Radiation Protection and Dose Management in Interventional Radiology, State of the Art

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Introduction

- There is an increased Worldwide emphasis on radiation safety
  - It created the need for better Radiation dose management
- IR carefully plans each Interventional procedure
  - consulting the referring Physician,
  - providing detailed explanation on the procedure to the patient
  - and finally obtaining an informed consent
- Such an attitude is part of our daily routine, but usually it does not include specific, case tailored means of Dose Management and patient, nor staff Radiation Protection

Procedure planning and Radiation Exposure

- We are very much aware of any possible procedure related complication and do the outmost to prevent it
- The most important contributor of the radiation exposure in IR is Fluoroscopy
- Time efficient performance of procedure will ultimately lead to shorter fluoroscopy time, less DSA runs and reduce exposure dose
- Cone Beam CT (CBCT) is a game changer as allows to perform procedure based on very few acquisitions.

Procedure Planning

- Procedure planning should integrate dose management measures
- The goal is an efficient and optimal use of radiation
  - not an irrational fear or negligence

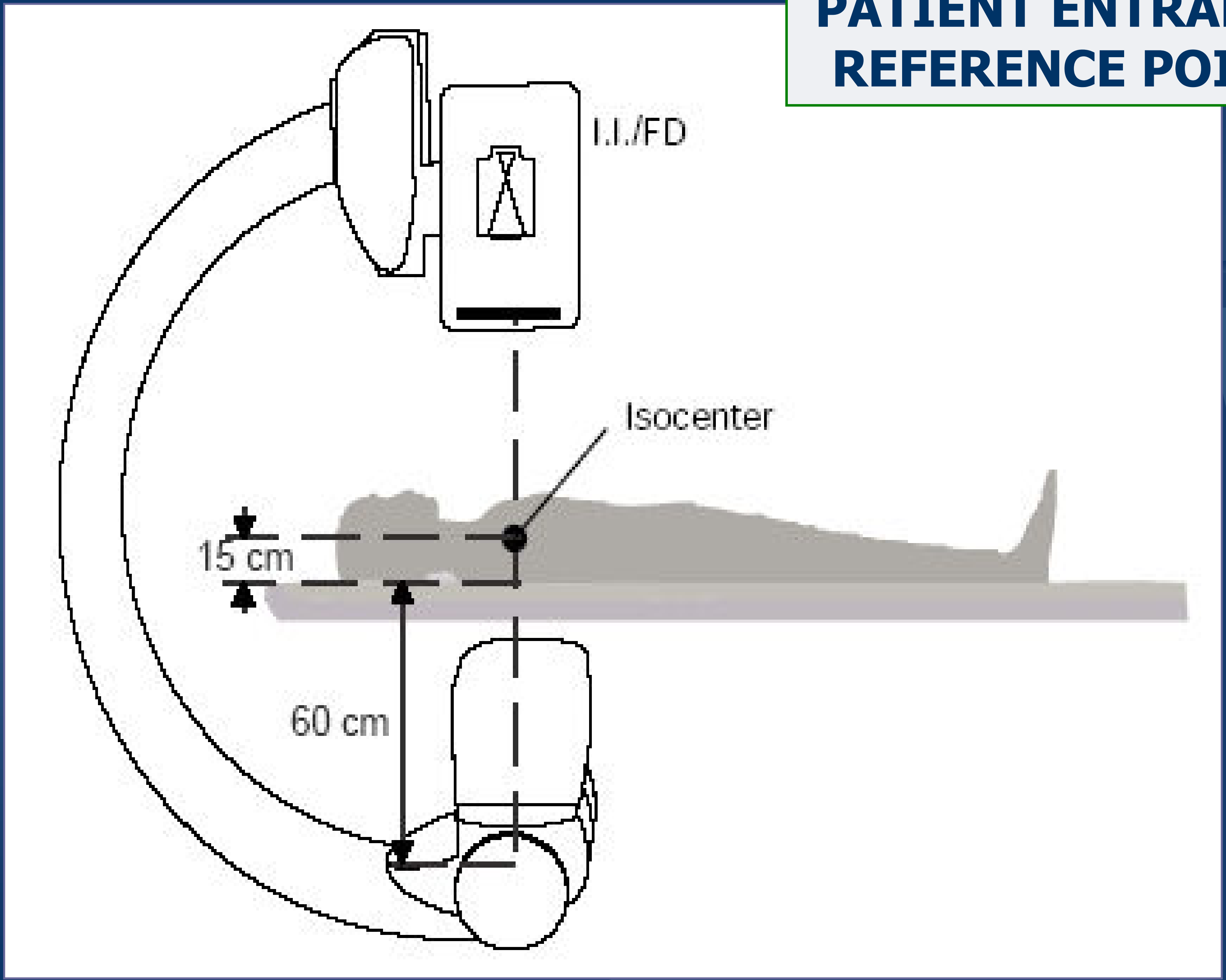
Pre-procedural Imaging

- CTA and/or MRA should be routinely used prior to almost any endovascular procedure.
- CTA has become a routine, must to have, imaging for diagnosis and localization of bleeding in set-up of trauma or GI bleeding
- Good pre procedural imaging allows:
  - proper planning of access,
  - choice of selective catheters for quick access,
  - safe and accurate performance of the intervention

Modality Based Patient Radiation Dose

- In most of the interventional C-arms systems:
  - Kerma Area Product (or Dose Area Product, DAP) in **Gy.cm^2**
  - Cumulative Skin Dose (or Air Kerma at the patient entrance reference point) in **mGy**.
- For rotational acquisitions and “like CT” modes (Cone Beam CT), the same quantities are used.
- For CT:
  - CT Dose Index, **CTDI** in mGy
  - Dose Length Product in **mGy.cm**

PATIENT ENTRANCE REFERENCE POINT



ALARA Principle

- Doses to the patient should be
- As
- Low
- As
- Reasonably
- Achievable
- To get diagnostic, not beautiful images
- To perform any Fluoro guided procedure within minimal Fluoro time…

“Passive” Radiation Protection

- The means that are provided with and by the Fluoroscopy system
- Operator independent and represent any possible active consented protection
- Passive methods are of no use if they are not utilized in daily practice.

“Active” Radiation Protection

- We are obligated to be protected from Ionizing Radiation using:
  - any available passive means,
  - dose reduction methods,
  - adjust our behavior to the hostile setting of the Fluoroscopy system
- The “active methods” allow proper performance of the procedures with the lowest radiation exposure for patients and staff

Radiation Protection is not a Gordian Knot.
More Like Borromean Rings.

If any one of these three Borromean rings is removed, the other two are no longer joined.

Guidelines for Patient Radiation Dose Management

Michael S. Stecker, MD, Stephen Balter, PhD, Richard B. Towbin, MD, Donald L. Miller, MD, Eliseo Vañó, PhD, Gabriel Bartal, MD, J. Fritz Angle, MD, Christine P. Chao, MD, Alan M. Cohen, MD, Robert G. Dixon, MD, Kathleen Gross, MSN, RN-BC, CRN, George G. Hartnell, MD, Beth Schueler, PhD, John D. Statler, MD, Thierry de Baère, MD, and John F. Cardella, MD, for the SIR Safety and Health Committee and the CIRSE Standards of Practice Committee

J Vasc Interv Radiol 2009; 20:S263–S273

SOCIETY OF INTERVENTIONAL RADIOLOGY

Enhanced care through advanced technology®

CIRSE

Journal of Vascular and Interventional Radiology

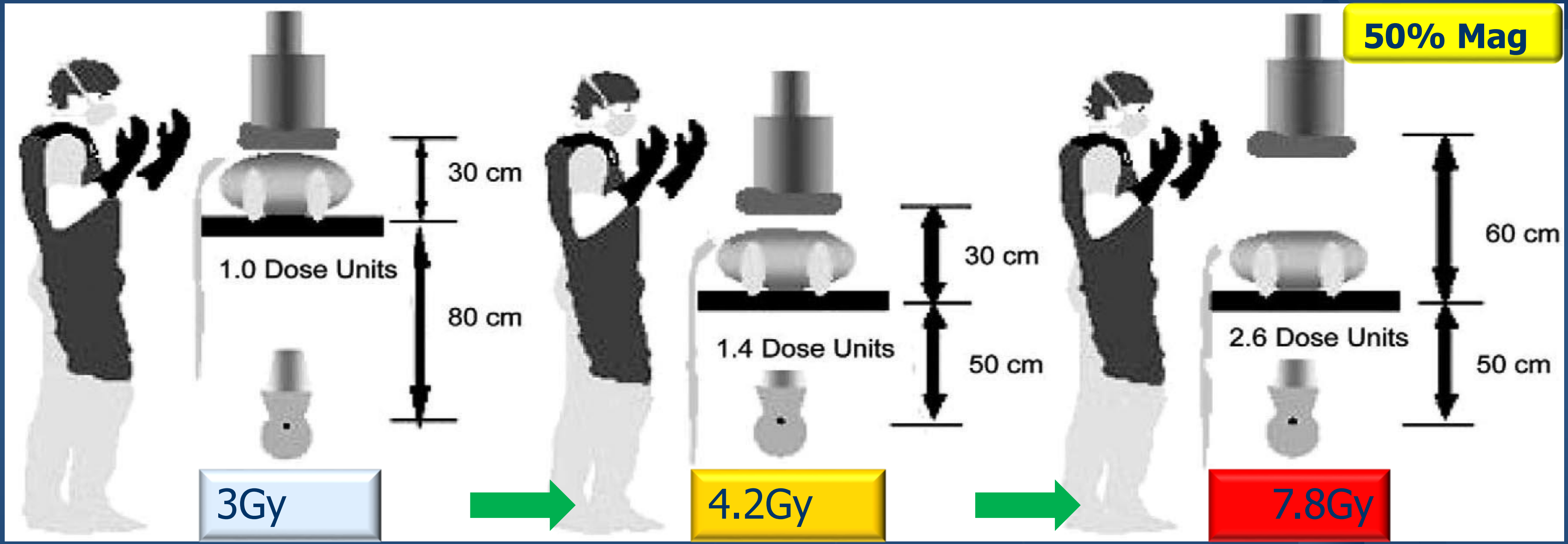
ELSEVIER

JVIR

Official Journal of the Society of Interventional Radiology

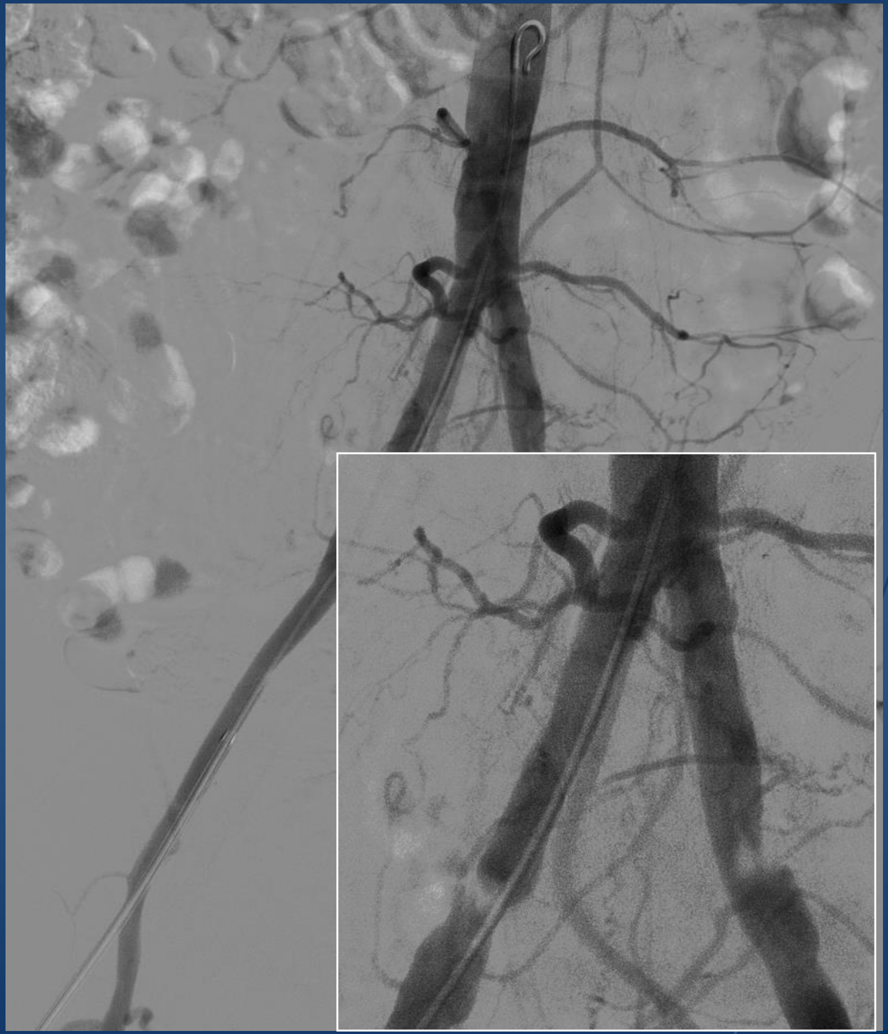
The CIRSE Executive Committee and the SIR Executive Council endorsed the document

X-Ray Tube and Image Receptor to Patient Distance



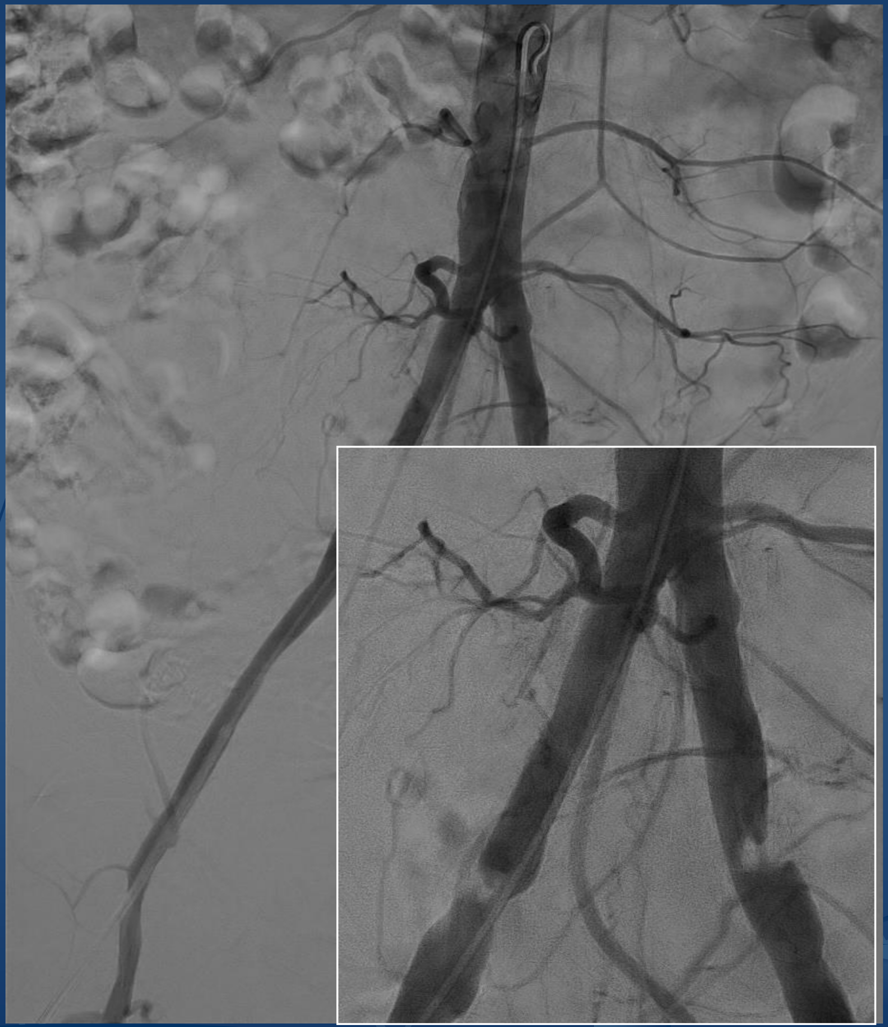
Wagner LK. *Minimizing Risks from Fluoroscopic X Rays. The Woodlands, Tex: R.M. Partnership; 2000.*

Mode #1 100% dose



DAP: 5538 mGy·cm^2/frame
AK: 12.3 mGy/frame

Mode #2 17% Dose



DAP: 925 mGy·cm^2/frame
AK: 2.1 mGy/frame

Dose Management in Embolization Procedures

- Procedures should be performed by dedicated IR using tailored dose management methods
- Use Cone Beam CT (CBCT) when available
- Reduce number of DSA runs
- Prefer Pulsed Fluoroscopy
- View images using
  - Last Image Hold (LIH)
  - and Last Fluoroscopy Hold (LFH)

Dose Management in Embolization

- Before collimation minimize tube current and select fixed exposure factor (kV and mA lock)
- Collimate primary beam to smallest useful area
- Use Virtual collimation
- Keep Fluoroscopy time to a minimum
- No spot films or DSA runs for image storage, but save images from LIH or LFH

Uterine Artery Embolization
Patient Dose Management

- Bilateral femoral access
  - two catheters, placed into the distal uterine arteries
  - simultaneous injections for embolization
- Low frequency pulsed fluoroscopy
- Pre - and post-embolization exposures
- Limit magnified and oblique fluoroscopy

Nicolic et al. JVIR 2001; 12:39–44

Uterine Artery Embolization
Patient Dose Management

- Over 50% reduction of estimated absorbed ovarian dose (EAOD) vs. routine methods
  - Mean EAOD for fluoro reduced from 22.34 to 9.5 cGy
  - Mean Absorbed Skin Dose (ASD) reduced from 162.32 (range 66 – 304) to 47.69 cGy
  - Threshold doses for induction of deterministic radiation injury to the skin is 400–500 cGy

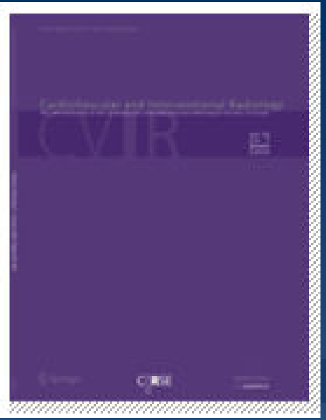
Nicolic et al. JVIR 2001; 12:39–44

Cardiovasc Intervent Radiol (2010) 33:230–239
DOI 10.1007/s00270-009-9756-7

CIRSE GUIDELINES

Occupational Radiation Protection in Interventional Radiology: A Joint Guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology

Donald L. Miller · Eliseo Vañó · Gabriel Bartal · Stephen Balter · Robert Dixon · Renato Padovani · Beth Schueler · John F. Cardella · Thierry de Baère

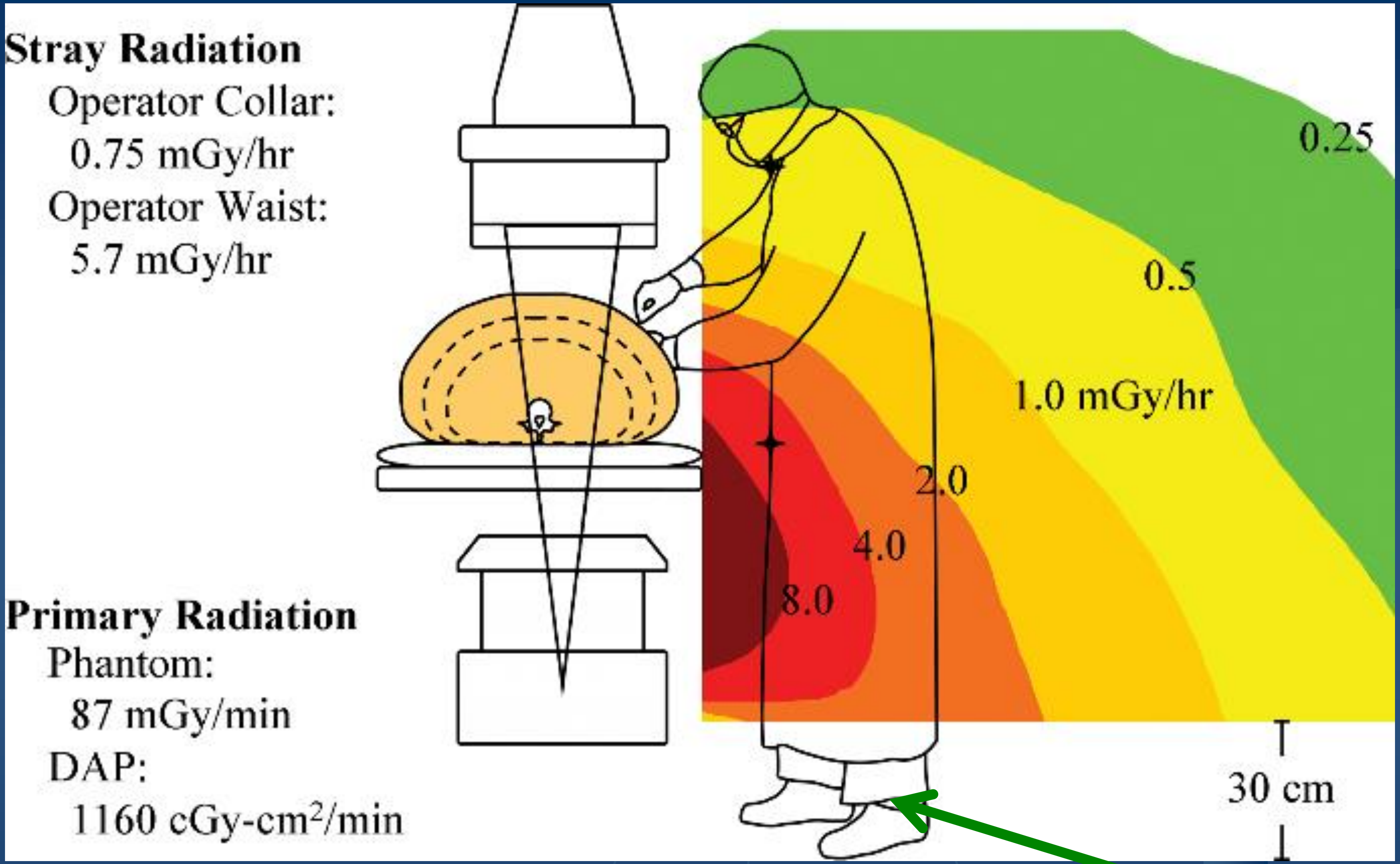


Also published in: J Vasc Interv Radiol. 2010 May;21(5):607-15.

Guidelines approved by the members of the CIRSE Standards of Practice committee and the SIR Safety and Health Committee

The CIRSE Executive Committee and the SIR Executive Council endorsed the document

CIRSE and SIR will update the guidelines during 2023-2024



Schueler et al. 2006 *RadioGraphics.* RSNA
An Investigation of Operator Exposure in Interventional Radiology.

Factors affecting staff doses

- The main source of radiation for the staff in a fluoroscopy room is the patient (scattered radiation)
- The scattered radiation is not uniform around the patient
- The level of dose rate around the patient is a complex function of a great number of factors


Advanced
MEDICAL IMAGING
Dr. Razdan
Interventional Radiology
XPF
BLOXR


XPF
BLOXR

Putting Radiation Protection to the Test Caps and Glasses Fall Short

- Scatter radiation extends tangentially
- No single thing is going to give all-round protection
- Need for a multipronged approach combining:
  - garb, shields, and technique
- Unlike other studies, these findings show that
  - radiation absorbent caps provide minimal brain protection
  - radiopaque eyeglasses provide incomplete protection of the ocular lenses

Fetterly et al. J Am Coll Cardiol Cardiovasc Intv. 2017

Are Leaded Glasses Reliable?

- Leaded eyeglasses may provide inadequate protection
  - Seeking and assessing alternative techniques
- Posterior subcapsular opacities were three times more common in Interventional Cardiologists
  - significant increase in risk after correcting for age, sex, smoking, and various other confounders

Table 1. Eyewear selection evaluated.

Eyewear	Lead equivalence[a] (mm)	Weight (g)	Approximate eyeglass lens cross section (cm^2)	Image
Lightweight	0.07	48	50	
Sportwrap	0.75	59	16	
Classic	0.75	120	28	

[a]Lead equivalence — the thickness of a pure lead sheet needed to provide the same level of radiation protection as the subject material.

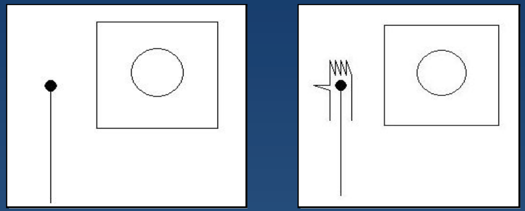
Table 2. Measured eye doses and calculated eyewear protection factors.

	Average eye dose (μSv)			Eyewear protection factor		
Eyewear	0 degree	45 degree	90 degree	0 degree	45 degree	90 degree
None	980	380	350	1.0	1.0	1.0
Lightweight	380	215	135	2.6	1.8	2.6
Sportwrap	120	85	245	8.2	4.5	1.4
Classic	105	75	90	9.3	5.1	3.9

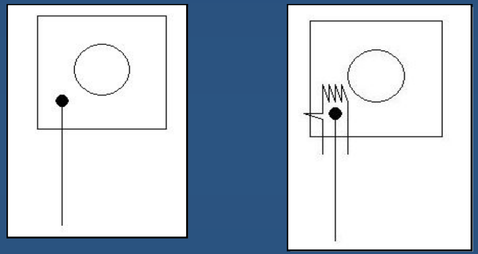
Exposure to the Hands

- No hand in the primary beam
- Use pulsed, low dose fluoroscopy when being close to the primary beam

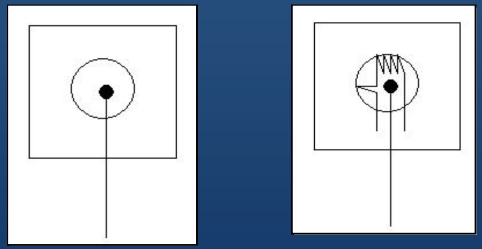
Hand position



2 mSv/h



20 mSv/h



25 mSv/h

Relative values of hand dose (with 0.03 mm Pb equivalent)

2 mSv/h and attenuation 53%

20 mSv/h and attenuation 49 – 45 % (with different patient ticknessess: 69 - 93 kV and 4.5 mm Al filtration.

25 mSv/h and relative attenuation 18 - 8% (with glove, kV moves to 93 - 103 kV. But, patient dose increase in around 30%.

Lead Gloves

- Does not protect from the primary beam!!
- Some protection from scatter
- Reduces your skill
- Cut the end of the gloves
- No need in Cardiac Lab's - false security
- Always keep your hands out of the FOV!!!

Measure Radiation During Procedures and Categorize them According to Dose

- Dose received by IR can vary by **more than an order of magnitude for the same type of procedure** and for similar patient dose
- Occupational doses are expressed in terms of **equivalent dose** in an organ or tissue **(H_T)** for exposure of part of the body and **effective dose (E)** for whole-body exposure
- The SI unit for both quantities is Sievert (Sv).
  - Equivalent dose and effective dose cannot be measured directly.
  - They must be calculated from other, simpler quantities that can be measured with personal dosimeters.

Sometimes, ceiling suspended screen is not properly used

Etiology of MSK problems in IRs

- Protective garments are effective in reducing the dose of exposure.
- Overload with negative effect on the MSK system (primarily spine).
- Etiological explanations:
  - whole-body biomechanical overload, cause the discomfort and fatigue
  - reduced ease of movement, limits joint movements and changing posture
- All of the above clarifies
  - the whole-body pain
  - or specific body area (neck or back) pain

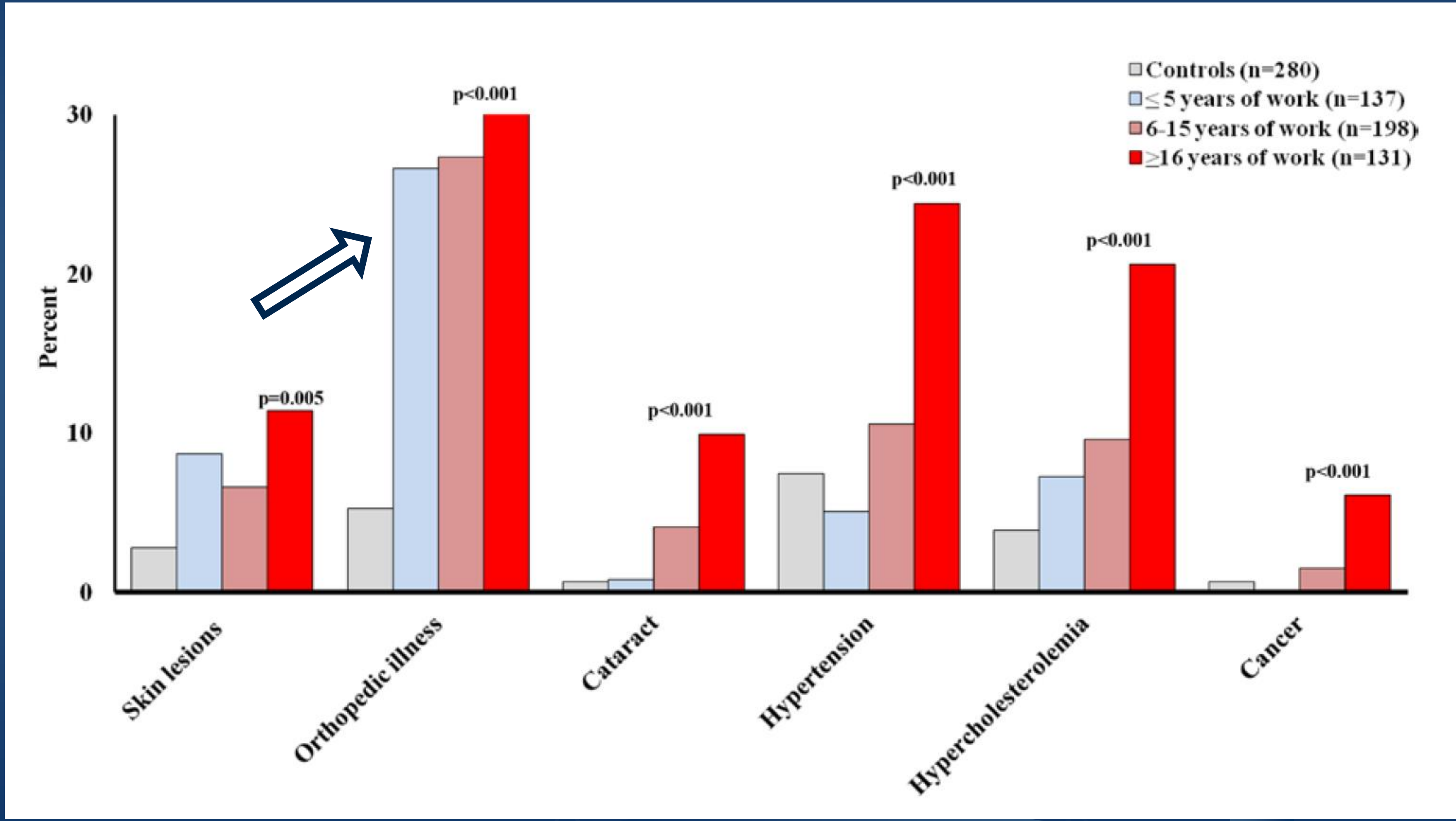
Prevalence of MSK Symptoms in IRs. JJ Morrison et al. JVIR'2020, V31, I8, 1308-1314

Musculoskeletal Pain in IRs. Research Highlights

- Nearly 9 of 10 interventional radiologists experience musculoskeletal (MSK) pain.
- Most subjects attributed MSK pain to work-related activities.
- Back, shoulder, and neck pains were the most common.
- Factors that increased risk for MSK pain comprise:
  - female sex,
  - BMI> 25,
  - practice length greater than 10 years.

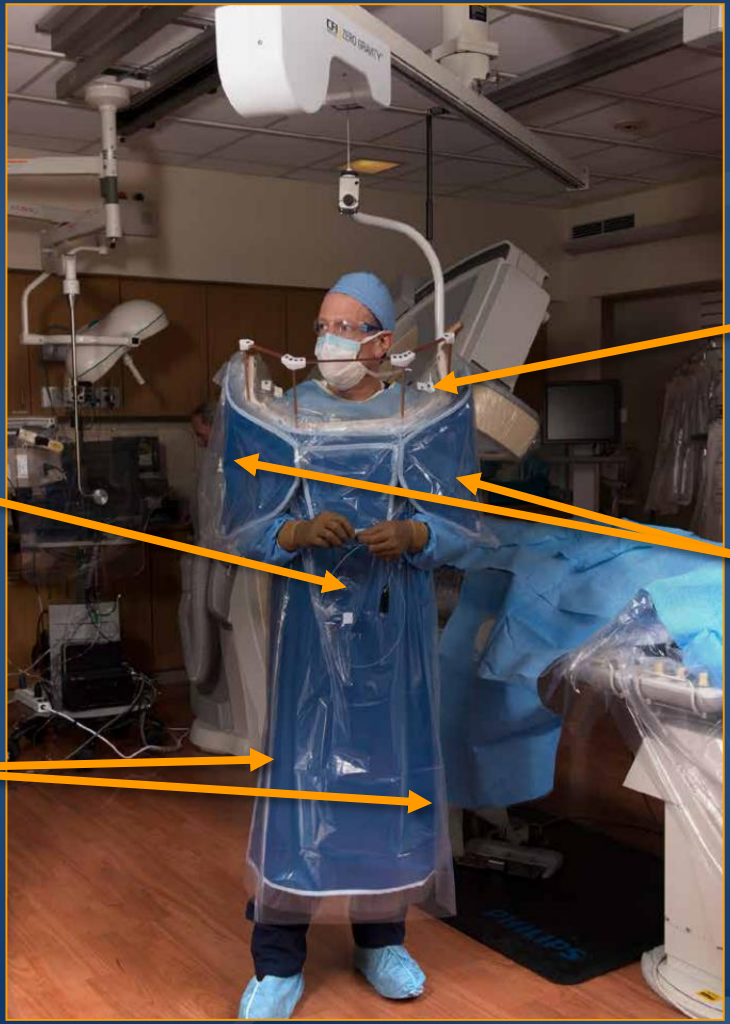
Prevalence of MSK Symptoms in IRs. JJ Morrison et al. JVIR'2020, V31, I8, 1308-1314

An Increased Rate of Health Problems Accross the Years of Work, Especially After 16 Years



Andreassi et. Al, 2016. *Circ Cardiovasc Interv.* 2016;9

Zero-Gravity
Suspended Radiation Protection System



Body shield
1.0 mm Pb equivalency

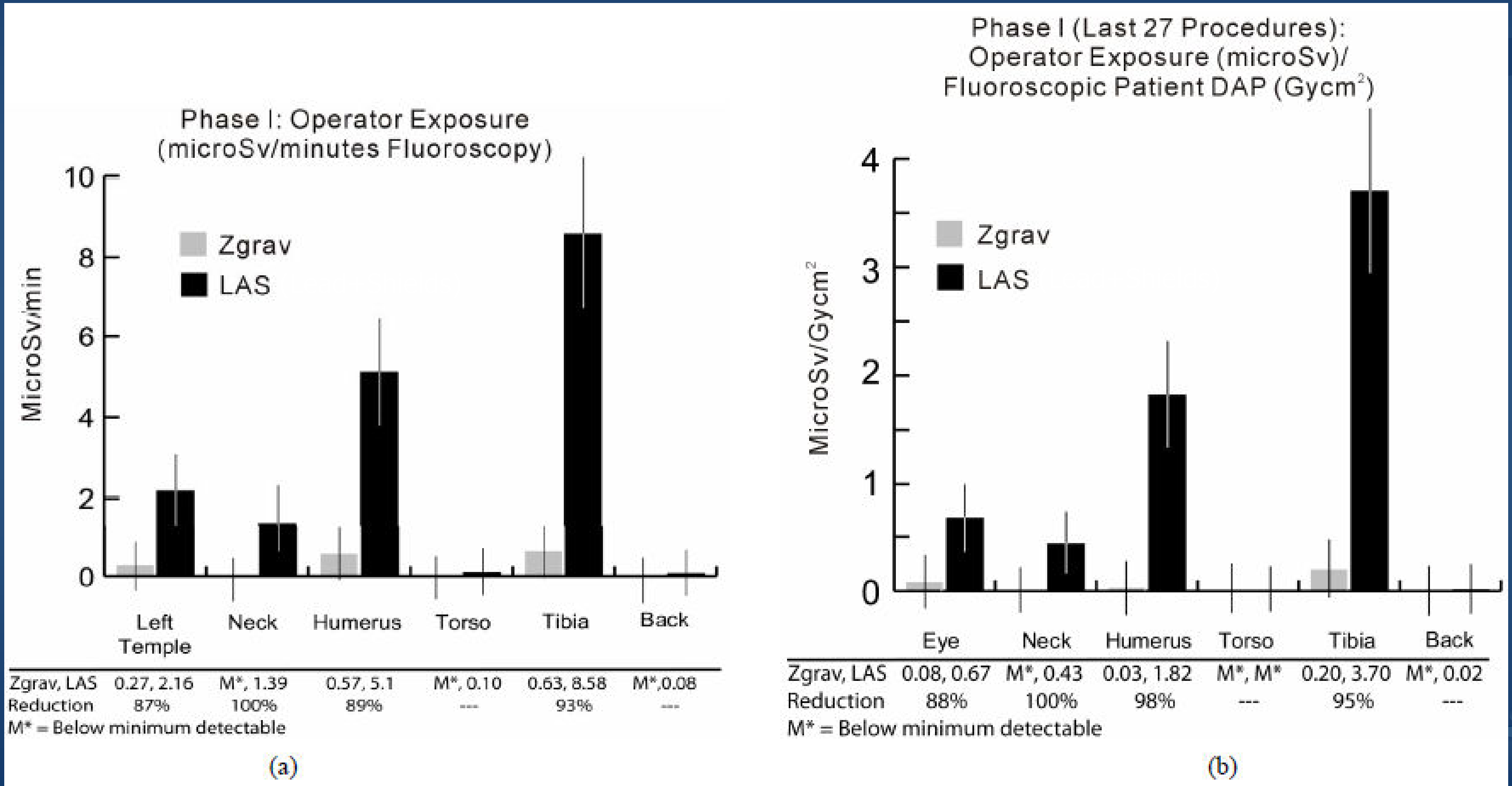
Body shield sides
0.5 mm Pb equivalency

Face shield
0.50mm Pb equivalency

Shoulder flaps
1.0 mm Pb equivalency

Comparison of Zero-Gravity with conventional aprons even if combined with ancillary shields

Results:



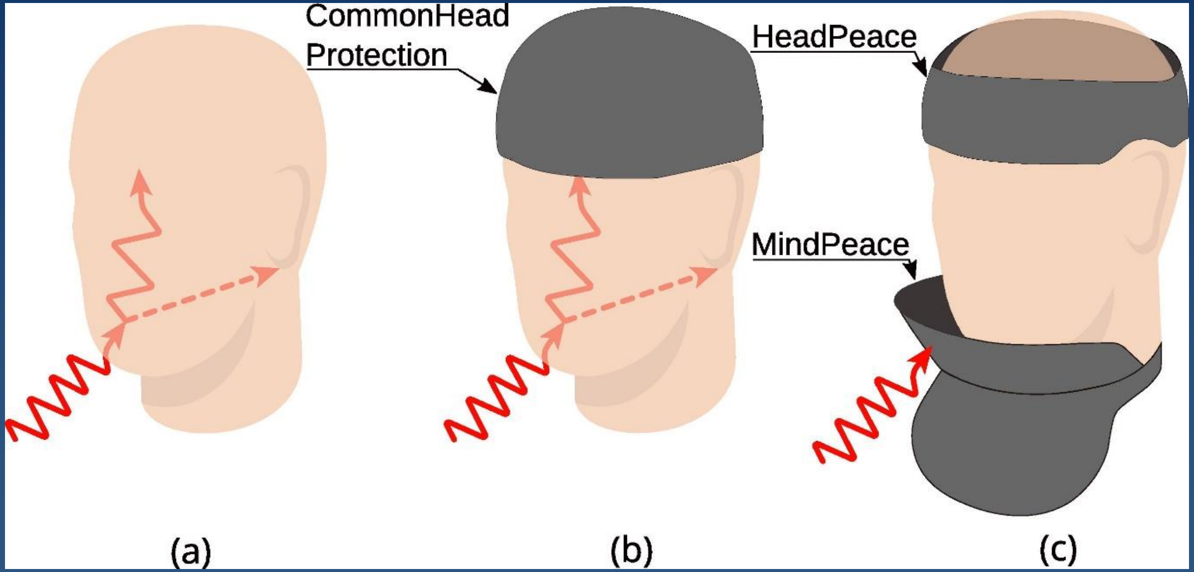
Source: Savage et al; Open Journal of Radiology, 2013, 3, 143-151

Live case using ZG + dosimeter

Live case: Prof. A. Roguin using ZG, with two digital dosimeters: LT forehead and LT chest

After 1 hour procedure.
Both dosimeters 0.0

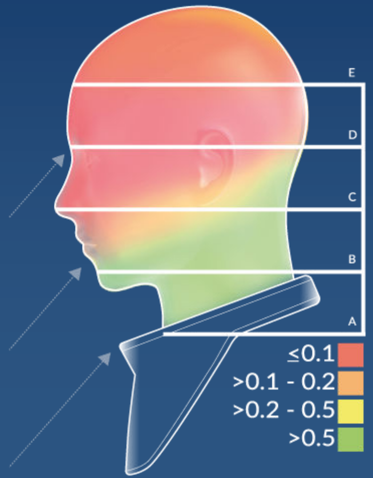
New Head Protection System (TexRay)

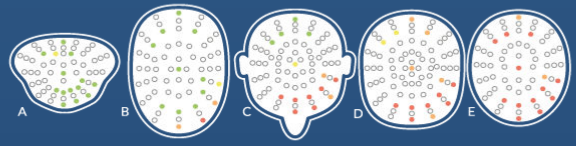


Barenfanger F, et al. Clinical evaluation of a novel head protection system for interventional radiologists.
European Journal of Radiology. V.147 pages 110-114. Feb'2022

Texray Neck Protector. Phantom Study

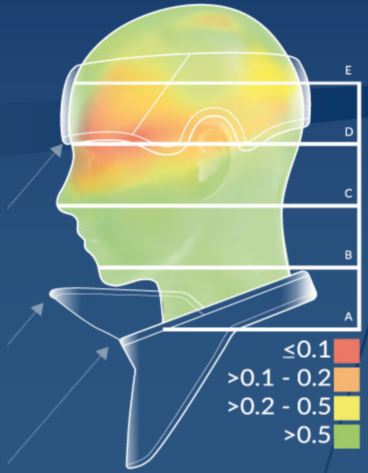
	A	B	C	D	E
1.1	0.97	0.15	0.06	0.06	0.10
2.1	0.97	0.07	0	0.11	0.03
3.1	0.88	0.17	0.11	0.05	0.09
4.1	0.80	0.32	0.04	0.09	0.03
9.1	0.58	0.72	0.66	0.19	0.25
1.3	0.96	0.50	0.10	0	0.07
2.3	0.93	0,44	0	0.04	0
3.3	0.80	0.63	0.09	0.04	0.08
4.3	0.80	0.86	0.15	0.11	0.11
8.3	0.59	0,85	0.70	0.29	0
10.3	0.38	0.82	0.64	0.43	0
11.3	0.70	0.87	0.73	0.31	0
16.3	0.91	0.73	0.01	0.01	0
M2	0.71	0.92	0.48	0.21	0

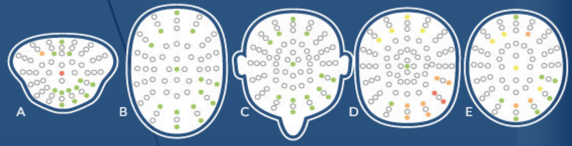




Schematic illustration of the reduction ratios for a standard thyroid collar in phantom slices A, B, C, D, E for the investigated exposure situation.

	A	B	C	D	E
1.1	0.97	0.95	0.84	0.17	0.90
2.1	0.97	0.94	0.73	0.19	0.90
3.1	0.90	0.94	0.51	0.08	0.90
4.1	0.86	0.95	0.46	0.15	0.90
9.1	0.62	0.83	0.55	0.32	0.58
1.3	0.95	0.96	0.84	0.20	0.22
2.3	0.89	0.87	0.81	0.18	0.17
3.3	0.84	0.96	0.75	0.08	0.40
4.3	0.83	0.94	0.75	0.24	0.50
8.3	0.59	0.82	0.69	0.46	0.23
10.3	0.56	0.80	0.69	0.38	0.32
11.3	0.70	0.94	0.76	0.48	0.40
16.3	0.91	0.92	0.78	0.54	0.70
M2	0.01	0.94	0.86	0.53	0.35





Schematic illustration of the expected result if MindPeace and HeadPeace reduction ratios were combined for the different phantom measurements in slices A, B, C, D and E.

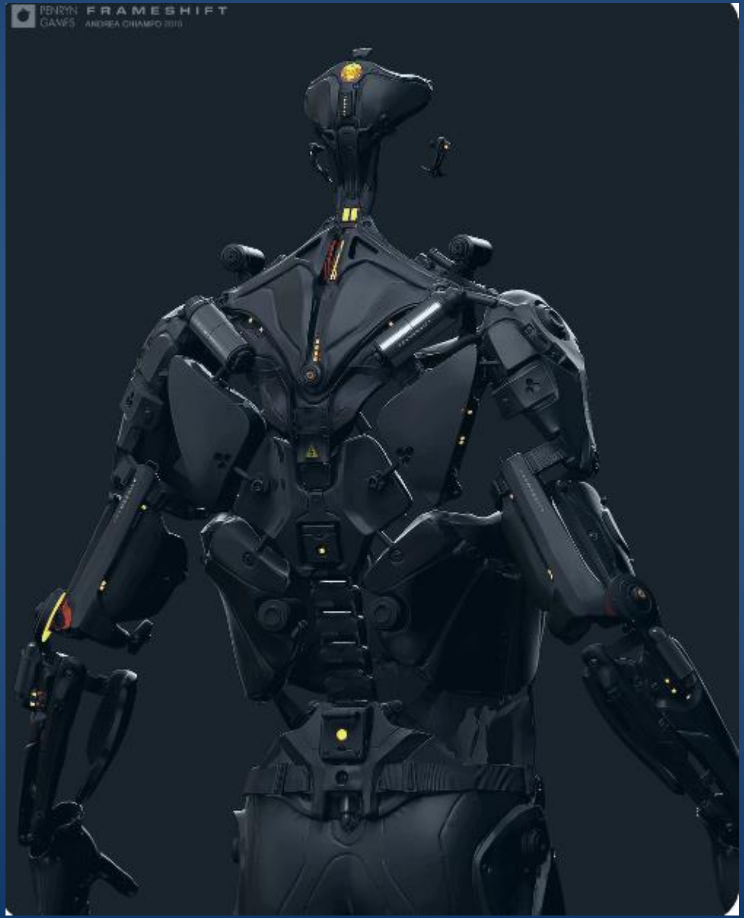
Conclusion: 74% radiation dose reduction towards the head and neck
Could be considered an appropriate protective device for head and neck without using cumbersome or hard to place equipment.

M Larsson et al. Evaluation of a novel thyroid collar designed to reduce head and neck radiation exposure during X-ray guided interventions. Poster presentation at the LINC meeting, Leipzig, Germany, 2020.

Endovascular Robotics and Personnel Safety

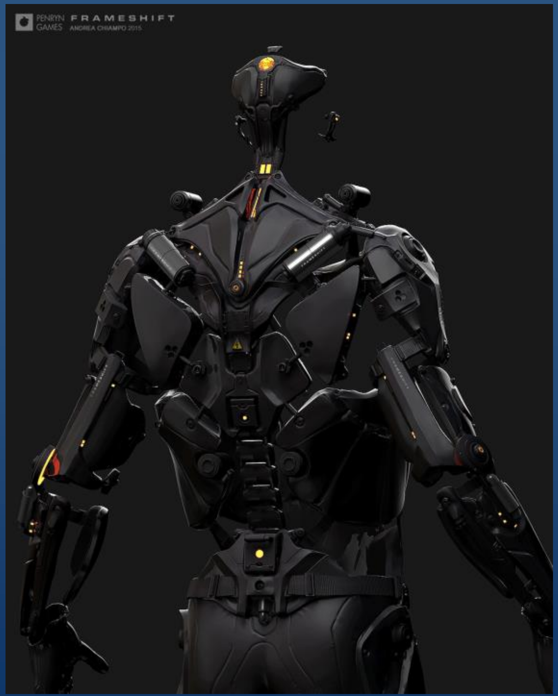
CorindusVascular Robotics, Inc, recently 510(k) clearance for the first automated robotic movement for the CorPathGRX.

Exoskeleton

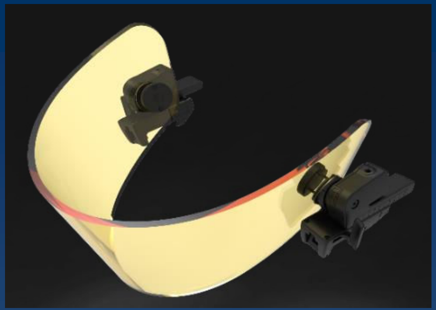


Exoskeleton

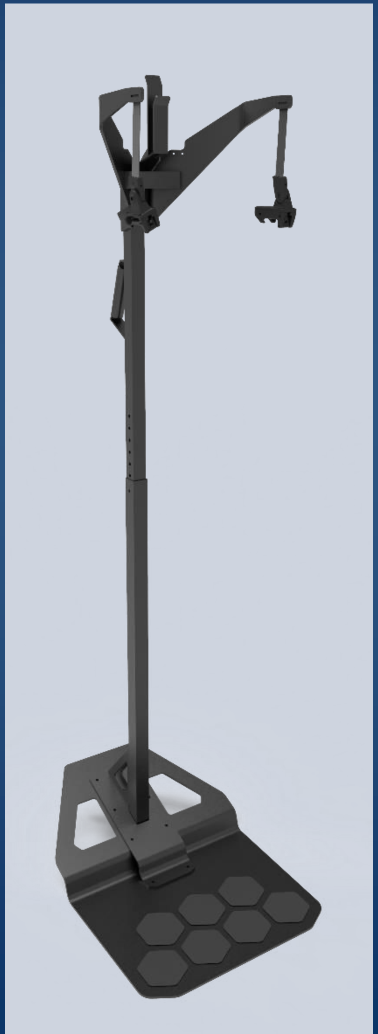
- Exoskeleton of Future
  IR carries all weight
  - and radiation protection



Home Made "Exoskeleton" Systems

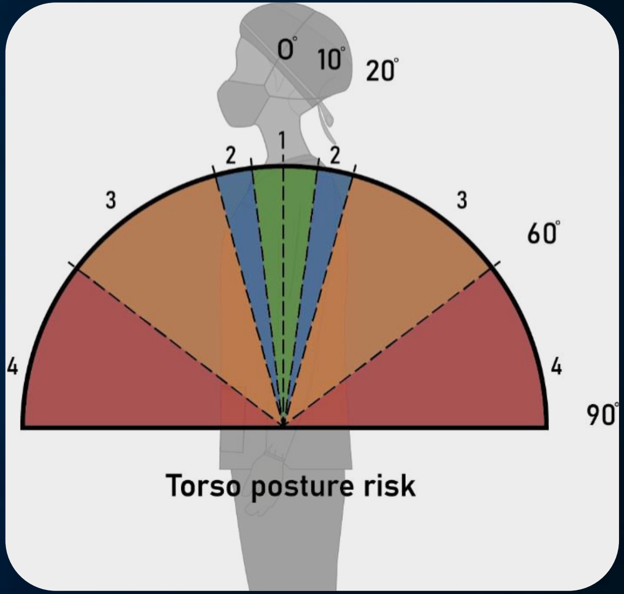


StemRad MD Exoskeleton



Exoskeleton system - StemRad MD Has a Potential to Improve Ergonomics of IRs

Protection type	Low-Risk (P_1) (%)	Mild-Risk (P_2) (%)	Moderate-Risk (P_3) (%)	High-Risk (P_4) (%)	Combined Ergonomic Risk (R)
Lead Apron (n=31)	62.9	19.5	11.4	6.2	1.54 (1.02 - 2.84)
StemRad MD (n=20)	93.9	5.4	0.7	0	1.10 (1 - 1.37)



StemRad MD vs. traditional lead is expected to significantly reduce high-risk postures.

StemRad MD

Personnel Protection Future

- The weight of lead aprons limits physician mobility and causes fatigue
- In the long-term this leads to orthopedic issues in most interventionalists
- New, lightweight, ultra-thin, disposable radiation protection becomes available and will likely become the new normal in cat labs
  - Will they really?
  - Well, not exactly

Good Radiation Management and Advise to other Staff Members RP Tools

- Substantial operator eye doses can be reached under unfavorable circumstances:
  - large patient,
  - high-dose fluoroscopy/fluorography,
  - certain gantry angulations,
  - underscoring the importance of proper protection, particularly for the eyes

The Key is an Intelligent Balance Between Comfort and Protection

- We have to be careful balancing between comfort and protection
  - use any possible means to reduce the strain without compromising safety.
- If you are a busy IR better choose a good protection apron based on your personal dosimetry data that relates to your real radiation risk
  - consult with your medical physicist in your decision process,
  - for any apron, request official results of multienergy (50-120 kVp) testing (IEC 61331–1 (2014) or DIN EN 61331–1 standards or equivalent

Should We Keep the Lead in the Aprons? Bartal G, Sailer AM, Vano E
Tech Vasc Interv Radiol - March 1, 2018; 21 (1); 2-6

Take Home Points... Be aware ...

Learn about patient radiation dose compared to other modalities

Great inaccuracies .. Not easy .. Look for advice of a Medical Physicist

Learn about radiation dose for the interventionalist

Be familiar with the factors influencing staff doses

Learn how to minimize patient radiation

Be familiar with the factors reducing patient doses

Practical tips to reduce operator radiation

Follow the practical rules of the Guidelines SIR-CIRSE:
low fluoro, reduce number of DSA images, collimate, geometry, distance, protection tools, protection rules and training in Radiation Protection

Last, but not the least.
A link to the video of the IAEA tutorial on RP in IR

http://ns-files.iaea.org/training/rpop/Radiation_dose/Tutorial_12_Real-time_dose_monitoring_systems/story.html

Thank You!