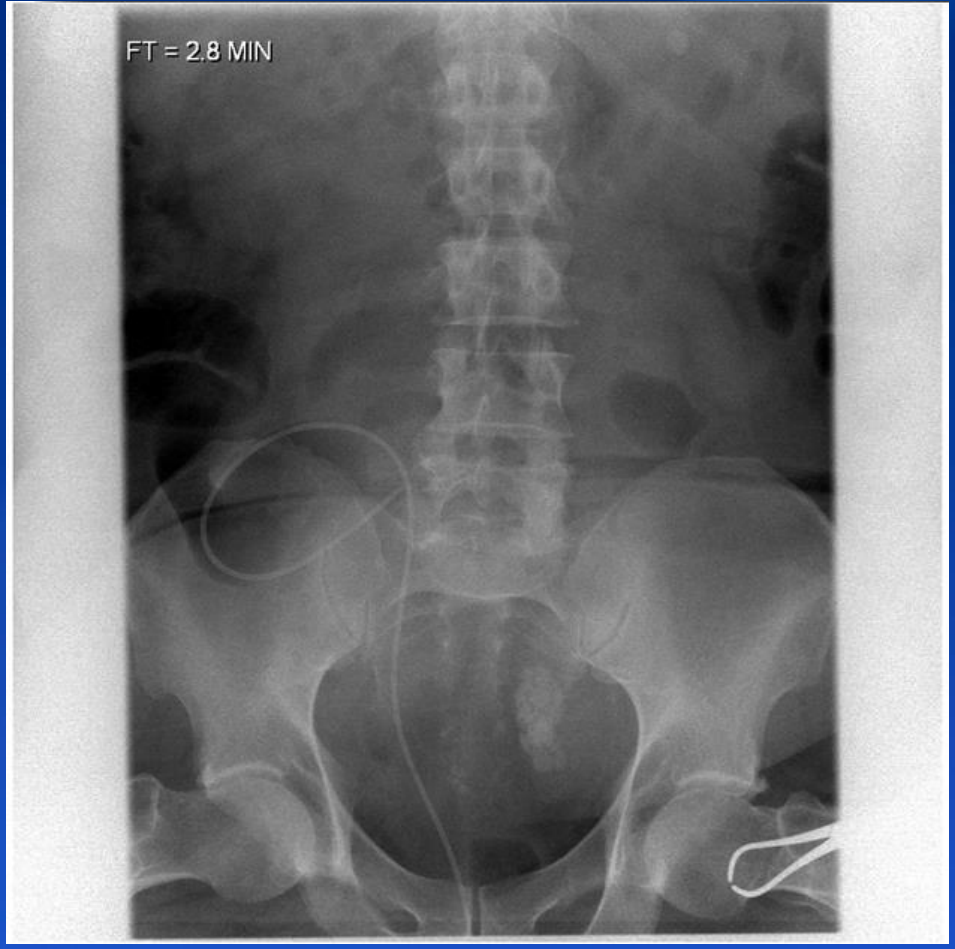

X-Ray Tube (source)
X-Ray Detector
SIEMENS
UROSKOP Omnia


Camera
Optics
Image Intensifier
Grid
Generator &
Automatic
Brightness
Control
Collimators
Filters
X-ray Tube


DIG. X-RAY
(D.R. "SAVE")
Fluoro
FLUORO
unfors
Xi
EXIT
ON/OFF
STEP
SELECT
DOSE: 1 sec fluoro
80.79 kV
31.77 µGy
.031 mGy


DIG. X-RAY
(D.R. "SAVE")
Digital spot
FLUORO
unfors
Over 30X more exposure!
DOSE: 1 Digital Spot
81.67 kVp
1.011 mGy
1.01 mGy



Fluoro Save

Digital Spot

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Procedural control

- Mark body surface for targeting
- Coning the radiation field
- Some advocate forgoing placement of an antegrade safety wire
- Drape the patients reduces scatter
- Laser guided c-arm
- Shielding – out of plane has no effect on image

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Alternative imaging

- Air nephrograms vs contrast
  - 50% reduction in radiation exposure

- US – costs less, sensitivity and specificity of 45% and 88% for stone detection
  - PCNL guidance
    - Reduced FT from 28.6s to 14.4s[1]
    - US only – no difference in SFR or complications[2]

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1. Basiri A, et al. J Endourol, 22:281; 2008.
2. Alan C, et al. Urol Res, 39:205; 2011.

TABLE 1. DEMOGRAPHICS, STONE CHARACTERISTICS, AND OUTCOMES

	Conventional (n = *50*)	*Fluoroless* (n = *50*)	p-*Value*
Age (years)	55.5 (19–95)	54.62 (16–83)	0.771
Gender			0.518
Female	18 (36%)	15 (30%)	
Male	32 (64%)	35 (70%)	
BMI	28.03 (17–51)	30.19 (19–67)	0.620
ASA	2.47	2.43	0.918
Location			
Kidney	3 (6%)	17 (34%)	0.002
Proximal	8 (16%)	5 (10%)	0.405
Mid	9 (18%)	2 (4%)	0.035
Distal	21 (42%)	14 (28%)	0.237
Multiple	9 (18%)	12 (24%)	0.513
Stone area (mm^2)	56.58 (15–201)	91.53 (14–480)	0.042
Laterality			0.689
Right	26	25	
Left	24	25	
Previous stent	13 (26%)	18 (36%)	0.387
Fluoroscopy time (seconds)	38.8 (5–156)	0	< 0.001
Mean operative time (minutes)	60.59 (25–120)	59.20 (25–121)	0.806
Stone-free rate	46 (92%)	46 (92%)	1.000
Postoperative complications	2 (4%)	2 (4%)	1.000
Repeat procedure	2 (4%)	4 (8%)	0.678

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If all else fails….

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Opportunities to Intervene

- While you can……

PCNL

	Number pts	Dose (mGy)	Fluoro time (s)	
Sierra-Diaz	34	9.71	58.3	
	348	452	96	

Sierra-Diaz E, et al. Dose Response 2018.

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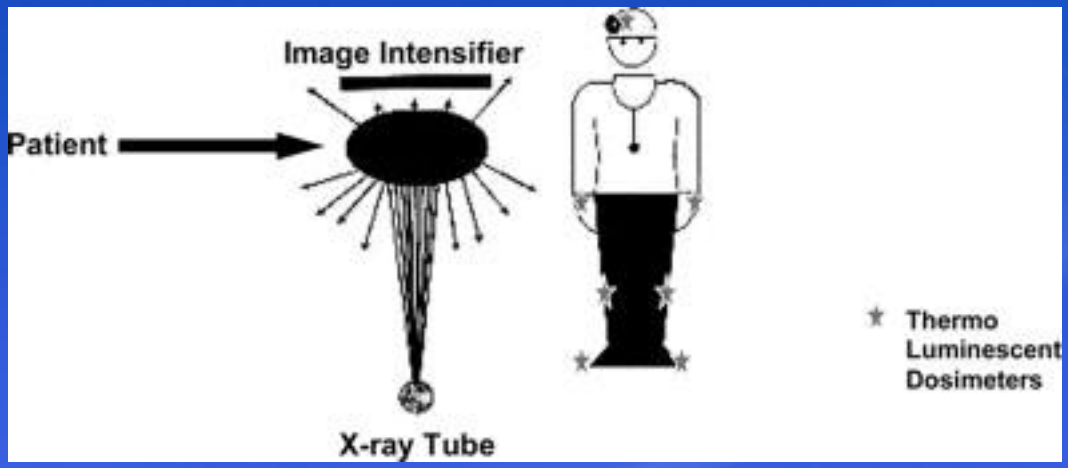
Radiation Exposure and the Urologist: What are the Risks?

- 4-month period, 18 ureteral procedures
- Average fluoroscopy time 78 seconds
- Mobile c-arm unit with under table x-ray tube
- Dosimetry – 7 positions on body
  - Forehead, little fingers, anterior legs, upper aspect of the foot/ankle



Hellawell et al. J of Urol. 2005; 174:948-952.

Radiation Exposure and the Urologist: What are the Risks?

	Surgeon		Assistant		Nurse	
	TLD	Calc	TLD	Calc	TLD	Calc
General ureteral procedures						
Eye (head)	1.9 ± 0.5	3.5	3.2 ± 0.8	2.4	0.8 ± 0.2	1.3
Hand	2.7 ± 0.7	10.0	2.1 ± 0.5	6.9	1.3 ± 0.3	2.5
Lower leg	11.6 ± 2.9	13.0	8.3 ± 2.1	9.0	0.8 ± 0.2	3.7
Foot	6.4 ± 1.6	13.0	5.7 ± 1.4	9.0	0.5 ± 0.1	3.7
PCNL procedures						
Eye (head)	40 ± 10	73	68 ± 17	51	16 ± 4*	27
Hand	48 ± 12	177	37 ± 9	123	24 ± 6*	44
Lower leg	167 ± 42	186	120 ± 30	130	11 ± 3*	57
Foot	93 ± 23	186	82 ± 21	130	8 ± 2*	57

* Extrapolated from ureteral procedure TLD data.

Average scattered radiation dose in μGy per case

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Hellawell et al. J of Urol. 2005; 174:948-952.

- 1184 urology residents in Europe surveyed
  - 124 returned
- Only 75% residents routinely wear lead aprons
- Only 30.6% “always” wear thyroid shields

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Baldwin DD. Urology 2013.
Soylemez H, et al. Urology 2013

What can we do?

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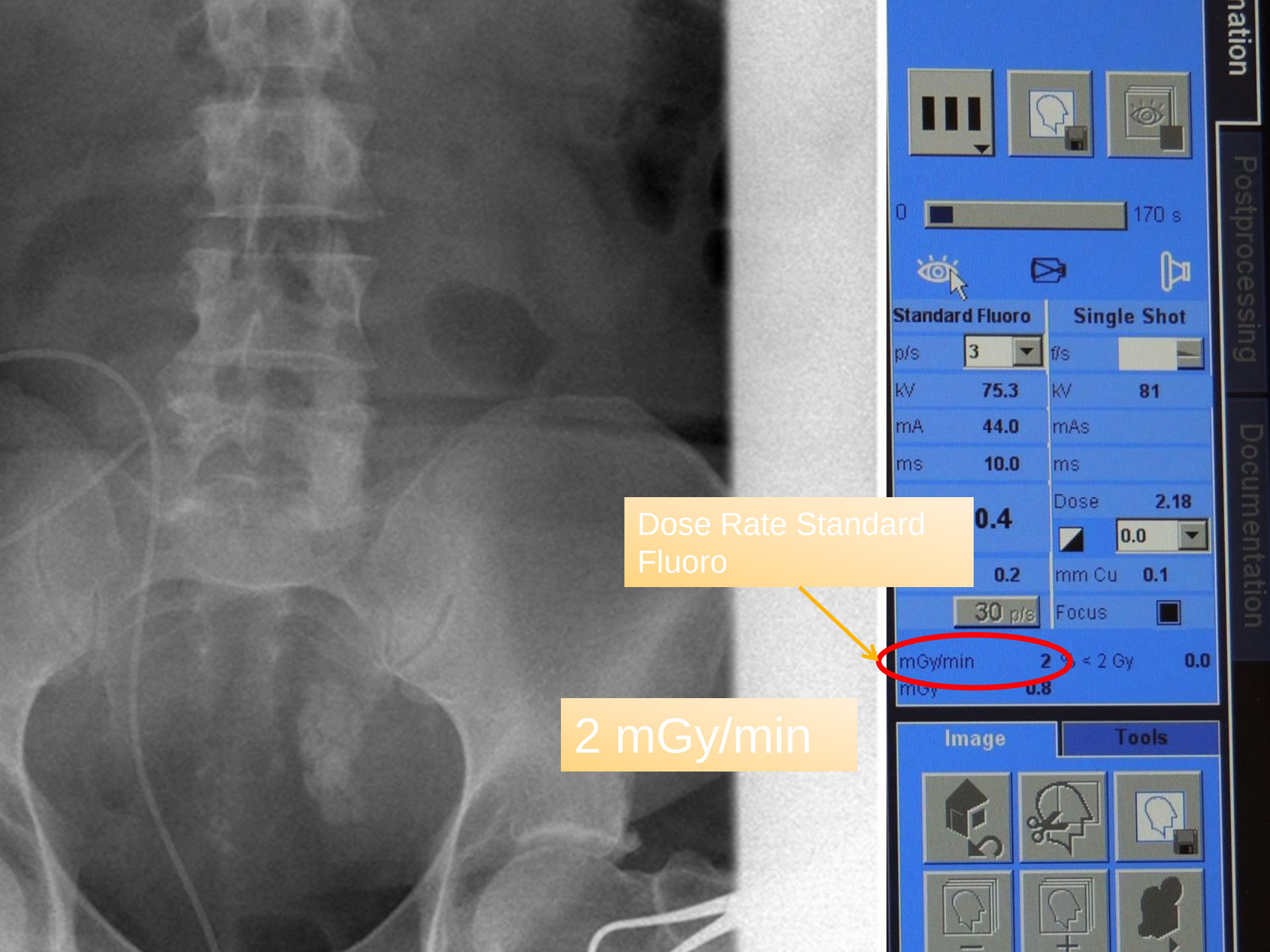
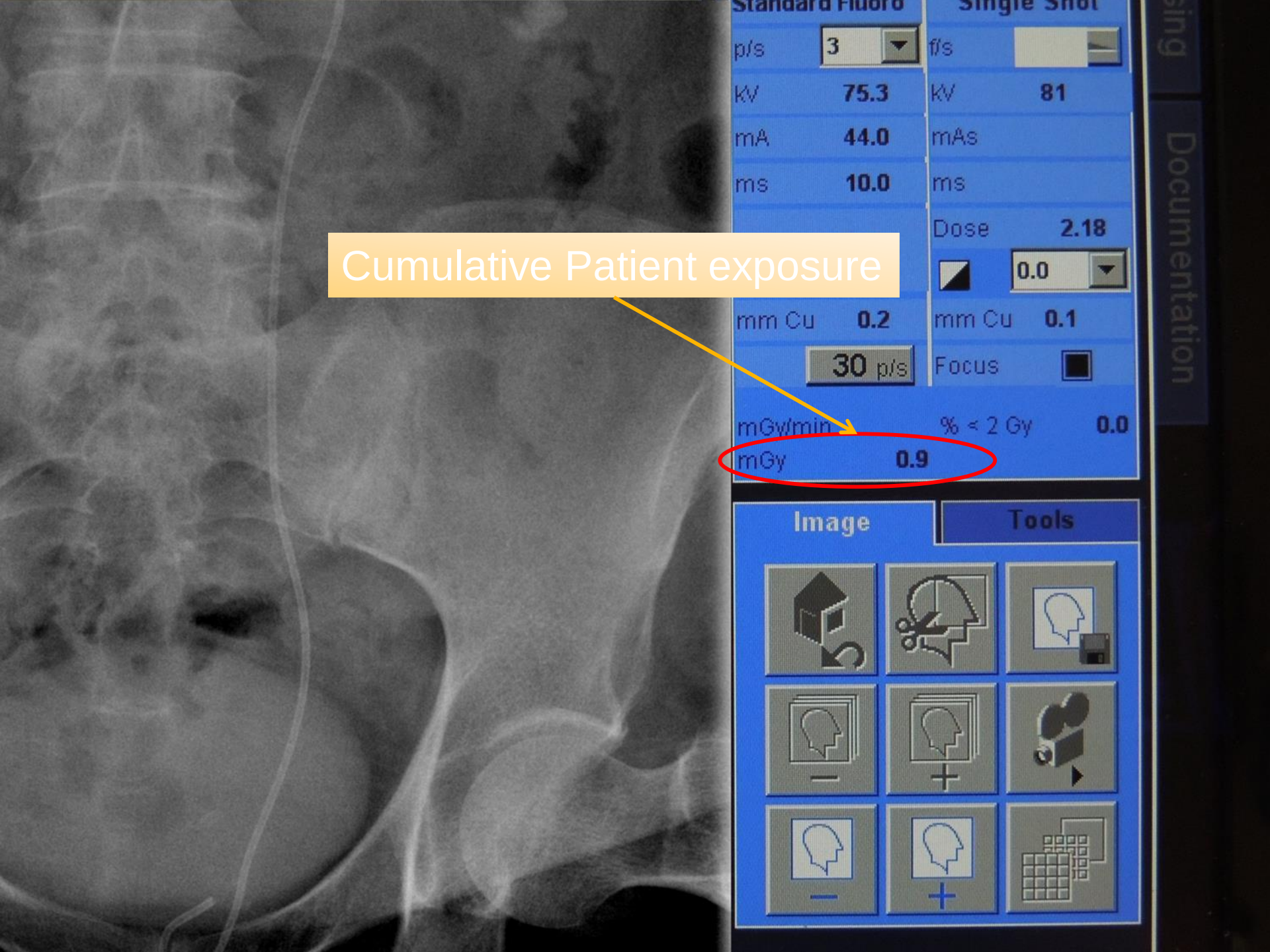
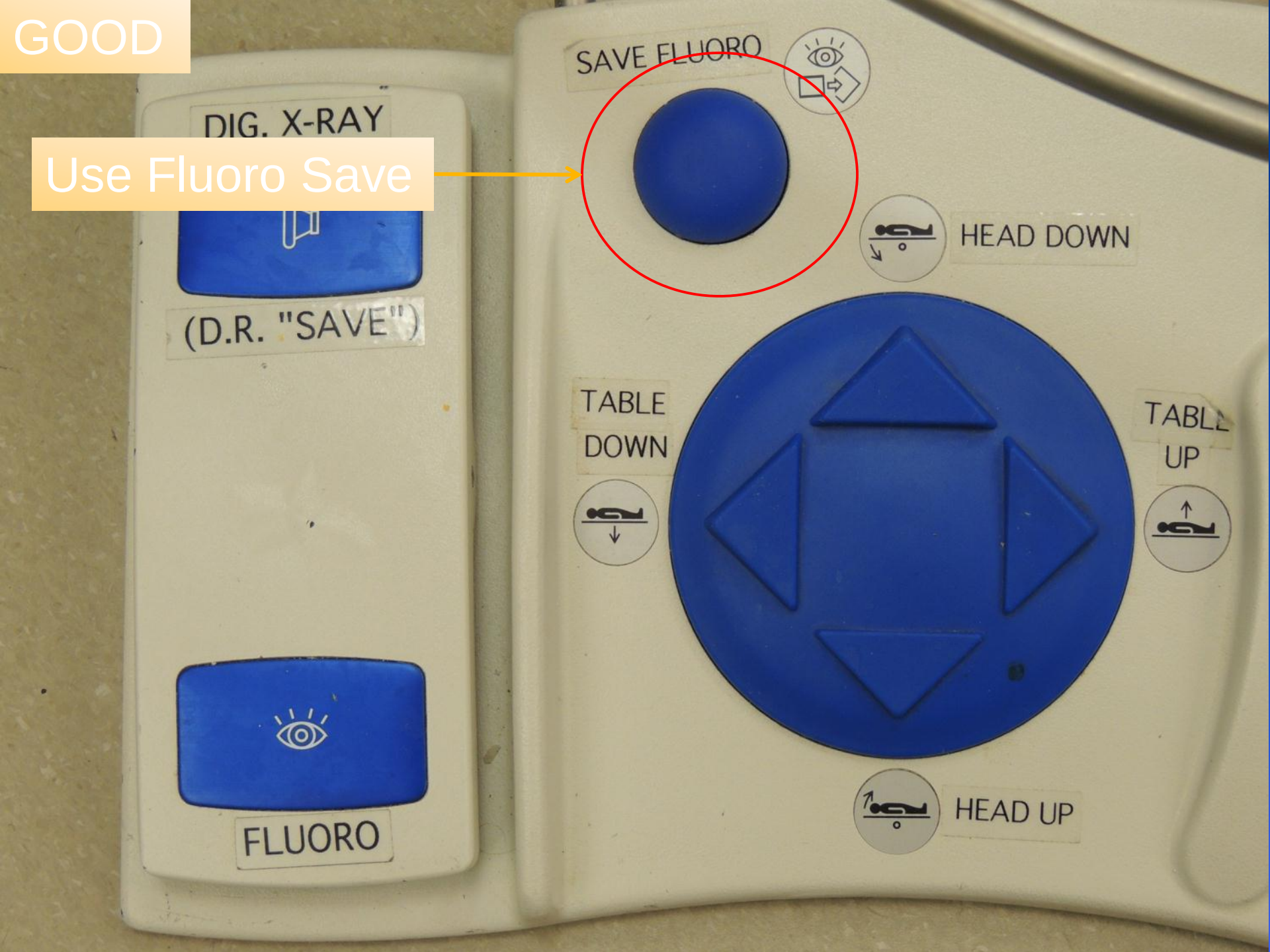
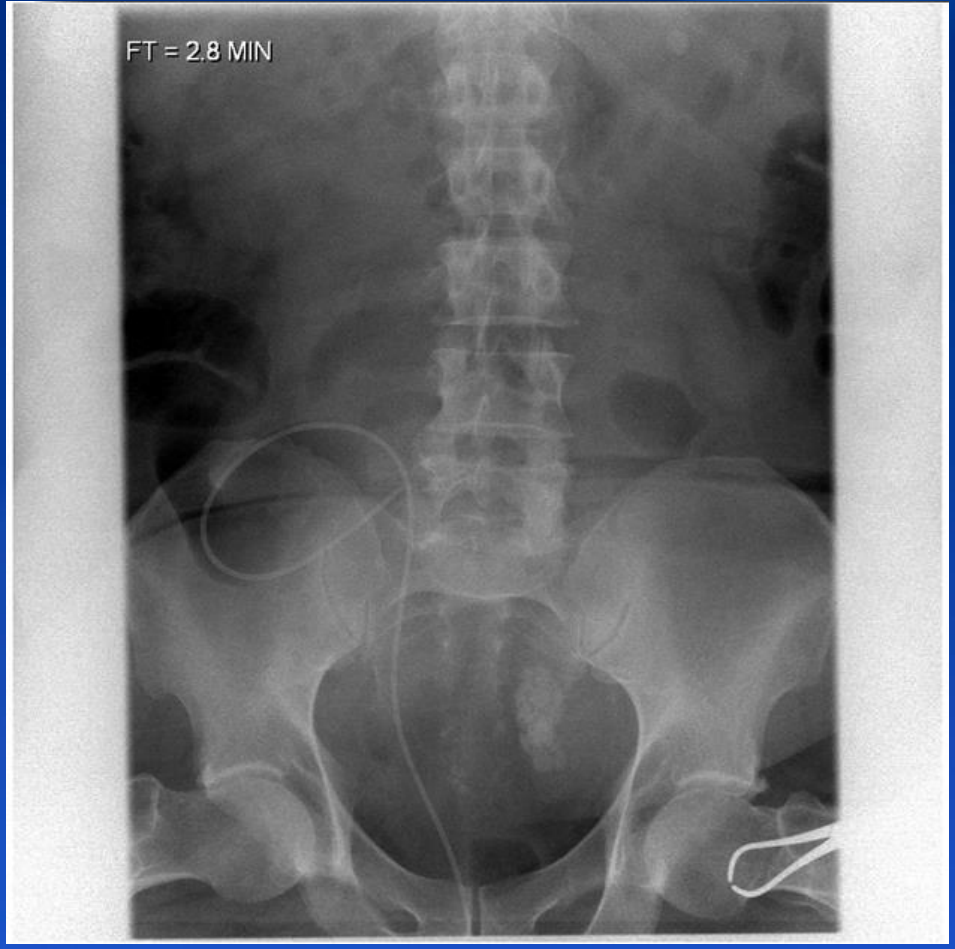

Dose Rate Standard Fluoro
2 mGy/min
Standard Fluoro
Single Shot
p/s
3
f/s
kV
75.3
kV
81
mA
44.0
mAs
ms
10.0
ms
Dose
2.18
0.4
0.0
0.2
mm Cu
0.1
30 p/s
Focus
mGy/min
2
< 2 Gy
0.0
0.8
Image
Tools
0
170 s
Postprocessing
Documentation


Cumulative Patient exposure
Standard Fluoro
Single Shot
p/s
3
f/s
kV
75.3
kV
81
mA
44.0
mAs
ms
10.0
ms
Dose
2.18
0.0
mm Cu
0.2
mm Cu
0.1
30 p/s
Focus
mGy/min
% < 2 Gy
0.0
mGy
0.9
Image
Tools
Documentation

- 97.8% have hard images for Qreads
  - Median # 3.0
  - Range 1.0 – 15.0


GOOD
Use Fluoro Save
SAVE FLUORO
DIG. X-RAY
(D.R. "SAVE")
HEAD DOWN
TABLE
DOWN
TABLE
UP
FLUORO
HEAD UP



Fluoro Save

Digital Spot

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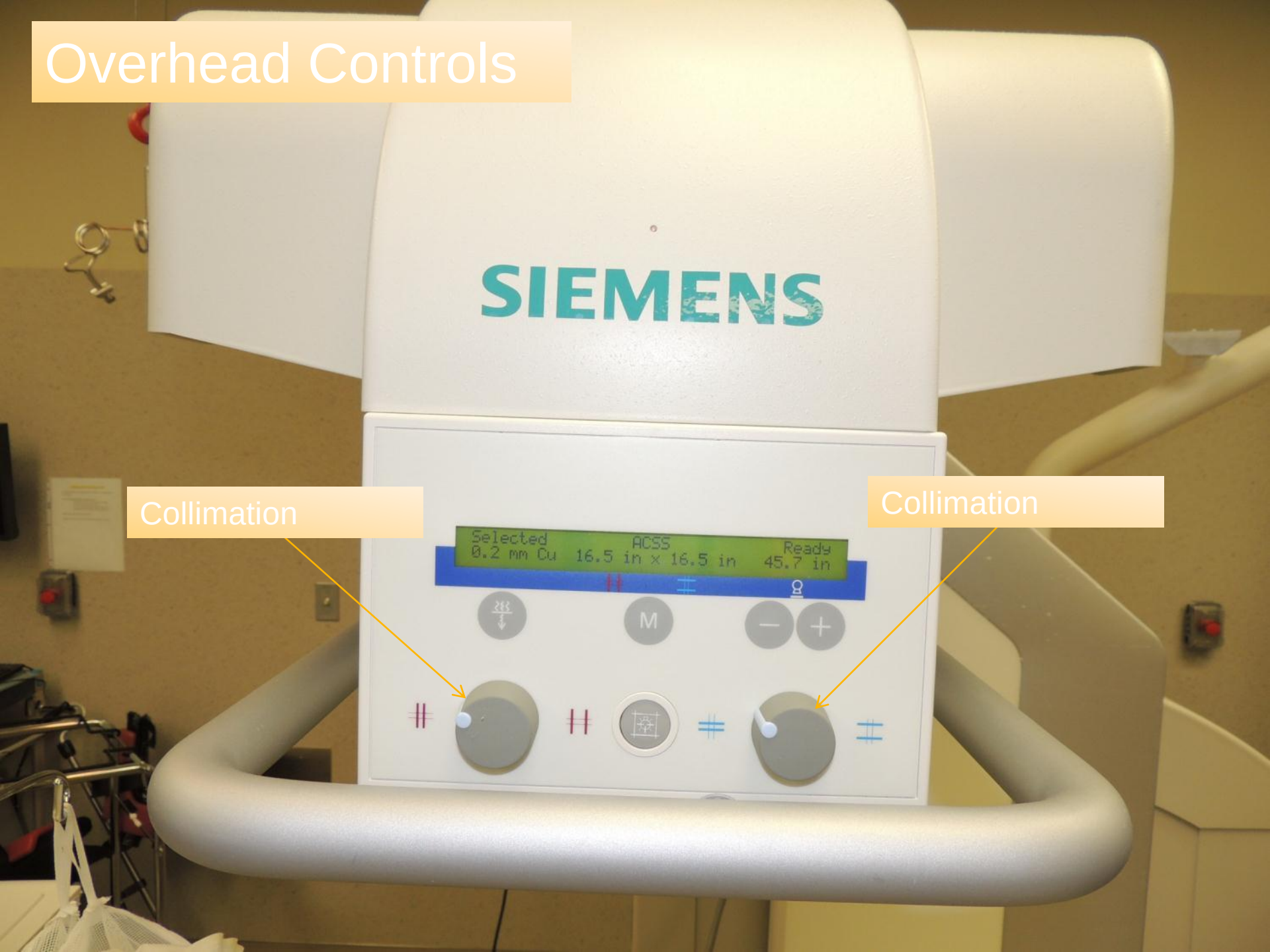
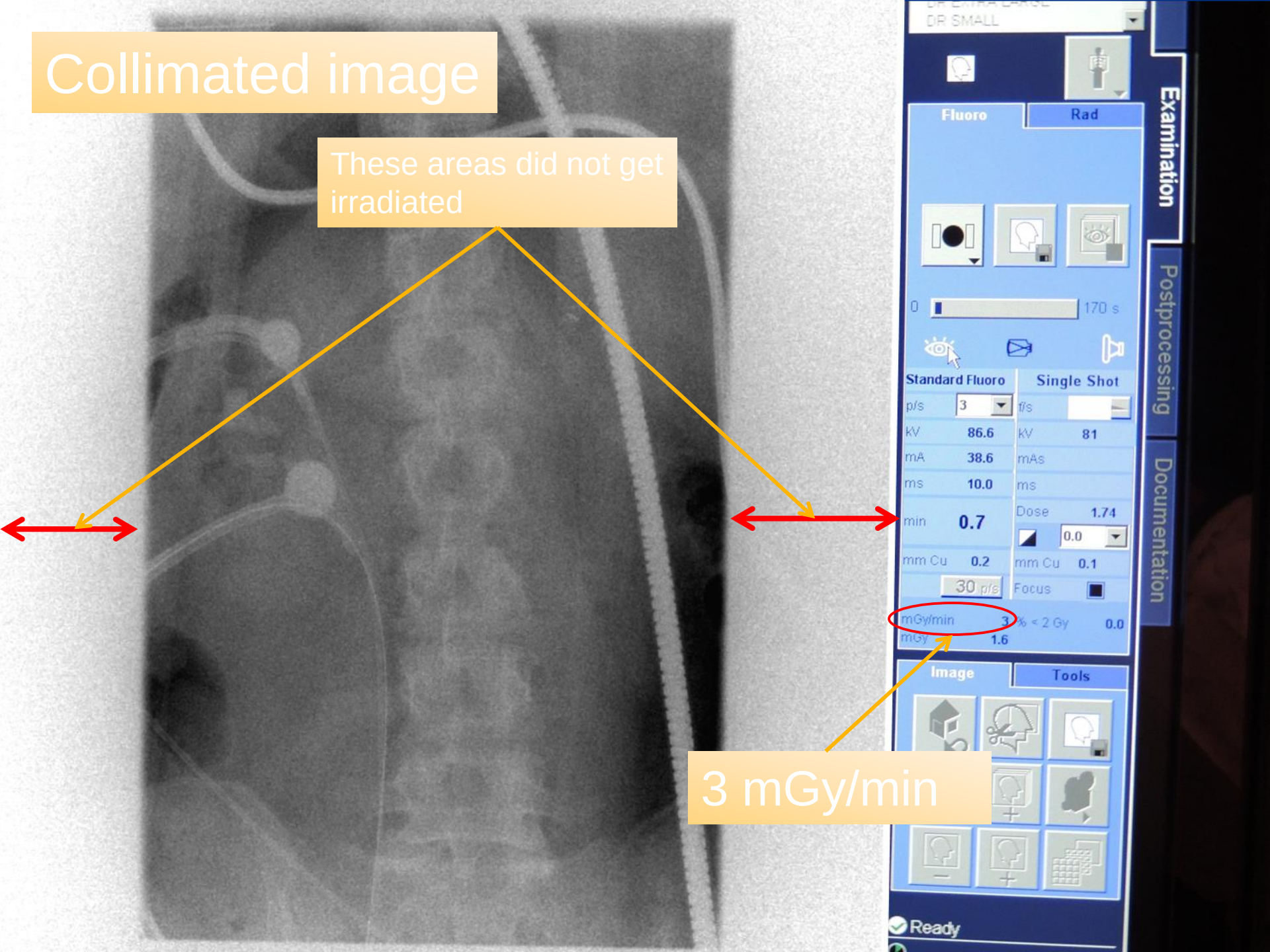
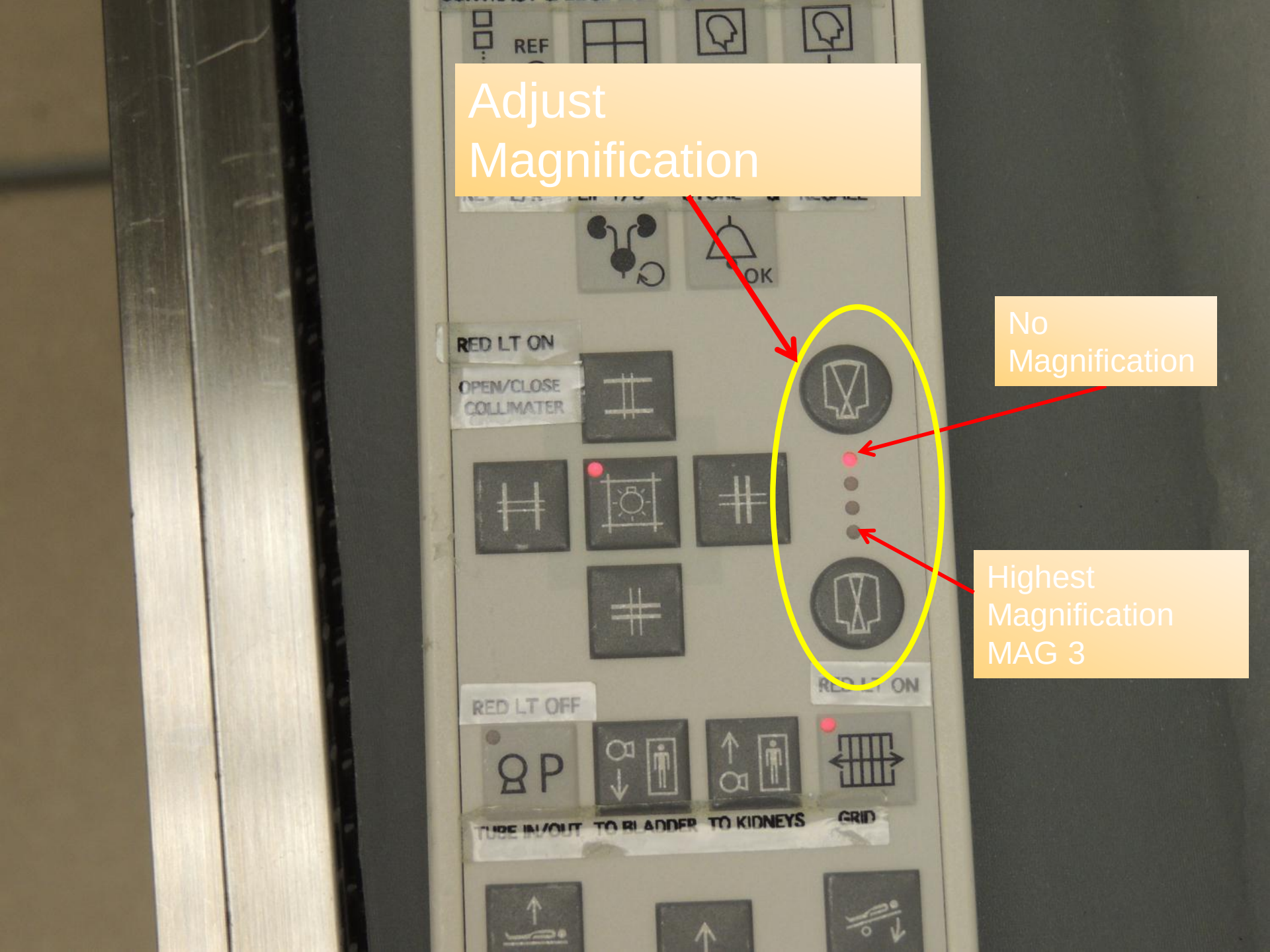
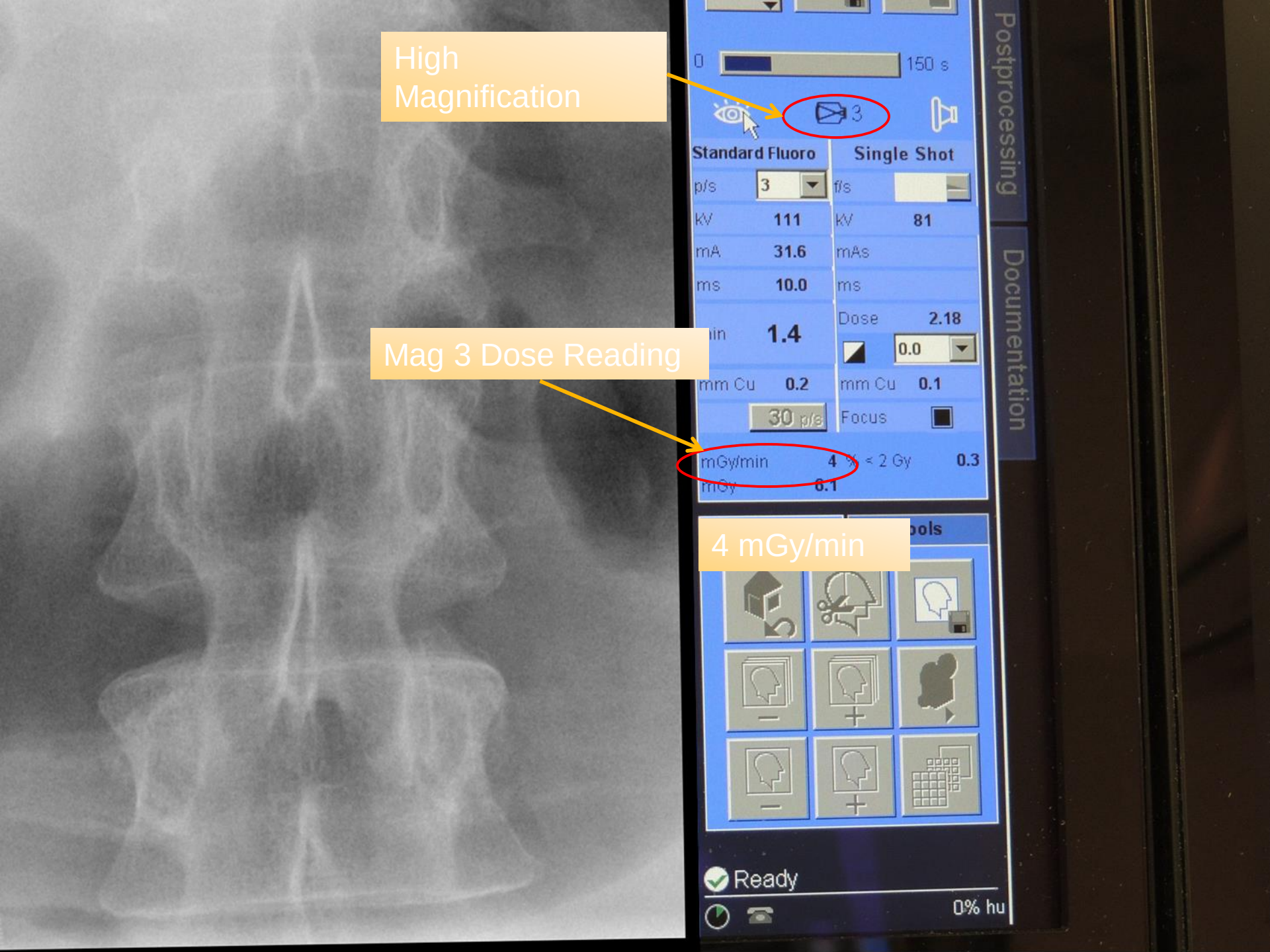
Overhead Controls



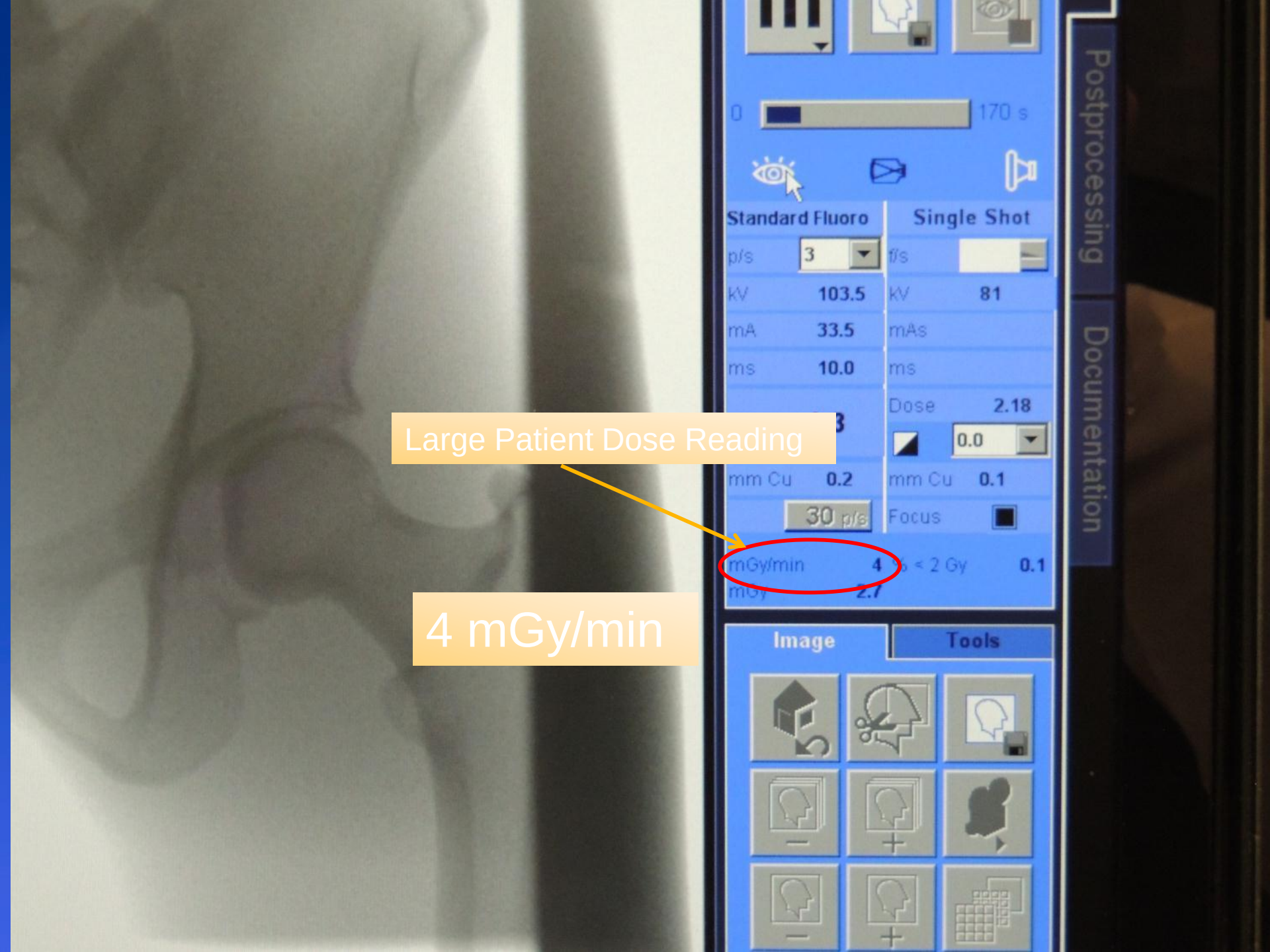
Hand Remote controls

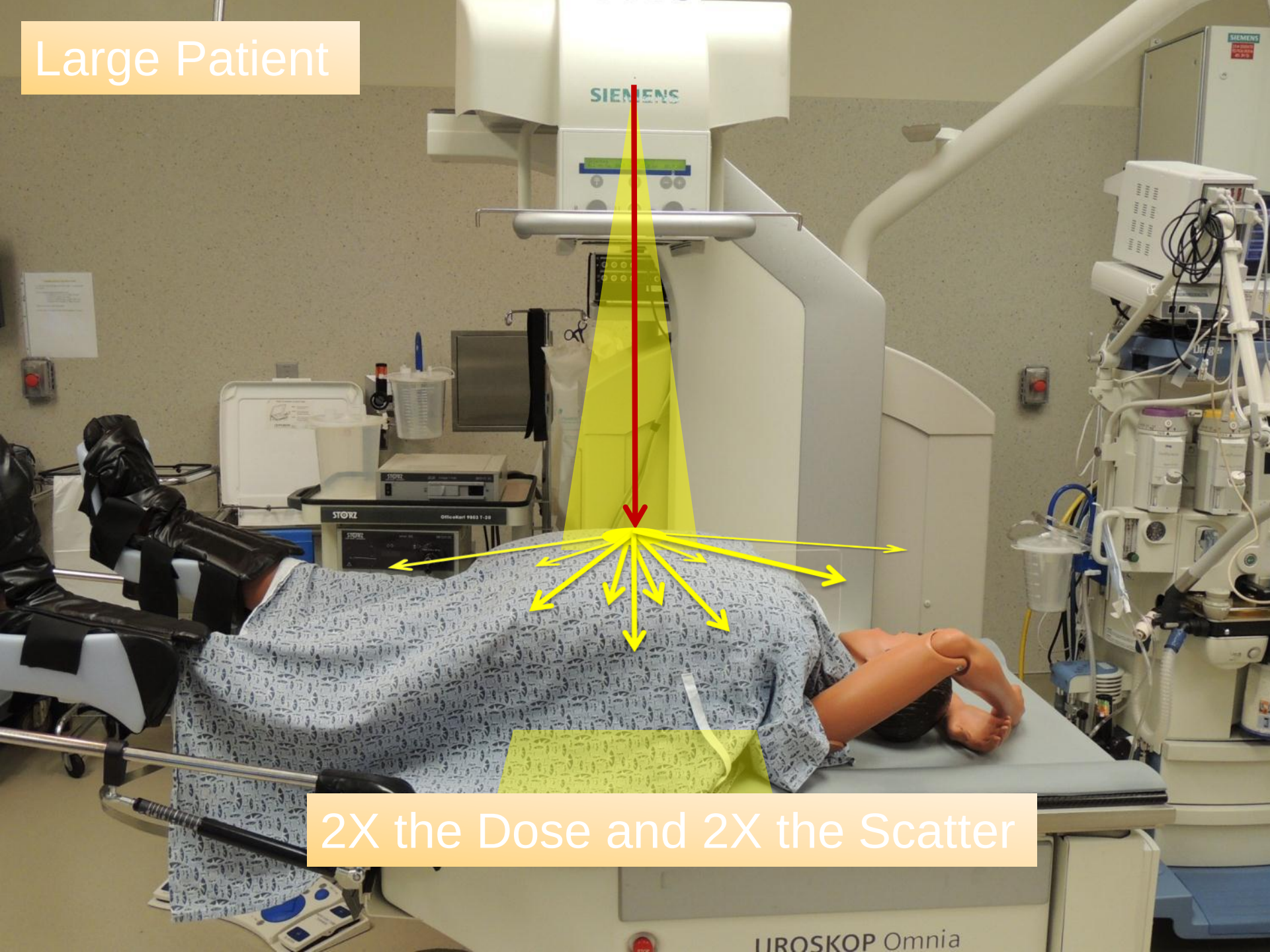

Collimated image
These areas did not get irradiated
3 mGy/min
DR SMALL
Fluoro
Rad
Examination
Postprocessing
Documentation
0
170 s
Standard Fluoro
Single Shot
p/s
3
f/s
kV
86.6
kV
81
mA
38.6
mAs
ms
10.0
ms
min
0.7
Dose
1.74
0.0
mm Cu
0.2
mm Cu
0.1
30 p/s
Focus
mGy/min
3
% < 2 Gy
0.0
mGy
1.6
Image
Tools
Ready

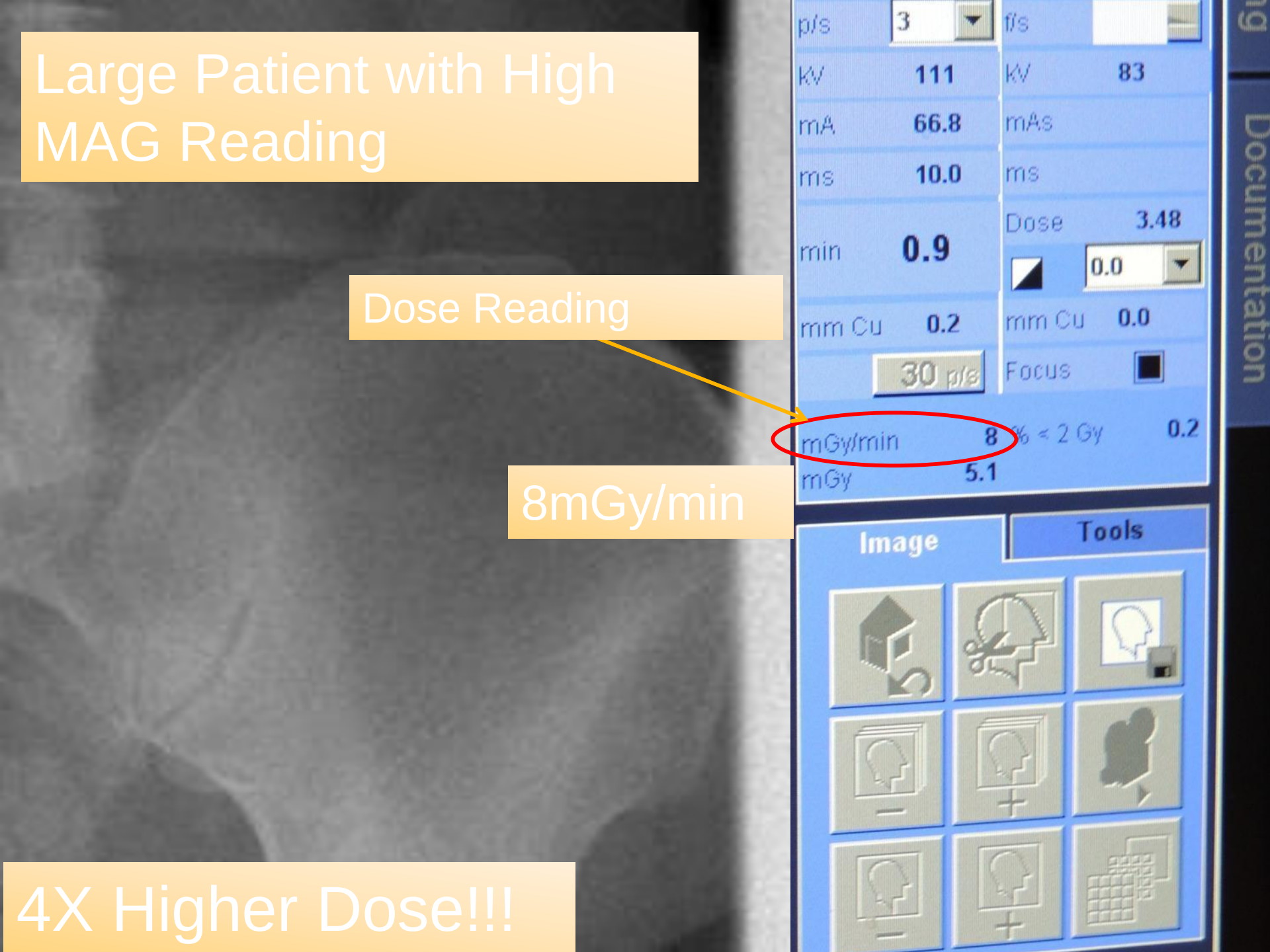

Adjust Magnification
No Magnification
Highest Magnification MAG 3
REF
OK
RED LT ON
OPEN/CLOSE COLLIMATER
RED LT OFF
TUBE IN/OUT
TO BLADDER
TO KIDNEYS
GRID


High Magnification
Mag 3 Dose Reading
4 mGy/min
Postprocessing
Documentation
0
150 s
3
Standard Fluoro
Single Shot
p/s
3
f/s
kV
111
kV
81
mA
31.6
mAs
ms
10.0
ms
Dose
2.18
1.4
0.0
mm Cu
0.2
mm Cu
0.1
30 p/s
Focus
mGy/min
4
< 2 Gy
0.3
mGy
6.1
Ready
0% hu


Large Patient
SIEMENS
STORZ


Large Patient Dose Reading
4 mGy/min
Postprocessing
Documentation
0
170 s
Standard Fluoro
Single Shot
p/s
3
f/s
kV
103.5
kV
81
mA
33.5
mAs
ms
10.0
ms
Dose
2.18
0.0
mm Cu
0.2
mm Cu
0.1
30 p/s
Focus
mGy/min
4
< 2 Gy
0.1
Image
Tools


Large Patient
SIEMENS
STORZ
UROSKOP Omnia
2X the Dose and 2X the Scatter


Large Patient with High MAG Reading
Dose Reading
8mGy/min
4X Higher Dose!!!
p/s
3
f/s
kV
111
kV
83
mA
66.8
mAs
ms
10.0
ms
min
0.9
Dose
3.48
0.0
mm Cu
0.2
mm Cu
0.0
30 p/s
Focus
mGy/min
8
% < 2 Gy
0.2
mGy
5.1
Image
Tools
Documentation