ΙΑΤΡΙΚΗ ΣΧΟΛΗ
Π.Γ.Ν. «ΑΤΤΙΚΟΝ» - Γ.Ν.Δ.Α. «Η ΑΓΙΑ ΒΑΡΒΑΡΑ»
ΕΡΓΑΣΤΗΡΙΟ ΕΦΑΡΜΟΣΜΕΝΗΣ ΙΑΤΡΙΚΗΣ ΦΥΣΙΚΗΣ
ΔΙΕΥΘΥΝΤΗΣ: ΕΥΣΤΑΘΙΟΣ Π. ΕΥΣΤΑΘΟΠΟΥΛΟΣ

Σύγχρονες Πρακτικές Ακτινοπροστασίας για Ασθενείς και Προσωπικό στην Επεμβατική Ακτινολογία

Αγάπη Πλουσή
Ακτινοφυσικός Ιατρικής
Εργαστήριο Εφαρμοσμένης Ιατρικής Φυσικής
Ιατρική Σχολή, ΕΚΠΑ

Εισαγωγή

- Οι νέες εξελίξεις στα απεικονιστικά συστήματα καθώς η βελτίωση των επεμβατικών συσκευών με την ανάπτυξη μικρότερων και πιο εύκαμπτων καθετήρων έχει αυξήσει σημαντικά τον αριθμό των ακτινοσκοπικά καθοδηγούμενων επεμβατικών πράξεων.

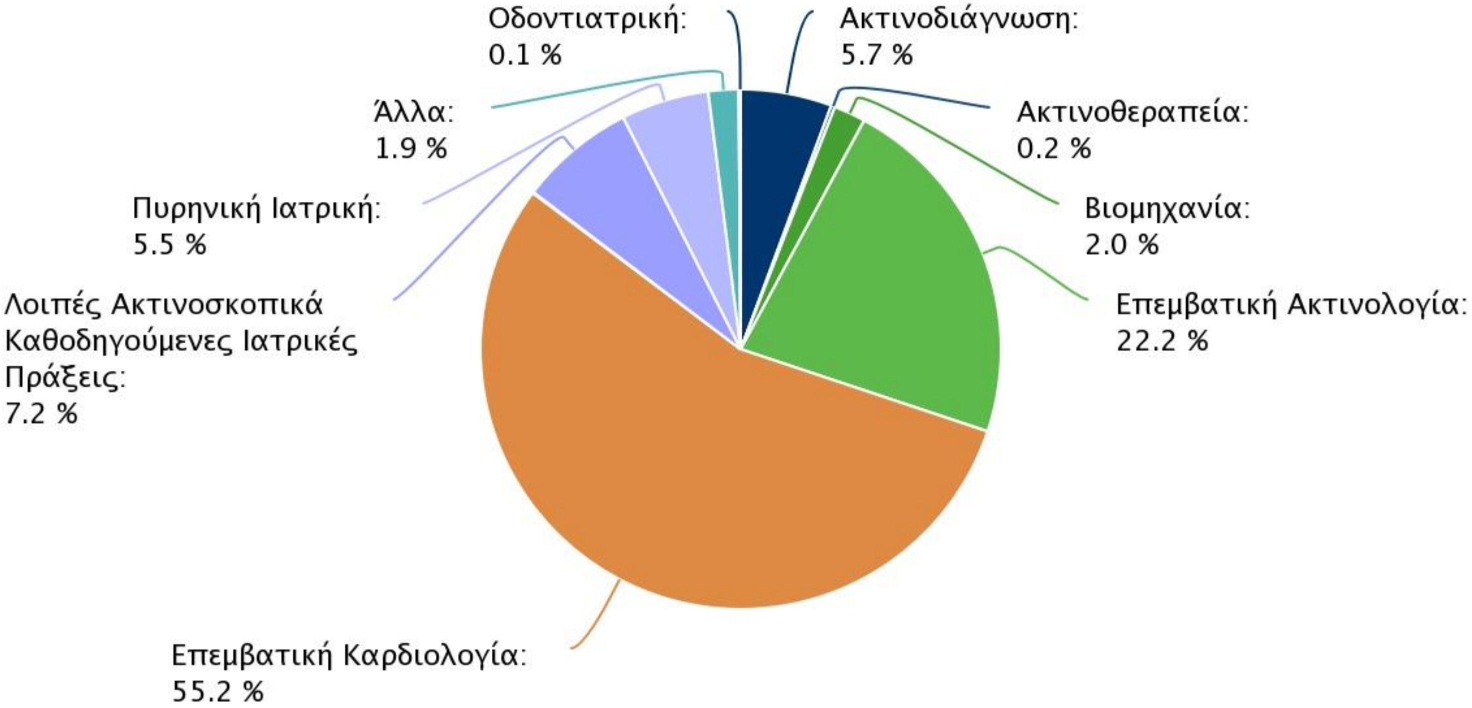
- Με την πάροδο του χρόνου, πολλές από τις ακτινοσκοπικά καθοδηγούμενες πράξεις έχουν τεκμηριωθεί και καθιερωθεί ως μέθοδος εκλογής, χάρη στη χαμηλότερη νοσηρότητα, τη μειωμένη θνητότητα και τη μικρότερη διάρκεια νοσηλείας σε σύγκριση με τις ανοικτές χειρουργικές τεχνικές.

- Πέραν των κλασικών ειδικοτήτων της Επεμβατικής Ακτινολογίας και Καρδιολογίας, ολοένα και περισσότεροι ιατροί — όπως ουρολόγοι, ορθοπαιδικοί και αγγειοχειρουργοί — πραγματοποιούν επεμβατικές πράξεις υπό ακτινοσκοπική καθοδήγηση, συχνά με περιορισμένη εκπαίδευση ή γνώση σε θέματα ακτινοπροστασίας.

Κατανομή της καταγραφόμενης μέσης ετήσιας δόσης

Ανά χώρο εργασίας

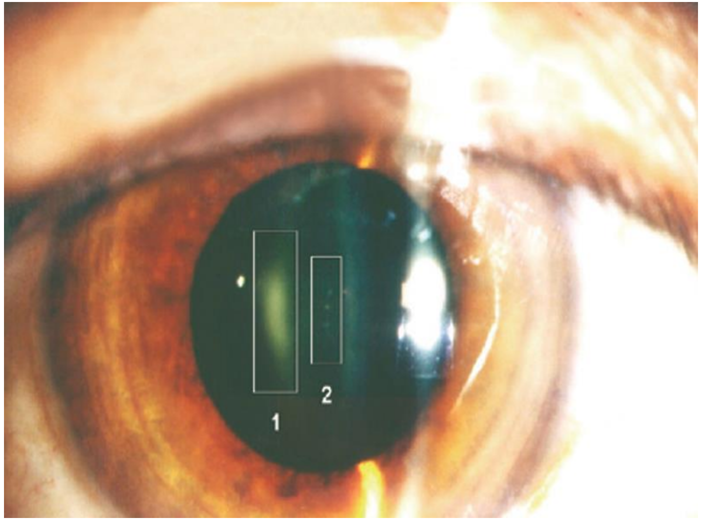
2021



https://eeae.gr/ασφάλεια-ακτινοβολιών/επαγγελματική-έκθεση/στατιστικά-στοιχεία

Εμφάνιση καθορισμένων αποτελεσμάτων

Εμφάνιση καθορισμένων αποτελεσμάτων



Radio-induced crystalline lens opacity in an interventional radiol`ogist submitted to high levels of radiation using an X-ray tube above the table. 1, indicates posterior subcapsular opacity; Region 2, perinuclear punctate opacities

Interventional cardiologists with pronounced typical hair loss. Chronic occupational dermatitis initially causes the skin to become dry, shiny and hairless, with atrophy of the epidermis.

Radiation-Induced DNA Damage in Operators Performing Endovascular Aortic Repair

Editorial, see p 2417

BACKGROUND: Radiation exposure during fluoroscopically guided interventions such as endovascular aortic repair (EVAR) is a growing concern for operators. This study aimed to measure DNA damage/repair markers in operators perfoming EVAR.

METHODS: Expression of the DNA damage/repair marker, γ-H2AX and DNA damage response marker, phosphorylated ataxia telangiectasia mutated (pATM), were quantified in circulating lymphocytes in operators during the peri-operative period of endovascular (infrarenal, branched, and fenestrated) and open aortic repair using flow cytometry. These markers were separately measured in the same operators but this time wearing leg lead shielding in addition to upper body protection and compared with those operating with unprotected legs. Susceptibility to radiation damage was determined by irradiating operators' blood in vitro.

RESULTS: γ-H2AX and pATM levels increased significantly in operators immediately after branched endovascular aortic repair/fenestrated endovascular aortic repair (P<0.0003 for both). Only pATM levels increased after infrarenal endovascular aortic repair (P<0.04). Expression of both markers fell to baseline in operators after 24 hours (P<0.003 for both). There was no change in γ-H2AX or pATM expression after open repair. Leg protection abrogated γ-H2AX and pATM response after branched endovascular aortic repair/fenestrated endovascular aortic repair. The expression of γ-H2AX varied significantly when operators' blood was exposed to the same radiation dose in vitro (P<0.0001).

CONCLUSIONS: This is the first study to detect an acute DNA damage response in operators performing fluoroscopically guided aortic procedures and highlights the protective effect of leg shielding. Defining the relationship between this response and cancer risk may better inform safe levels of chronic low-dose radiation exposure.

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Sources of Funding, see page 2415

Key Words: aortic aneurysm ■ DNA damage ■ endovascular ■ occupational exposure ■ radiation

Clinical Perspective

What Is New?

- This is the first study to detect acute radiation-induced DNA damage in operators who carried out endovascular aortic repair by demonstrating an increase in the expression of DNA damage/repair markers, γ-H2AX, and phosphorylated ataxia telangiectasia mutated in their circulating lymphocytes immediately after procedures.
- In vitro irradiation studies demonstrated that operators had a variable susceptibility to radiation-induced DNA damage.
- The use of leg lead shielding abrogated the DNA damage response in operators.

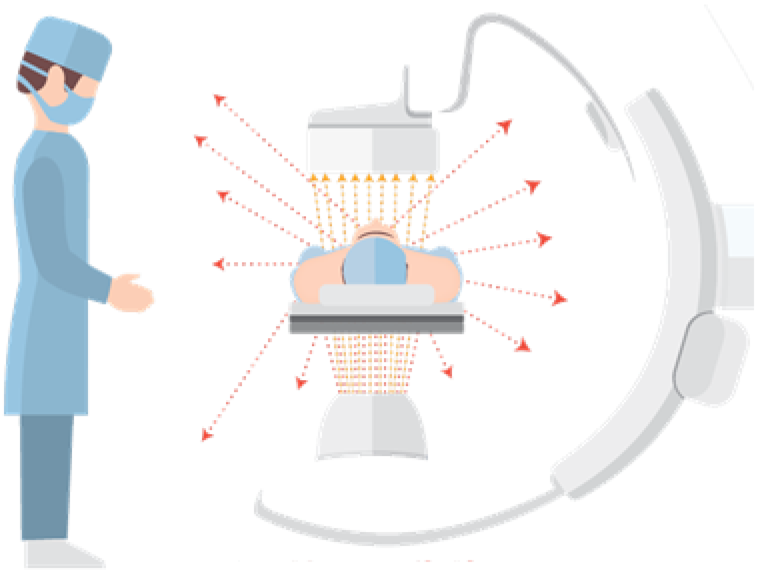
What Are the Clinical Implications?

- Conventional dosimetry fails to account for the biological consequences of radiation exposure to operators during fluoroscopically guided procedures.
- Safe radiation exposure limits have been set without considering any interindividual differences in susceptibility to deleterious effects.
- Wearing lower leg protective lead shielding is essential for reducing scatter radiation-induced DNA damage.
- The use of cellular markers, including γ-H2AX and phosphorylated ataxia telangiectasia mutated, which readily lend themselves to high-throughput sampling, may facilitate individual risk profiling, improve our understanding of the mechanisms involved in occupational radiation-induced mutagenesis, and define optimal protection strategies.

Πηγές ακτινικής επιβάρυνσης για το προσωπικό

- Κυριότερη πηγή ακτινικής επιβάρυνσης για το προσωπικό αποτελεί η σκεδαζόμενη ακτινοβολία από το σώμα του ασθενούς.

- ~1% της ακτινοβολίας φτάνει στον ανιχνευτή, ~10-20% σκεδάζεται, ~ 80% απορροφάται από το σώμα του ασθενούς (απορροφούμενη δόση).



Δόσεις ακτινοβολίας στους ασθενείς

Procedure		Values reported in the literature (mSv)
Interventional Radiology	Head and/or neck angiography	0.8 – 19.6
	Thoracic angiography of pulmonary artery or aorta	4.1 – 9.0
	Abdominal angiography or aortography	4– 48
	TIPS*	20 – 180
	Pelvic vein embolization	44 – 78
Interventional Cardiology	Coronary angiography (diagnostic)	2.0 – 15.8
	PTCA**, stent placement or radiofrequency ablation	6.9 – 57

*TIPS= Transjugular intrahepatic portosystemic shunt

**PTCA= Percutaneous transluminal coronary angioplasty

Mettler FA Jr, Huda W, Yoshizumi TT, et al. (2008) Effective doses in radiology and diagnostic nuclear medicine: a catalogue. Radiology 248(1): 254-63

Δόσεις ακτινοβολίας στο προσωπικό

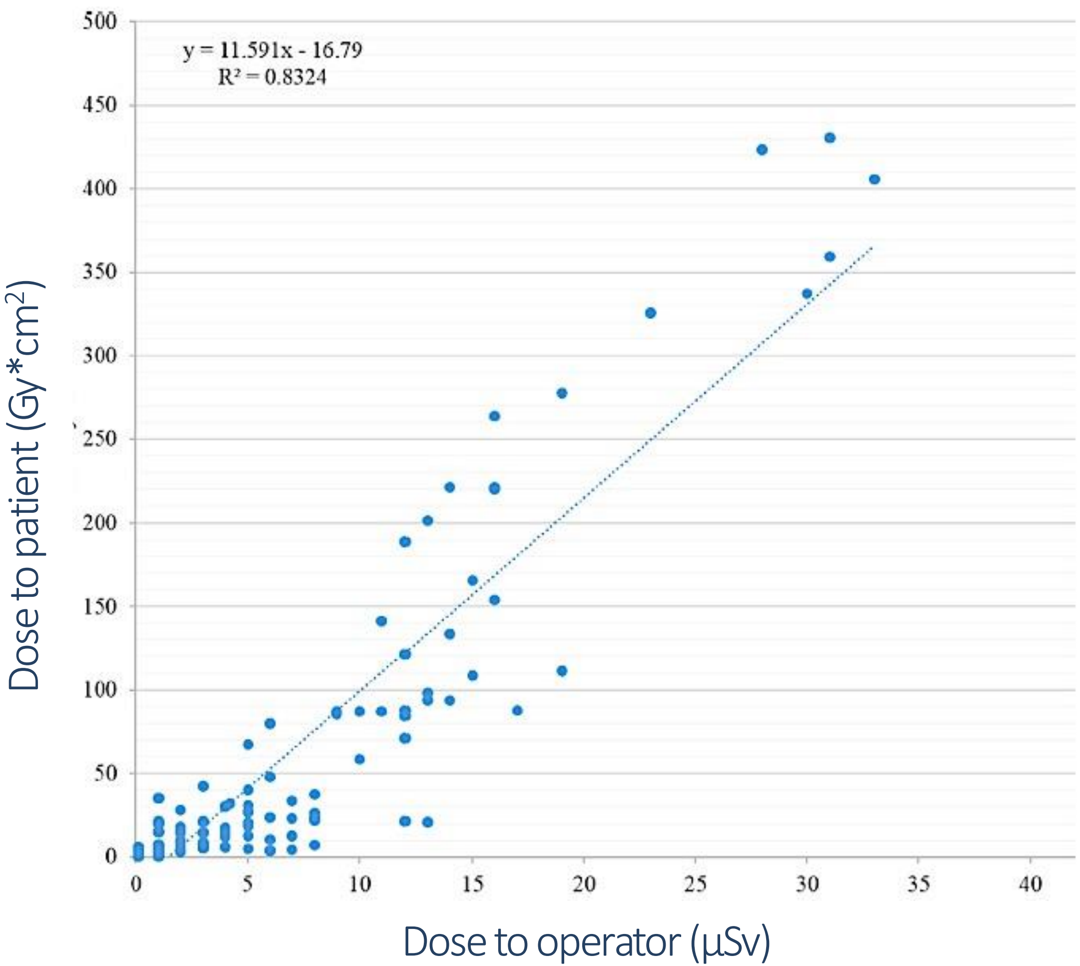
Procedure		Effective dose per procedure (µSv)
Interventional Radiology	PCNL*	1.5 – 56
	Vertebroplasty	0.1 – 100
	TIPS**	2.5 – 74
	Head & neck endovascular therapeutic procedures	1.8 – 53
	ERCP***	0.2 – 49
Interventional Cardiology	Diagnostic catheterization	0.02 – 38
	Percutaneous coronary interventions (PCI)	0.17 – 31.2

*PCNL= Percutaneous nephrolithotomy

**TIPS= Transjugular intrahepatic portosystemic shunt

***ERCP= Endoscopic retrograde cholangiopancreatography

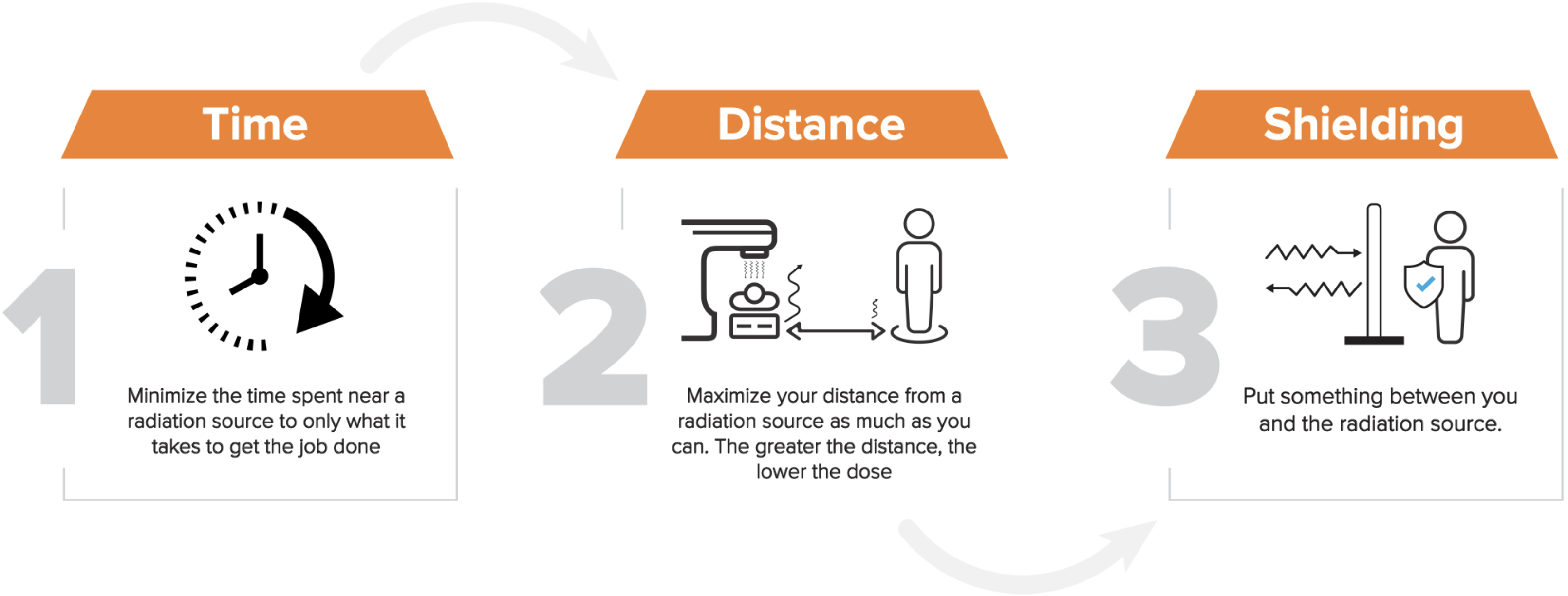
Kim KP, Miller DL, Balter S, et al. (2008) Occupational radiation doses to operators performing cardiac catheterization procedures. Health Phys 94: 211-227



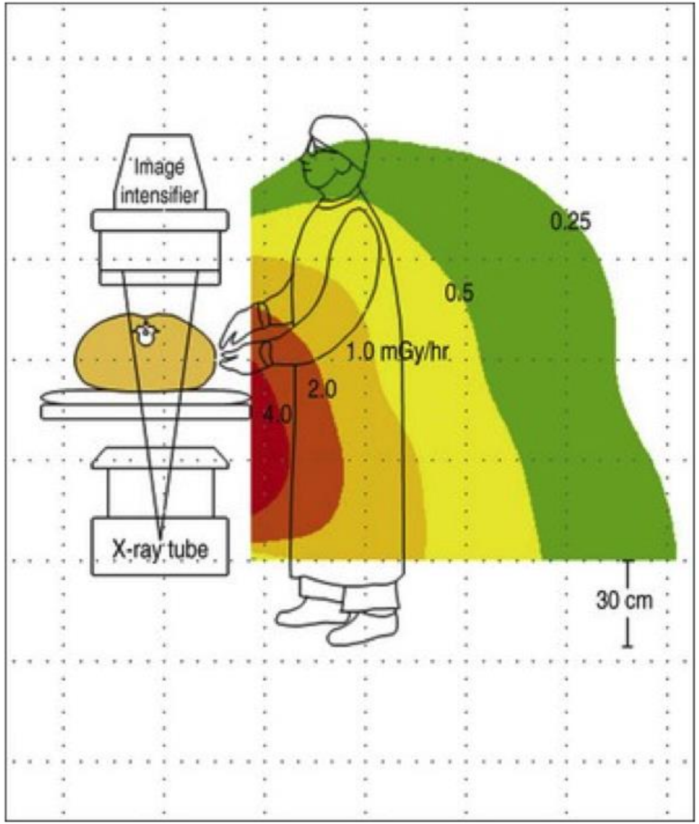
Heilmaier et al. 2016. Combined Use of a Patient Dose Monitoring System and a Real-Time Occupational Dose Monitoring System for Fluoroscopically Guided Interventions

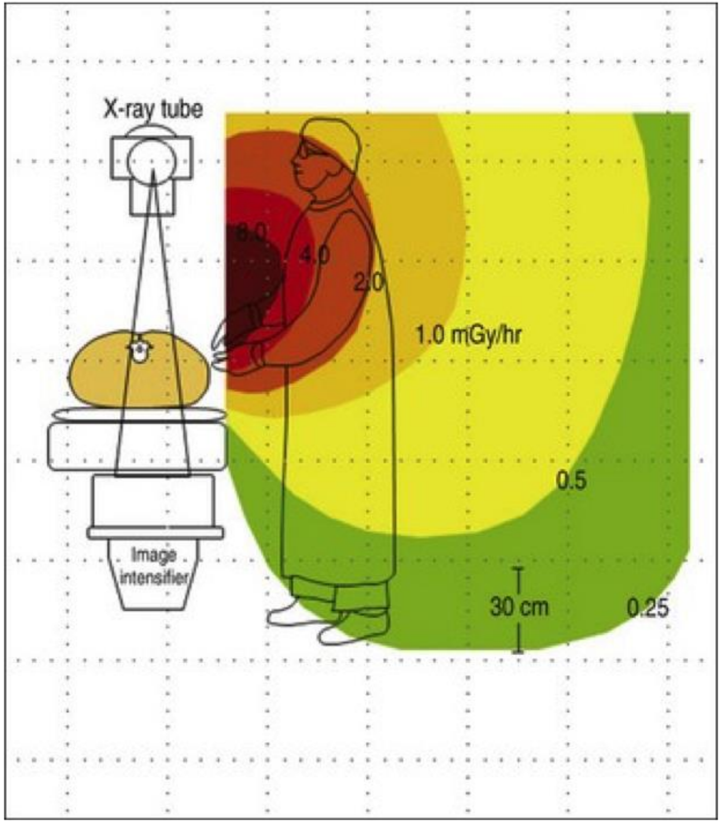
Πρακτικοί τρόποι ακτινοπροστασίας σε ακτινοσκοπικά καθοδηγούμενες επεμβατικές πράξεις

Καλή χρήση της αρχής «χρόνος-απόσταση-θωράκιση»

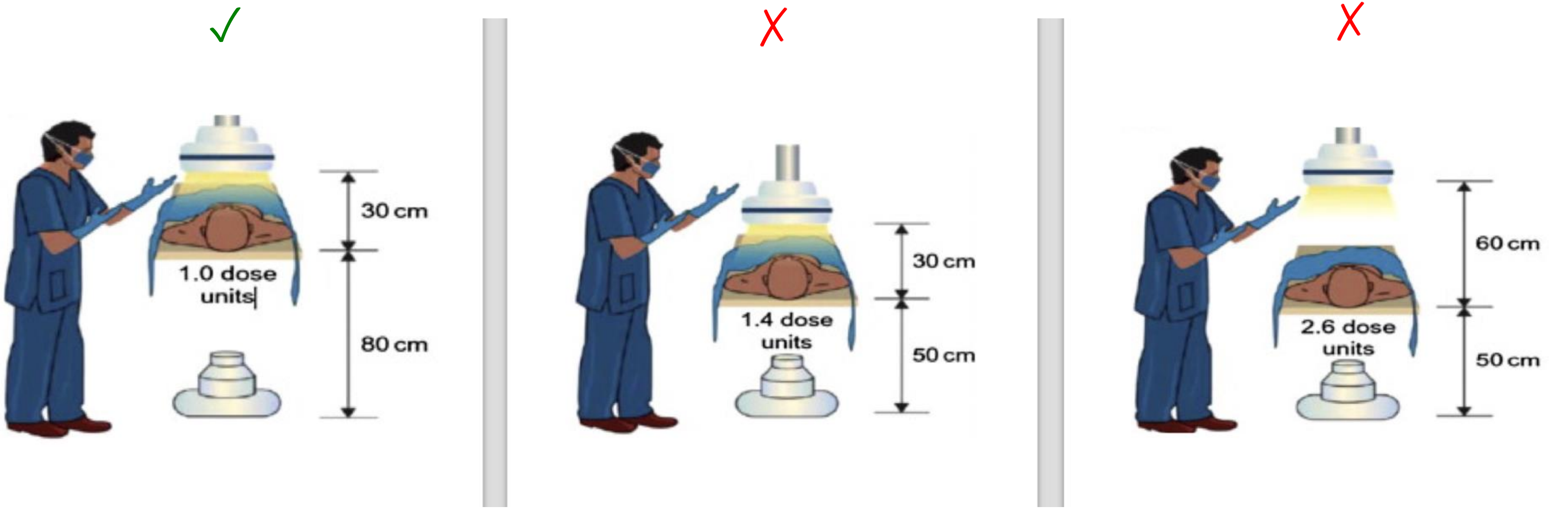


Κρατήστε τη λυχνία ακτίνων-χ κάτω από το τραπέζι

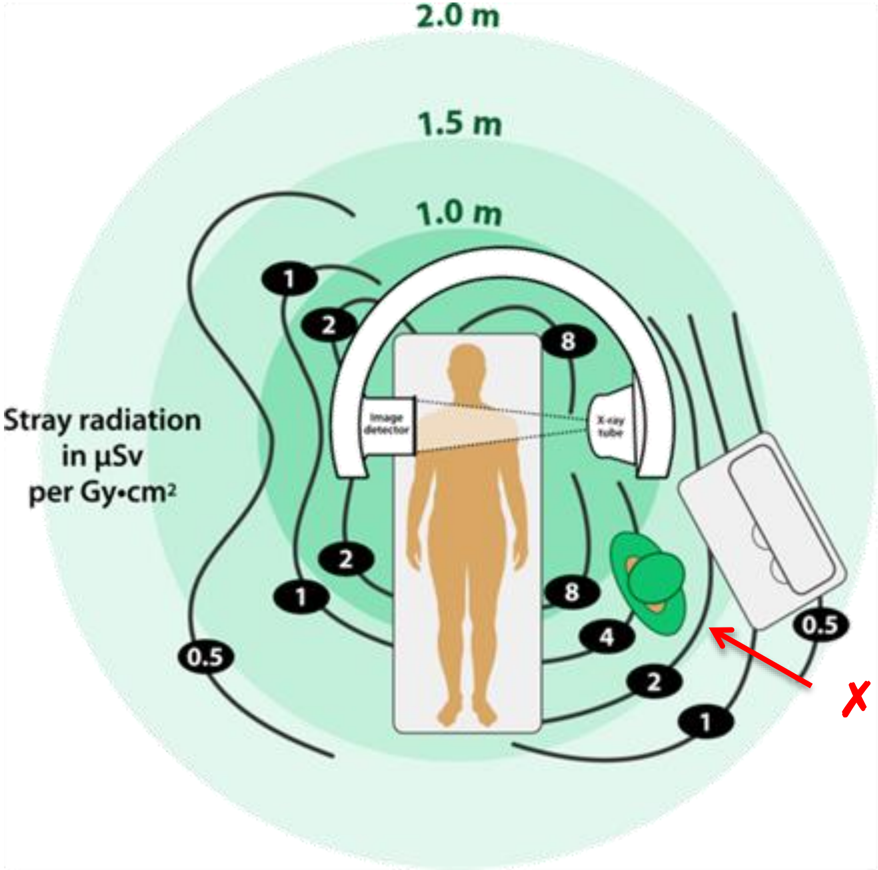




Τοποθετήστε τον ενισχυτή εικόνας κοντά στον ασθενή



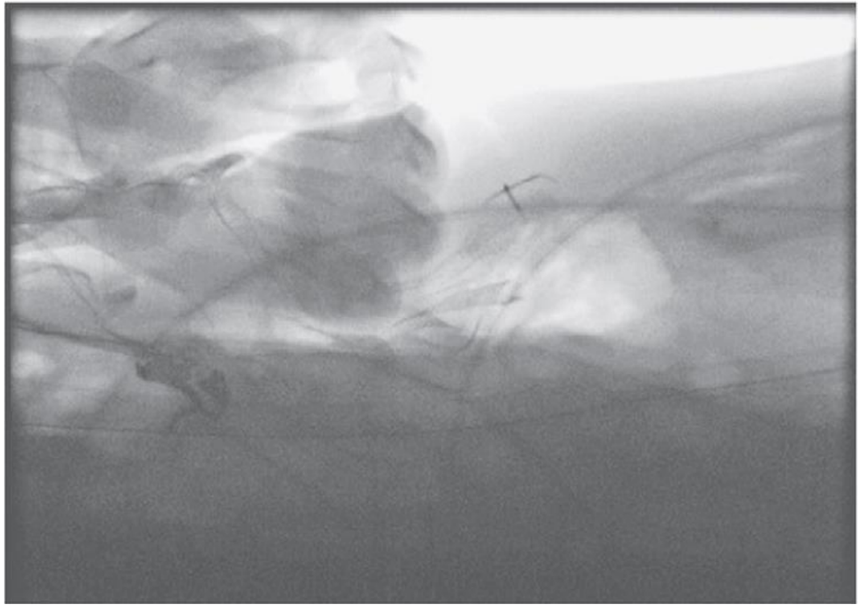
Τοποθετήστε τον εαυτό σας στη σωστή θέση!



✗ Λάθος θέση

Κρατήστε τα χέρια σας μακριά από την πρωτογενή δέσμη

Front view



Lateral view

Βελτιστοποιήστε την τεχνική σας κατά την ακτινοσκοπικά καθοδηγούμενη πράξη

- Χρήση πρωτοκόλλων χαμηλής δόσης ακτινοβολίας
- Ελαχιστοποίηση του αριθμού των ακτινοσκοπικών εικόνων
- Ελαχιστοποίηση του χρόνου ακτινοσκόπησης
- Αποφυγή ακτινοβόλησης της ίδιας περιοχής (μεταβολή του σημείου εισόδου)
- Αξιοποίηση συστημάτων πλοήγησης (navigation systems), όπου αυτά είναι διαθέσιμα
- Χρήση παλμικής ακτινοσκόπησης με τον ελάχιστο δυνατό ρυθμό:

  30 pulses/sec ⟹ 15 pulses/sec: 47% μείωση της δόσης

  30 pulses/sec ⟹ 7.5 pulses/sec: 72% μείωση της δόσης
- Μείωση της καταγραφής (cine/acquisition) και χρήση του ελάχιστου δυνατού αριθμού εικόνων ανά sec (frames/sec)

Br J Radiol. 1998 Jun;71(846):634-9.

Patient radiation doses during cardiac catheterization procedures.

Betsou S[1], Efstathopoulos EP, Katritsis D, Faulkner K, Panayiotakis G.

Fluoroscopy vs Cinefluorography

Time

Ka,r
(DAP)

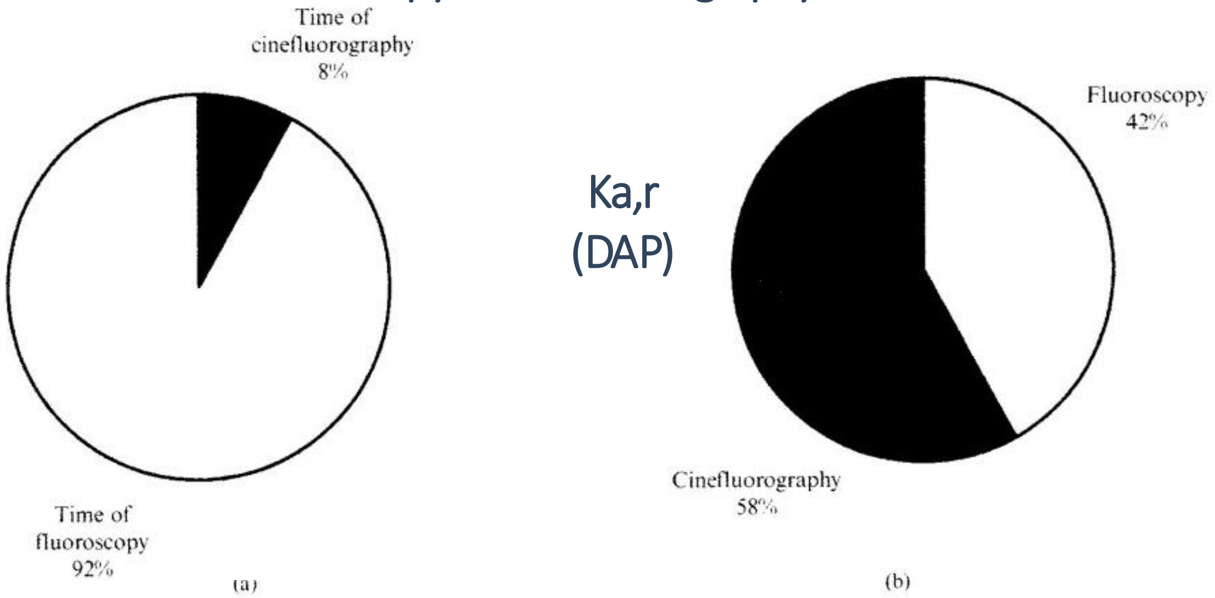
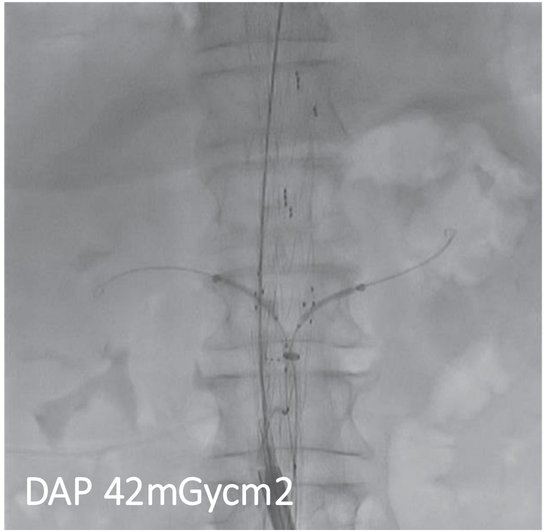


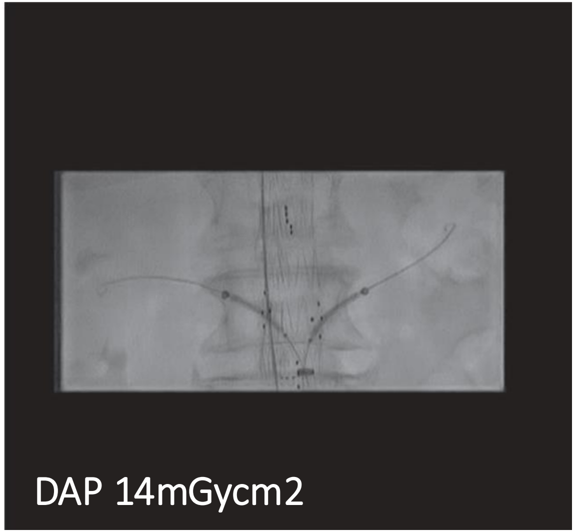
Figure 2. (a) Contribution of fluoroscopy and cinefluorography to dose–area product (DAP) and (b) percentage of fluoroscopy and cinefluorography time during the representative procedure performed on the phantom.

Βελτιστοποιήστε την τεχνική σας κατά την ακτινοσκοπικά καθοδηγούμενη πράξη

Χρήση κατευθυντήρα: περιορισμός της δέσμης ακτίνων-χ στην περιοχή ενδιαφέροντος

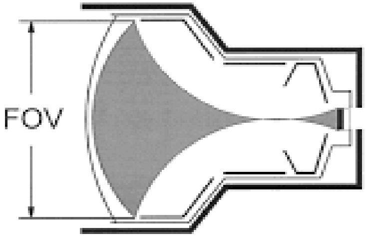
Μείωση μεγέθους πεδίου ακτινοβόλησης ⟹ Μείωση σκεδαζόμενων φωτονίων ⟹ Μείωση της δόσης ακτινοβολίας



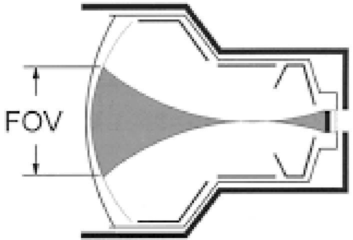


Βελτιστοποιήστε την τεχνική σας κατά την ακτινοσκοπικά καθοδηγούμενη πράξη

Αποφύγετε τη χρήση μεγέθυνσης



Normal Operation



Magnification Mode

Μικρό μέγεθος πεδίου (FOV)

μεγάλη μεγέθυνση

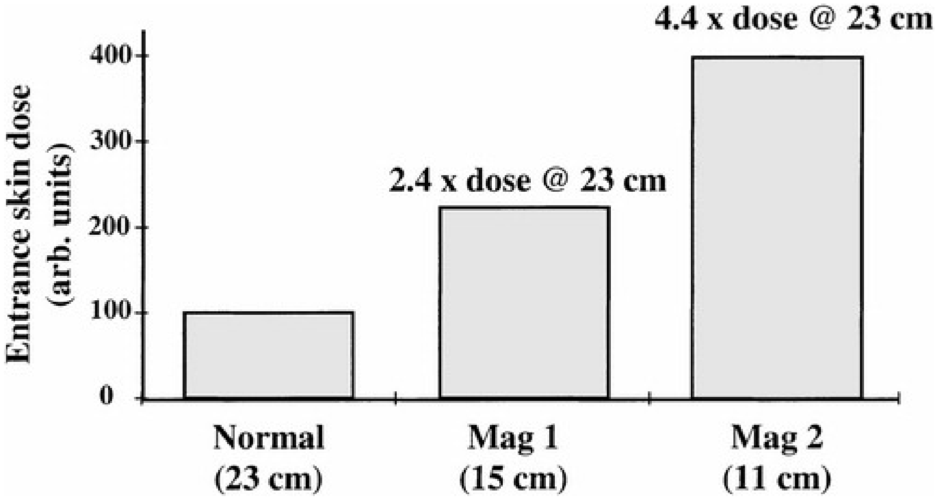
καλύτερη ΧΔΙ

υψηλότερη δόση ακτινοβολίας

Μέγεθος πεδίου – Μεγέθυνση

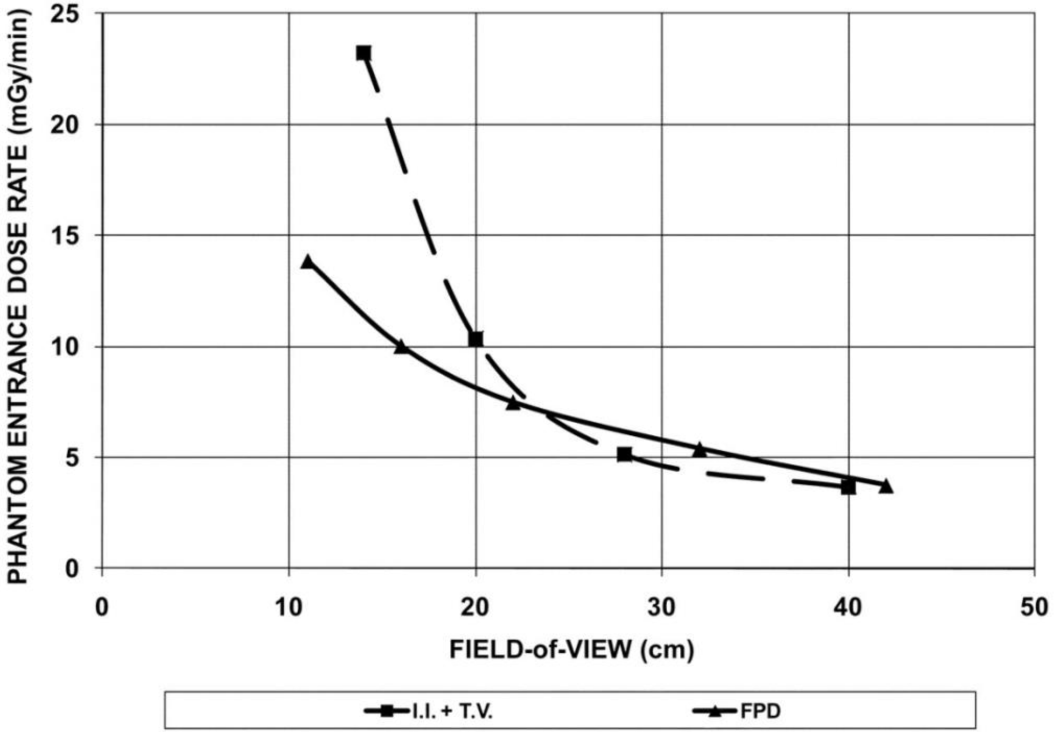
Dose increase =
[input screen diameter/
input screen diameter during magnification]^2

e.g. Dose increase = $[23/15]^2 = 2.4$



Mahese et al. 2001. Fluoroscopy:
Patient Radiation Exposure Issues. Radiographics 21(4)

Μέγεθος πεδίου – Μεγέθυνση



Χρήση του ακτινοπροστατευτικού εξοπλισμού

A Thyroid protection collar

B Outside personal dosimeter (in the pocket)

C Protective eyeglasses

D Radiation panoramic full-face mask for face shielding

E Protective one-piece apron

F Additional protection for the gonads

Protective apron with additional 0.5 mm Pb

Pregnant radiation worker


Take Proper Care of Your Apron

Χρήση του ακτινοπροστατευτικού εξοπλισμού

Lead equivalent thickness (mm)	Weight (kg)	kVp		
		50	75	100
0.25	1-5	97%	66%	51%
0.50	3-7	99.9%	88%	75%
1.00	5-12	99.9%	99%	94%

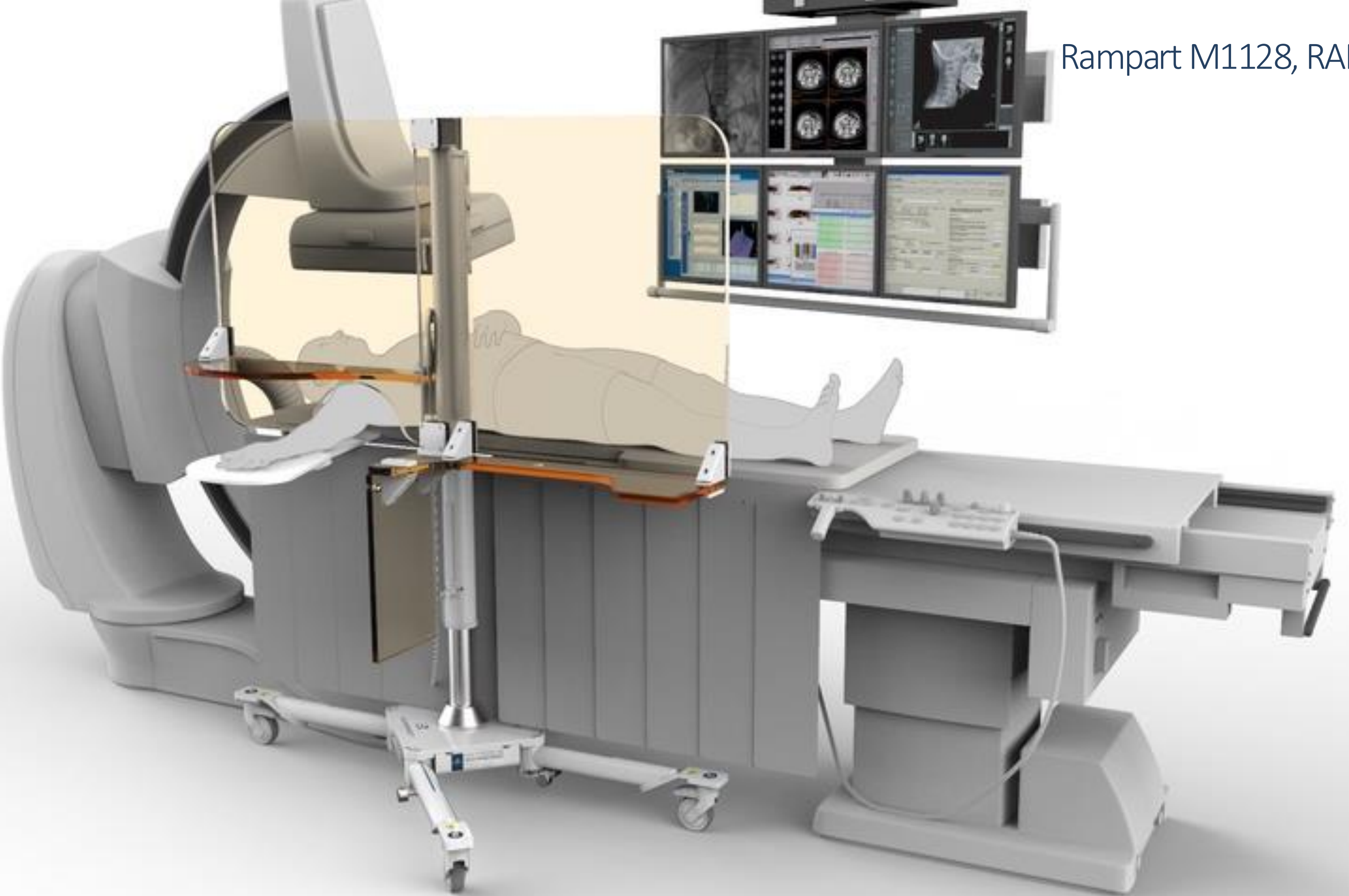
Zero-Gravity, BIOTRONIK

CorPath GRX (Corindus Vascular Robotics,
now part of Siemens Healthineers)

Χρήση του ακτινοπροστατευτικού εξοπλισμού

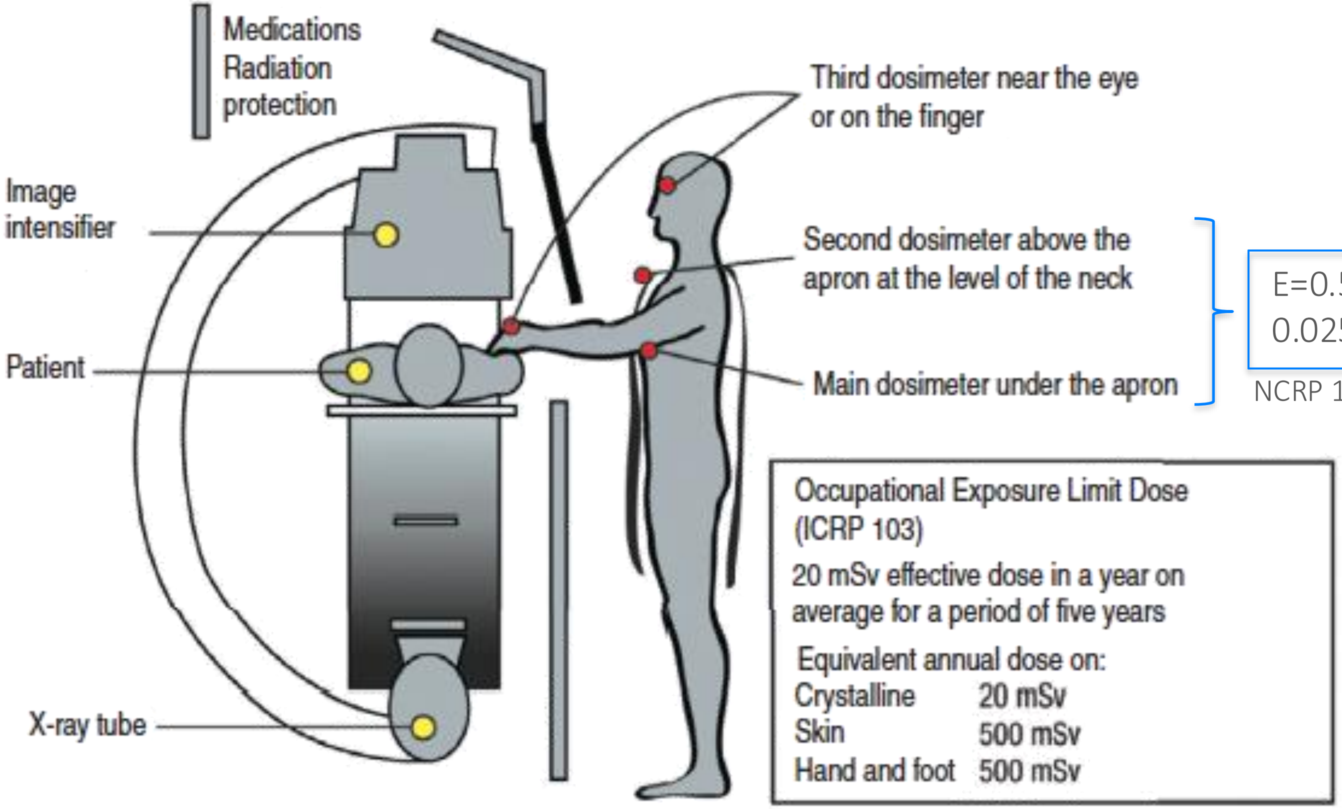
Eggnest, Egg Medical

Rampart M1128, RAMPARTIC




RADPAD®
PAD® Protection

Χρήση του ατομικού σας δοσιμέτρου και γνώση της δόσης σας!



E=0.5*dosimeter inside + 0.025*dosimeter outside

NCRP 122

Χρήση του ατομικού σας δοσιμέτρου και γνώση της δόσης σας!

Δοσίμετρα θερμοφωταύγειας (Thermoluminescent Dosimeters– TLD)

Δοσίμετρο σώματος

Δοσίμετρο καρπού

Δοσίμετρο δαχτύλου

Δοσίμετρο ματιού

Χρήση του ατομικού σας δοσιμέτρου και γνώση της δόσης σας!

Δοσίμετρα άμεσης ανάγνωσης (Real time or active dosimeters)

Παρακολούθηση της δόσης του ασθενούς

- Θέσπιση επίπεδων «ενεργοποίησης» **(trigger levels)** για την πρόληψη ακτινικών δερματικών βλαβών, αλλά και την έγκαιρη αναγνώριση και αντιμετώπισή τους.

- Προτεινόμενα trigger levels σε επεμβατικές πράξεις (ICRP 120):

  – Peak Skin Dose (PSD) > 3 Gy
  – Air Kerma at the patient entrance reference point> 5 Gy
  – Kerma-area product > 500 Gy·cm^2

- Ενέργειες όταν υπερβεί ένα trigger level:

  – Άμεση καταγραφή της δόσης
  – Ενημέρωση του προσωπικού
  – Οργάνωση προγράμματος κλινικής παρακολούθησης του ασθενούς για 2–4 εβδομάδες
  – Εκτίμηση δέρματος για ενδεχόμενες πρώιμες ή όψιμες δερματικές αντιδράσεις

Συνεχής εκπαίδευση σε θέματα ακτινοπροστασίας

Το ιατρικό προσωπικό πρέπει να έχει επαρκή εκπαίδευση και κατάρτιση ώστε να:

- Διατηρεί τη δόση σε όσο το δυνατόν χαμηλότερα επίπεδα (ALARA principle)
- Είναι εξοικειωμένο με τα συστήματα ακτινοσκόπησης που χρησιμοποιεί
- Χρησιμοποιεί σωστά τον ακτινοπροστατευτικό εξοπλισμό που διαθέτει το Εργαστήριο
- Γνωρίζει τα μέτρα ακτινοπροστασίας για παιδιά και εγκύους

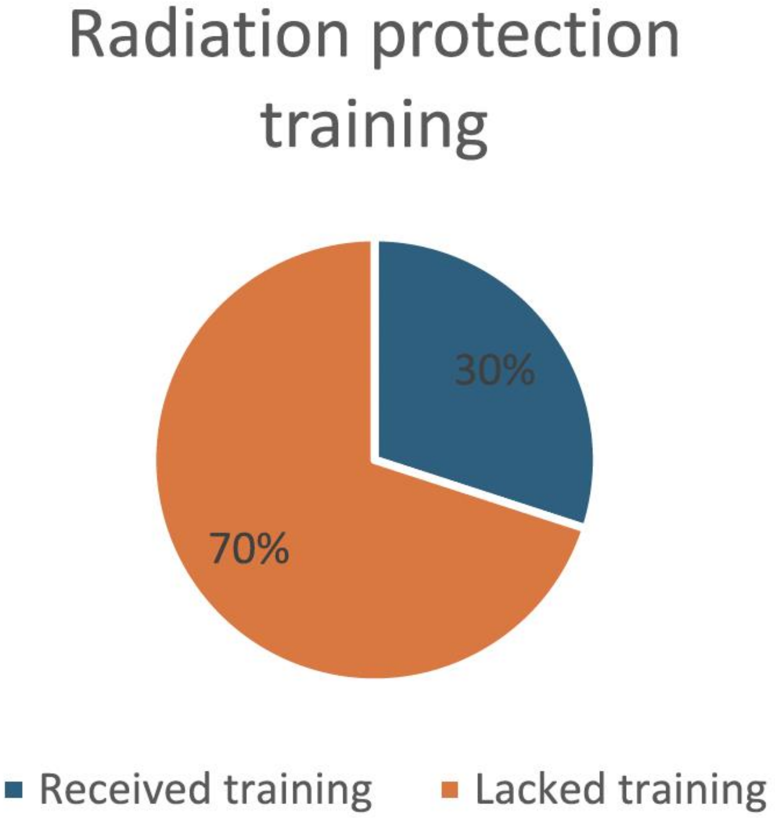
Gasiea et al. CVIR Endovascular (2025) 8:32
https://doi.org/10.1186/s42155-025-00540-3

CVIR Endovascular

ORIGINAL ARTICLE Open Access

Radiation protection: safety measures and knowledge among interventional radiologists- a UK-based analysis of current practices and recommendations for improvement

Rayhan Y. Gasiea[1], Andy Rogers[2], Raghuram Lakshminarayan[3], Mo Hamady[4*] and Bella Huasen[5]



EUROPEAN COMMISSION

RADIATION PROTECTION NO 175

GUIDELINES ON RADIATION PROTECTION EDUCATION AND TRAINING OF MEDICAL PROFESSIONALS IN THE EUROPEAN UNION

Directorate-General for Energy
Directorate D — Nuclear Safety & Fuel Cycle
Unit D.3 — Radiation Protection
2014


NORTHDOCKS

Προγράμματα ελέγχου ποιότητας

Διασφαλίζουν:

- Υψηλή ποιότητα εικόνας με τη λιγότερη δυνατή έκθεση ασθενών και προσωπικού σε ακτινοβολία (βελτιστοποίηση).
- Ορθή και αξιόπιστη λειτουργία του εξοπλισμού, με έγκαιρη αναγνώριση και διόρθωση αποκλίσεων ή βλαβών.
- Την ασφάλεια του ασθενούς και του προσωπικού, ελαχιστοποιώντας κινδύνους από κακή λειτουργία ή αυξημένα επίπεδα ακτινοβολίας.

Fully Automatic and Real-Time Catheter Segmentation in X-Ray Fluoroscopy

Pierre Ambrosini[1,3(✉)], Daniel Ruijters[2], Wiro J. Niessen[1,3,4], Adriaan Moelker[3], and Theo van Walsum[1,3]

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Abstract. Augmenting X-ray imaging with 3D roadmap to improve guidance is a common strategy. Such approaches benefit from automated analysis of the X-ray images, such as the automatic detection and tracking of instruments. In this paper, we propose a real-time method to segment the catheter and guidewire in 2D X-ray fluoroscopic sequences. The method is based on deep convolutional neural networks. The network takes as input the current image and the three previous ones, and segments the catheter and guidewire in the current image. Subsequently, a centerline model of the catheter is constructed from the segmented image. A small set of annotated data combined with data augmentation is used to train the network. We trained the method on images from 182 X-ray sequences from 23 different interventions. On a testing set with images of 55 X-ray sequences from 5 other interventions, a median centerline distance error of 0.2 mm and a median tip distance error of 0.9 mm was obtained. The segmentation of the instruments in 2D X-ray sequences is performed in a real-time fully-automatic manner.

Keywords: Catheter · Guidewire · Tracking · X-ray · Fluoroscopy · Deep learning · Convolutional neural network · Segmentation

ARTICLE

Use of Artificial Intelligence to Reduce Radiation Exposure at Fluoroscopy-Guided Endoscopic Procedures

Ji Young Bang, MD, MPH[1], Matthew Hough, MS[2], Robert H. Hawes, MD[1] and Shyam Varadarajulu, MD[1]

OBJECTIVES: **Exposure to ionizing radiation remains a hazard for patients and healthcare providers. We evaluated the utility of an artificial intelligence (AI)-enabled fluoroscopy system to minimize radiation exposure during image-guided endoscopic procedures.**

METHODS: **We conducted a prospective study of 100 consecutive patients who underwent fluoroscopy-guided endoscopic procedures. Patients underwent interventions using either conventional or AI-equipped fluoroscopy system that uses ultrafast collimation to limit radiation exposure to the region of interest. The main outcome measure was to compare radiation exposure with patients, which was measured by dose area product. Secondary outcome was radiation scatter to endoscopy personnel measured using dosimeter.**

RESULTS: **Of 100 patients who underwent procedures using traditional ($n = 50$) or AI-enabled ($n = 50$) fluoroscopy systems, there was no significant difference in demographics, body mass index, procedural type, and procedural or fluoroscopy time between the conventional and the AI-enabled fluoroscopy systems. Radiation exposure to patients was lower (median dose area product 2,178 vs 5,708 mGym^2, $P = 0.001$) and scatter effect to endoscopy personnel was less (total deep dose equivalent 0.28 vs 0.69 mSv; difference of 59.4%) for AI-enabled fluoroscopy as compared to conventional system. On multivariate linear regression analysis, after adjusting for patient characteristics, procedural/fluoroscopy duration, and type of fluoroscopy system, only AI-equipped fluoroscopy system (coefficient 3,331.9 [95% confidence interval: 1,926.8–4,737.1, $P < 0.001$) and fluoroscopy duration (coefficient 813.2 [95% confidence interval: 640.5–985.9], $P < 0.001$) were associated with radiation exposure.**

DISCUSSION: **The AI-enabled fluoroscopy system significantly reduces radiation exposure to patients and scatter effect to endoscopy personnel (see Graphical abstract, Supplementary Digital Content, http://links.lww.com/AJG/B461).**

SUPPLEMENTARY MATERIAL accompanies this paper at http://links.lww.com/AJG/B440, http://links.lww.com/AJG/B441, http://links.lww.com/AJG/B461

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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

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Preamble

The members of the Cardiovascular and Interventional Society of Europe (CIRSE) Standards of Practice committee and the Society of Interventional Radiology (SIR) Safety and Health Committee represent experts in a broad spectrum of interventional procedures from both the private and the academic sectors of medicine. Generally, these committee members dedicate the vast majority of their professional time to performing interventional procedures; as such, they represent a valid broad expert constituency of the subject matter under consideration.

Technical documents specifying the exact consensus and literature review methodologies as well as the institutional affiliations and professional credentials of the authors of this document are available upon request from SIR, 3975 Fair Ridge Drive, Suite 400 North, Fairfax, VA 22033, USA.

Methodology

CIRSE and SIR produce their safety-related documents using the following process. The CIRSE Standards of Practice and SIR Safety and Health Committee members conceptualize documents of relevance and timeliness. A recognized expert is identified to serve as the principal author for the document. Additional authors may be assigned, dependent on the magnitude of the project.

An in-depth literature search is performed using electronic medical literature databases. As appropriate, a critical review of peer-reviewed articles and regulatory documents is performed with regard to the study methodology, results, and conclusions. The qualitative weight of these articles is evaluated and used to write the document such that it contains evidence-based data, when available. Agreement was reached on all statements in this document without the need for utilizing modified Delphi consensus techniques.

Clinical Practice Guidelines

Eur J Vasc Endovasc Surg (2023) 65, 171–222

EJVES Open Access

CLINICAL PRACTICE GUIDELINE DOCUMENT

Editor's Choice – European Society for Vascular Surgery (ESVS) 2023 Clinical Practice Guidelines on Radiation Safety☆

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ESVS Guidelines Committee [b], Frederico Bastos Gonçalves, Martin Björck, Nabil Chakfé, Gert J. de Borst, Raphaël Coscas, Nuno V. Dias, Florian Dick, Robert J. Hinchliffe, Stavros K. Kakkos, Igor B. Koncar, Philippe Kolh, Jes S. Lindholt, Santi Trimarchi, Riikka Tulamo, Christopher P. Twine, Frank Vermassen

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Σας ευχαριστώ για την προσοχή σας!