Strategies for optimal occupational radiation protection during vascular intervention

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NHS Foundation Trust

KING'S HEALTH PARTNERS

Disclosures

Cook Medical: Proctoring, Speaker’s fees, Grant support

Open Access Protocol

BMJ Open

Occupational radiation exposure and its health effects on interventional medical workers: study protocol for a prospective cohort study

REUTERS

HEALTH

Long-Term Low-Dose Radiation Exposure May Increase Leukemia Risk

Leukemia was already known to be caused by exposure to high doses of radiation, like that released by the atomic bombs dropped on Japan in 1945

8 Radioactive Jobs and Their Cancer Risks

By Chris Iliades, MD

Reviewed by Pat F. Bass III, MD, MPH

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4 Cance

What Healthcare Workers Need to Know About Radiation Effects

By Ashley Brooks on 3/8/2016

0

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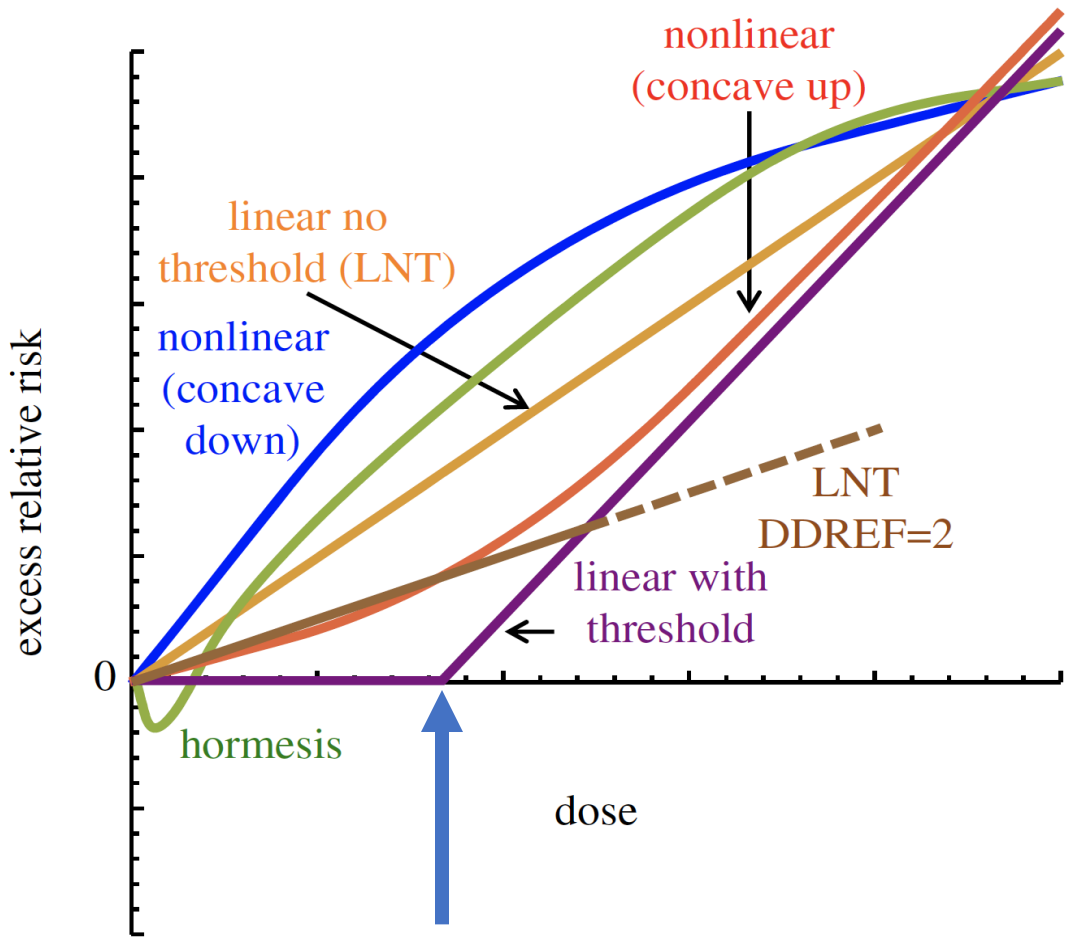
You've done the research, weighed your options and you're sure the healthcare field has everything you're looking for in a profession. Working in this field has all the perks of a stable and in-demand career, plus the added benefit of knowing you're making a difference every day you head to work.

APR 15, 2016 01:41 PM PDT

Occupational Hazard: Radiation Exposure Puts Medical Staff at Risk

Low Dose Risk Theories



100mSV

McLean AR et al. Proc. R. Soc. 2017

Gudmundsdottir et al. Environmental Health (2017) 16:86
DOI 10.1186/s12940-017-0295-4

Environmental Health

RESEARCH Open Access

Incidence of cancer among licenced commercial pilots flying North Atlantic routes

Eva Maria Gudmundsdottir[1*], Jon Hrafnkelsson[2] and Vilhjalmur Rafnsson[3]

Abstract

Background: To evaluate cancer incidence among licenced commercial pilots in association with cosmic radiation.

Methods: Cohort study where ionizing radiation dose of cosmic radiation was estimated from airline data and software program and cancer incidence was obtained by record linkage with nation-wide cancer registry. All licenced commercial male airline pilots were followed from 1955 to 2015, ever or never employed at airline with international routes. Standardized incidence ratios were calculated and relative risk by Poisson regression, to examine exposure-response relation.

Results: Eighty three cancers were registered compared with 92 expected; standardized incidence ratios were 0.90 (95% CI 0.71 to 1.11) for all cancers, 3.31 (95% CI 1.33 to 6.81) for malignant melanoma, and 2.49 (95% CI 1.69 to 3.54), for basal cell carcinoma of skin. The risk for all cancers, malignant melanoma, prostate cancer, basal cell carcinoma of skin, and basal cell carcinoma of trunk increased with an increase in number of employment years, cumulative air hours, total cumulative radiation dose, and cumulative radiation dose sustained up to age of 40 years. The relative risk for the highest exposure categories of cumulative radiation dose were 2.42 (95% CI 1.50 to 3.92) for all cancers, 2.57 (95% CI 1.18 to 5.56) for prostate cancer, 9.88 (95% CI 1.57 to 190.78) for malignant melanoma, 3.61 (95% CI 1.64 to 8. 48) for all basal cell carcinoma, and 6.65 (95% CI 1.61 to 44.64) for basal cell carcinoma of trunk.

Conclusions: This study was underpowered to study brain cancer and leukaemia risk. Basal cell carcinoma of skin is radiation-related cancer, and may be attributed to cosmic radiation. Further studies are needed to clarify the risk of cancers in association with cosmic radiation, other workplace exposure, host factors, and leisure sun-exposure, as clothes, and glass in cockpit windows shield pilots from the most potent ultraviolet-radiation.

Keywords: Basal cell carcinoma of skin, Malignant melanoma, Prostate cancer, Cosmic radiation, Aircrew, Cancer registry

Background

Previous cancer incidence studies on airline pilots have reported increased incidence of specific cancers, predominantly skin cancer [1, 2], prostate cancer [1, 3], and brain cancer [3]. In some studies there are indications of increased risk of the radiation-related cancer, acute myeloid leukaemia [3, 4]; however, that result has not been confirmed in a larger study [1]. In studying the occupational exposure of pilots, attention has been drawn to ionizing radiation of cosmic origin [5]. Cosmic radiation at the cruising altitude of commercial jet flights is a mixture of primary and secondary radiation, mainly gamma rays and neutrons and other particles, including heavy nuclei [6], where the neutrons constitute 30 to 60% of the radiation.

Studies on flight attendants have also reported increased incidence of cancers, both skin and breast cancer [7–9].

As early as 1999, the International Agency for Research on Cancer (IARC) concluded that there was sufficient evidence that neutrons are carcinogenic to humans [10]; however, the conclusion was based on results from animal studies only, as adequate studies on

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Full list of author information is available at the end of the article

Factors dictating incidence of cancer:

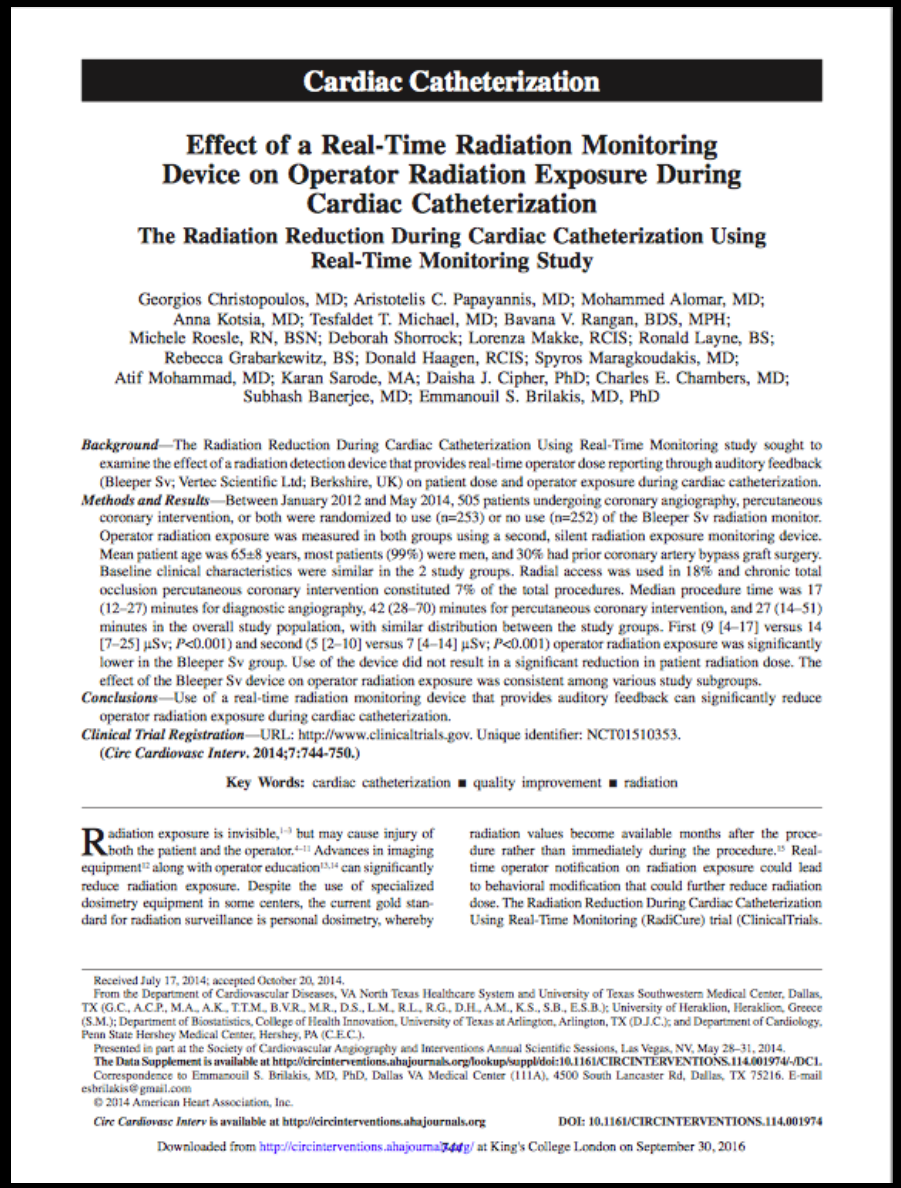
- Years employment
- Cumulative air hours
- Total radiation dose
- Cumulative radiation dose up to 40 yrs age

	Relative risk
All cancers	2.4 [1.5-3.92]
Prostate	9.88 [1.57-190.78]
Melanoma	3.61 [1.64 to 8. 48]
Basal Cell	6.65 [1.61 to 44.64]

Gudmundsdottir et al. Environmental Health 2017

Real time dose feedback

Real time dose feedback



Cardiac Catheterization

Effect of a Real-Time Radiation Monitoring Device on Operator Radiation Exposure During Cardiac Catheterization

The Radiation Reduction During Cardiac Catheterization Using Real-Time Monitoring Study

Georgios Christopoulos, MD; Aristotelis C. Papayannis, MD; Mohammed Alomar, MD; Anna Kotsia, MD; Tesfaldet T. Michael, MD; Bavana V. Rangan, BDS, MPH; Michele Roesle, RN, BSN; Deborah Shorrock; Lorenza Makke, RCIS; Ronald Layne, BS; Rebecca Grabarkewitz, BS; Donald Haagen, RCIS; Spyros Maragkoudakis, MD; Atif Mohammad, MD; Karan Sarode, MA; Daisha J. Cipher, PhD; Charles E. Chambers, MD; Subhash Banerjee, MD; Emmanouil S. Brilakis, MD, PhD

Background—The Radiation Reduction During Cardiac Catheterization Using Real-Time Monitoring study sought to examine the effect of a radiation detection device that provides real-time operator dose reporting through auditory feedback (Bleeper Sv; Vertec Scientific Ltd; Berkshire, UK) on patient dose and operator exposure during cardiac catheterization.

Methods and Results—Between January 2012 and May 2014, 505 patients undergoing coronary angiography, percutaneous coronary intervention, or both were randomized to use (n=253) or no use (n=252) of the Bleeper Sv radiation monitor. Operator radiation exposure was measured in both groups using a second, silent radiation exposure monitoring device. Mean patient age was 65±8 years, most patients (99%) were men, and 30% had prior coronary artery bypass graft surgery. Baseline clinical characteristics were similar in the 2 study groups. Radial access was used in 18% and chronic total occlusion percutaneous coronary intervention constituted 7% of the total procedures. Median procedure time was 17 (12–27) minutes for diagnostic angiography, 42 (28–70) minutes for percutaneous coronary intervention, and 27 (14–51) minutes in the overall study population, with similar distribution between the study groups. First (9 [4–17] versus 14 [7–25] µSv; $P<0.001$) and second (5 [2–10] versus 7 [4–14] µSv; $P<0.001$) operator radiation exposure was significantly lower in the Bleeper Sv group. Use of the device did not result in a significant reduction in patient radiation dose. The effect of the Bleeper Sv device on operator radiation exposure was consistent among various study subgroups.

Conclusions—Use of a real-time radiation monitoring device that provides auditory feedback can significantly reduce operator radiation exposure during cardiac catheterization.

Clinical Trial Registration—URL: http://www.clinicaltrials.gov. Unique identifier: NCT01510353.

(***Circ Cardiovasc Interv*. 2014;7:744-750.**)

Key Words: cardiac catheterization ■ quality improvement ■ radiation

Radiation exposure is invisible,[1–3] but may cause injury of both the patient and the operator.[4–11] Advances in imaging equipment[12] along with operator education[13,14] can significantly reduce radiation exposure. Despite the use of specialized dosimetry equipment in some centers, the current gold standard for radiation surveillance is personal dosimetry, whereby radiation values become available months after the procedure rather than immediately during the procedure.[15] Real-time operator notification on radiation exposure could lead to behavioral modification that could further reduce radiation dose. The Radiation Reduction During Cardiac Catheterization Using Real-Time Monitoring (RadiCure) trial (ClinicalTrials.

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Presented in part at the Society of Cardiovascular Angiography and Interventions Annual Scientific Sessions, Las Vegas, NV, May 28–31, 2014.

The Data Supplement is available at http://circinterventions.ahajournals.org/lookup/suppl/doi:10.1161/CIRCINTERVENTIONS.114.001974/-/DC1.

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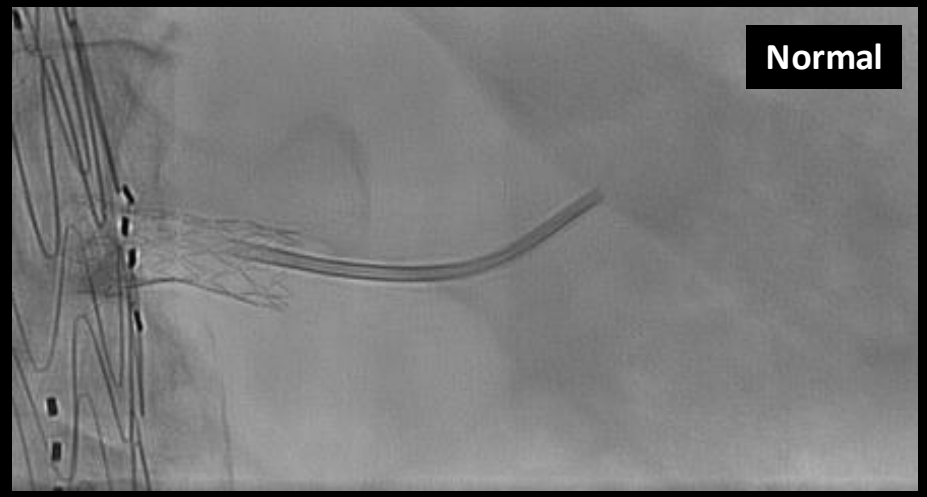
***Circ Cardiovasc Interv* is available at http://circinterventions.ahajournals.org** **DOI: 10.1161/CIRCINTERVENTIONS.114.001974**

Exposures during standard and complex aortic repair

	Median (IQR) (n=24)	Standard EVAR/TEVAR (IQR) (n=13)	Complex Cases Branched/Fenestrated (IQR) (n=11)	p
Total Operating Time (mins)	178 (10-164)	117 (105-147)	232 (217-282)	0.0001
Total Fluoroscopy Time (mins)	40 (22-68)	22 (21-36)	71 (205-293)	0.0001
Total DAP ($mGy.m^2$)	135,369 (74440-201708)	98236 (38106-168855)	194839 (104525-239903)	NS
Primary Operator Dose (µSv)	57 (10.3-124.9)	41.4 (22.3-85.3)	69.9 (48.9-111)	NS

Lowest dose that allows adequate image quality

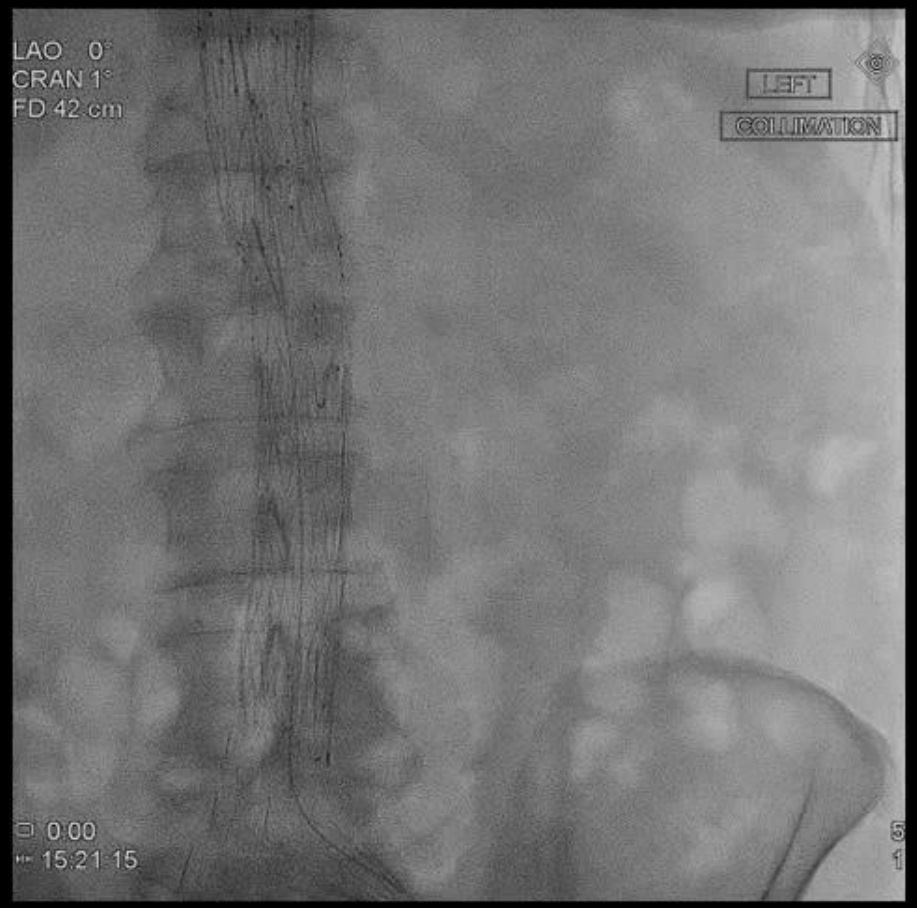


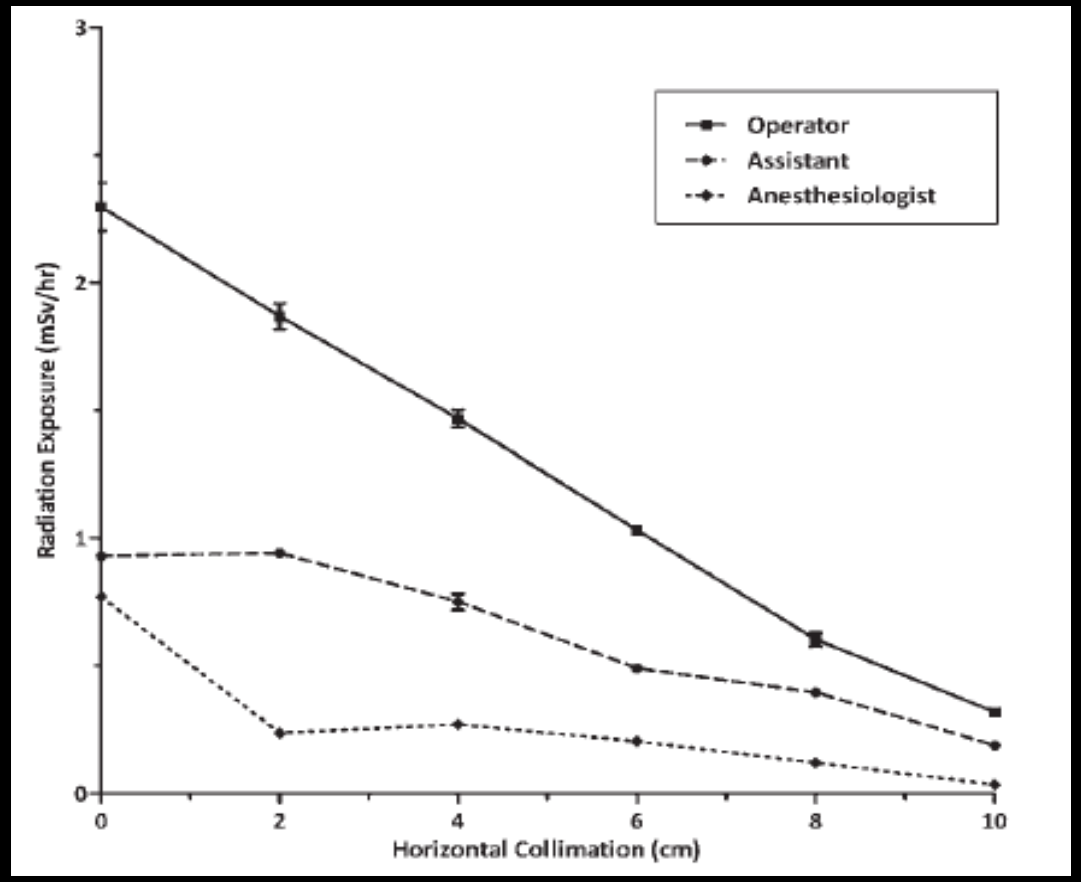
Localisation vs Characterisation

X-ray tube:
- Copper filtration
- Tube potential (kV)
- Pulse duration (ms)
- Tube current (mA)

Setting	Dose (mGy/s)
Fluoflavor 1 (Low)	0.076
Fluoflavor 2 (Medium)	0.113
Fluoflavor 3 (Normal)	0.267

Active management of field of view: Collimation





25% collimation ≈ 25% reduction DAP
Reduce scatter
Reduce exposure surrounding tissues

Haqqani et al. JVS 2012

Majority of radiation exposure occurs during DSA runs

Occupational Radiation Exposure During Endovascular Aortic Procedures

A.P. Patel [a], D. Gallacher [b], R. Dourado [c], O. Lyons [a], A. Smith [a], H. Zayed [a], M. Waltham [a], T. Sabharwal [c], R. Bell [a], T. Carrell [a], P. Taylor [a], B. Modarai [a,*]

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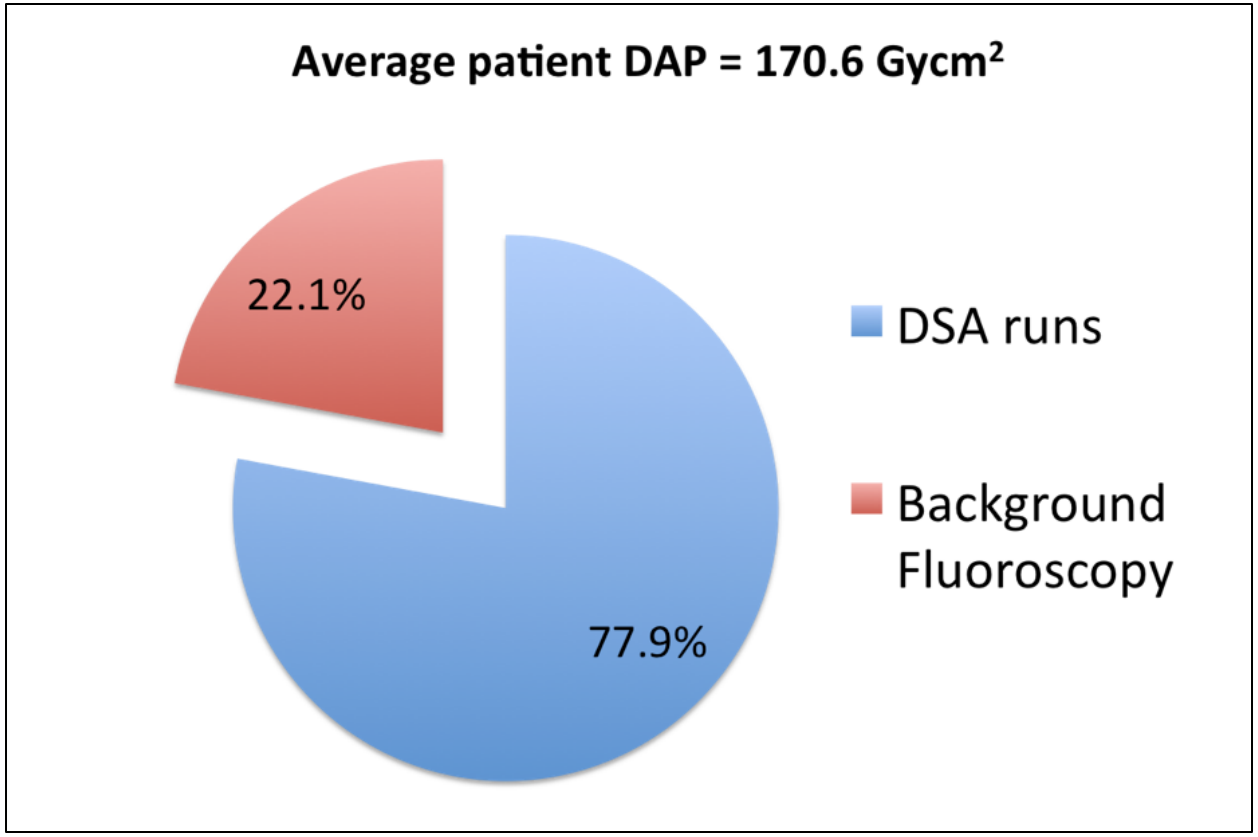
[b] Department of Medical Physics, Guy's & St Thomas' NHS Foundation Trust, United Kingdom
[c] Department of Interventional Radiology, Guy's & St Thomas' NHS Foundation Trust, United Kingdom

WHAT THIS PAPER ADDS
The dangers of radiation exposure while performing endovascular operations are not well recognised by vascular interventionists. The present study assesses the radiation dosage received by the operating team during endovascular aortic procedures and demonstrates that particular behaviours increase this dose considerably. A greater awareness of these behaviours would help to reduce the amount of radiation to which patients and members of the operating team are exposed.

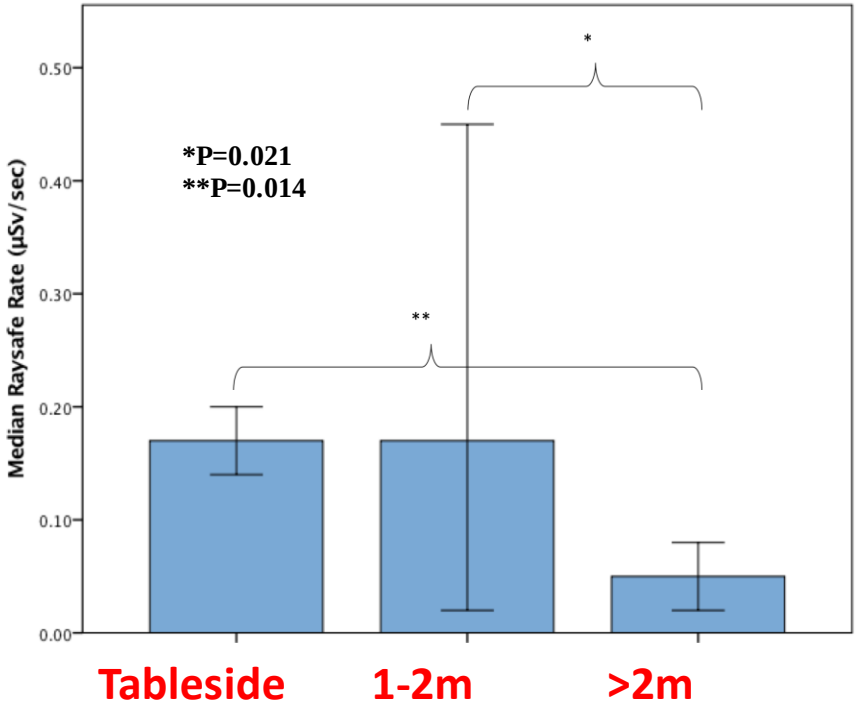
Objectives: To measure the radiation exposure of the operating team during endovascular aortic procedures, and to determine factors that predict high exposures.
Materials and methods: Electronic dosimeters placed over and under protective lead garments, were used to prospectively record radiation exposure during endovascular aortic repairs performed in a designated interventional radiology suite. Univariate and multivariate linear regression analyses of predictors of radiation exposure were performed.
Results: A total of 26 infra-renal and 10 thoracic endovascular cases were studied. Median (IQR) patient age and body mass index were 76.0 (70.0–81.8) years and 26.2 (23.9–28.9) kg/m^2 respectively. Over-lead exposure to the operator was higher for thoracic than for infra-renal procedures (421.0 [233.8–597.8] µSv vs. 52.5 [27.8–179.8] µSv, $p = .0003$), reflecting a significant exposure to unprotected parts of the body. Under-lead exposures for operator and assistant were 5.5 (2.0–14.2) µSv and 1.0 (0.0–2.3) µSv respectively, which for an average caseload would comply with total body effective dose limits. Type of case and percentage of digital subtraction angiography (DSA) time in left anterior oblique angulations predicted dose to the operator ($p < .0001$).
Conclusions: Thoracic procedures, DSA runs and obliquity of the C-arm are strong predictors of radiation exposure during endovascular aortic repairs. Understanding scatter radiation dynamics and instigating measures to minimise radiation exposure should be mandatory.

Article history: Received 27 February 2013, Accepted 29 May 2013, Available online XXX
Keywords: Occupational radiation exposure, Dosimetry, Endovascular, Aortic repair



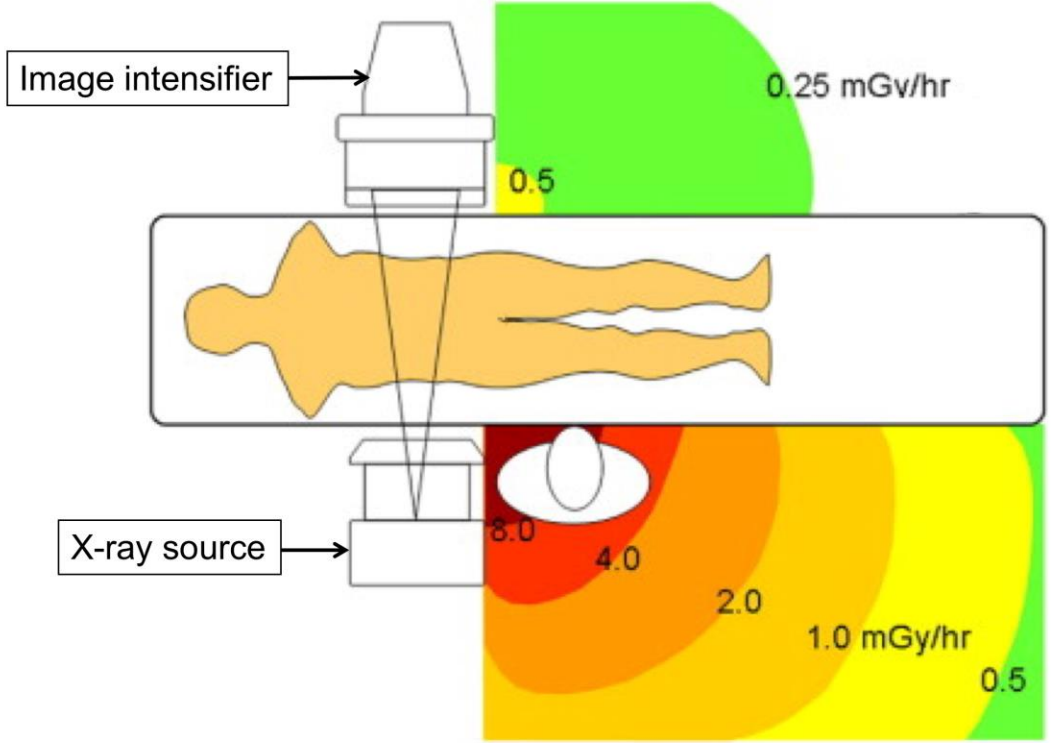
Patel, Modarai et al. Eur J Vasc Endovasc Surg 2013

Predictors of operator dose during DSA: Operator position

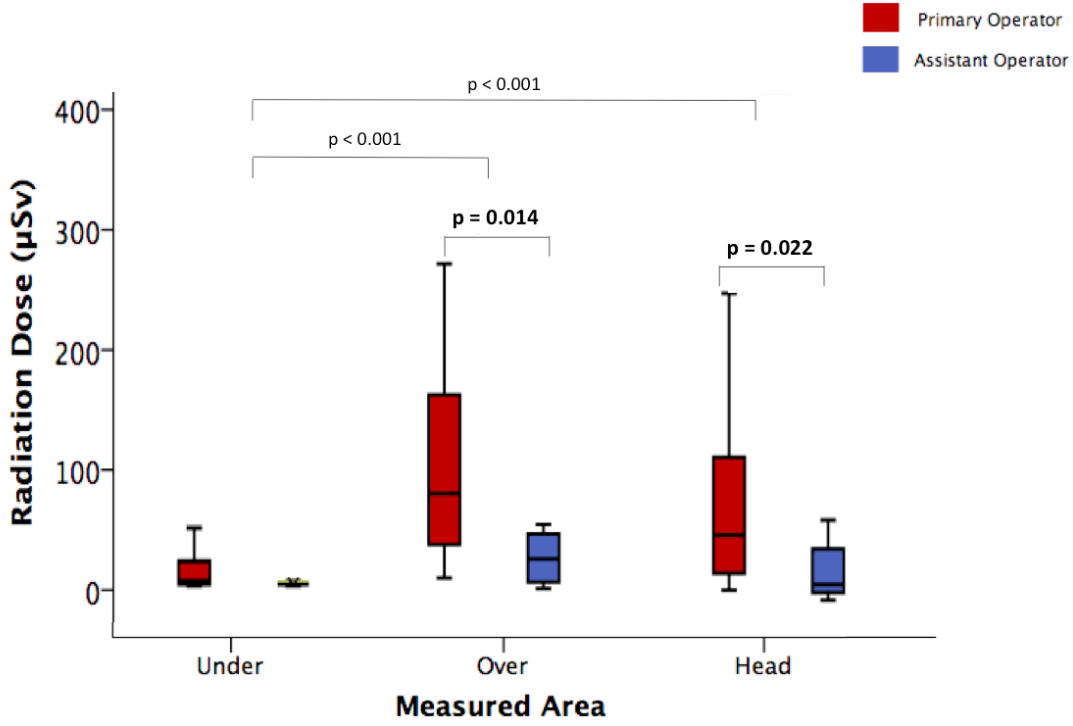


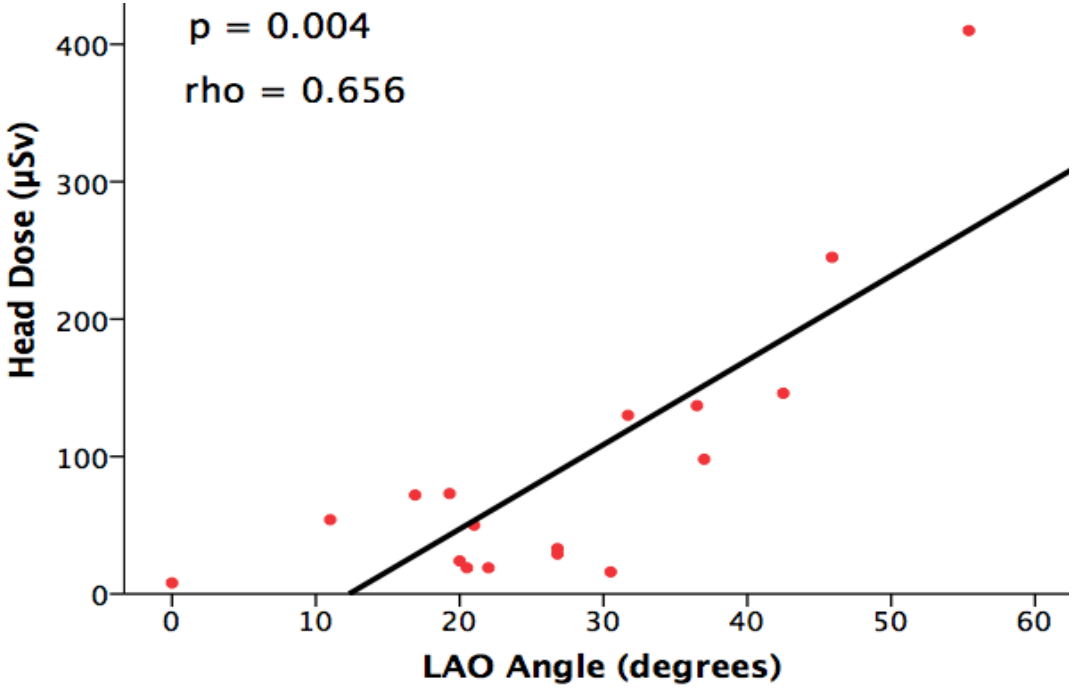
	Median (IQR) (n=24)	IEVAR / TEVAR (IQR) (n=13)	BEVAR / FEVAR (IQR) (n=11)	p
Total number DSA runs	24 (11-106)	14 (8-18)	28 (23-31)	0.001
No of DSA runs PO stepped back (% of runs)	80 (17%)	49 (26%)	31 (11%)	NS

Predictors of operator dose during DSA: Angulation of C-arm



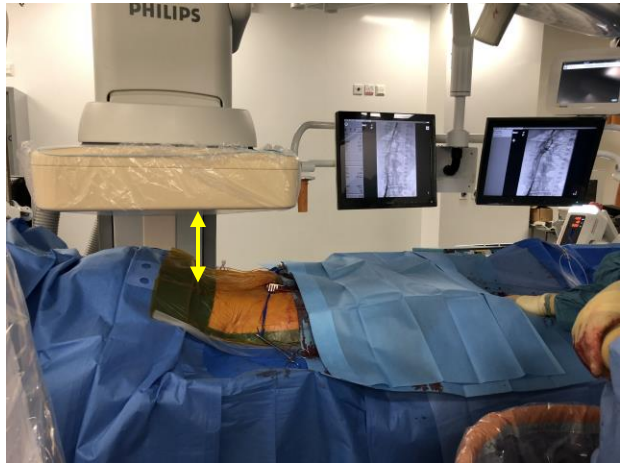
Angulation of C-arm and head exposure

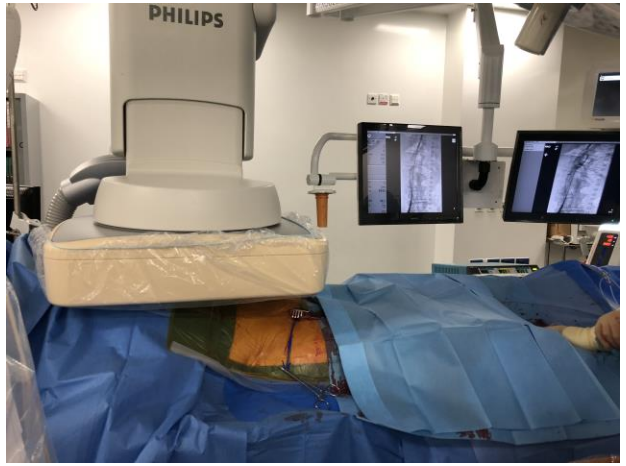


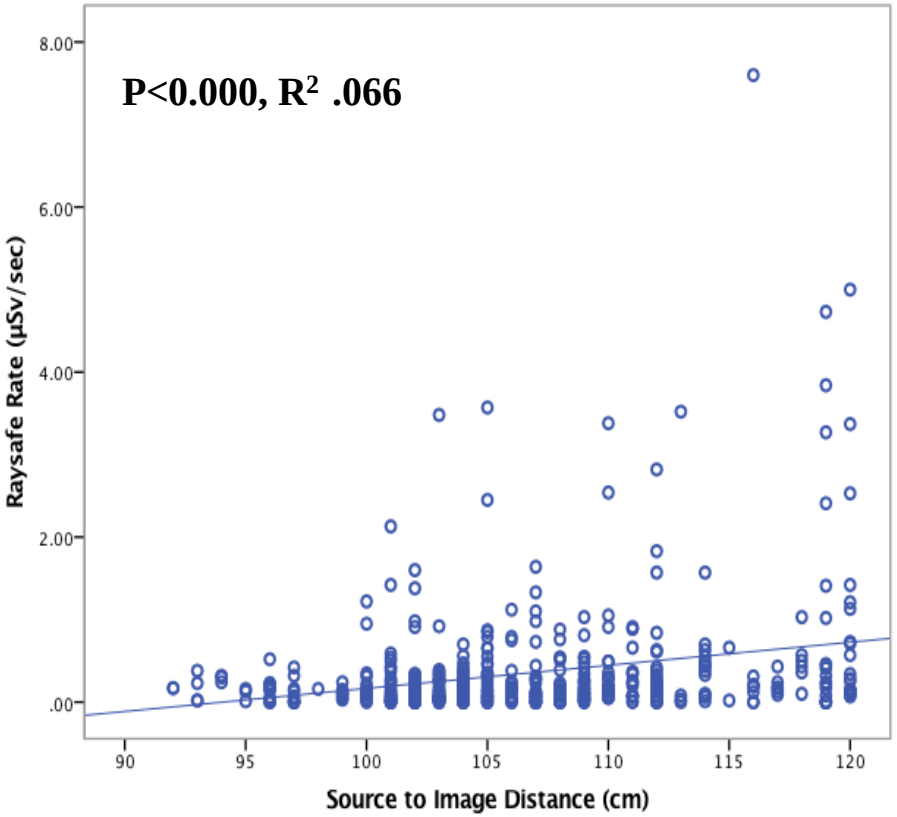


Albayati, Modarai et al. EJVES 2015

Predictors of operator dose during DSA: Source to image distance







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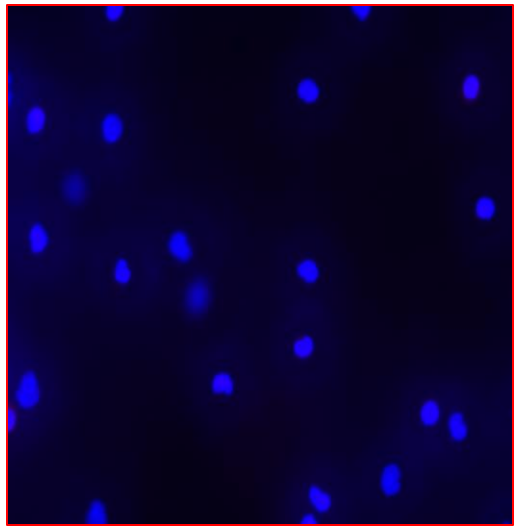
Circulation. 2017 Dec 19;136(25):2406-2416. doi: 10.1161/CIRCULATIONAHA.117.029550. Epub 2017 Oct 20.

Radiation-Induced DNA Damage in Operators Performing Endovascular Aortic Repair.

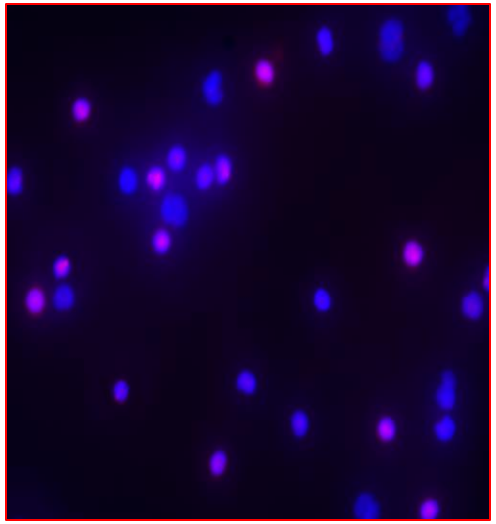
El-Sayed T[1], Patel AS[1], Cho JS[1], Kelly JA[1], Ludwinski FE[1], Saha P[1], Lyons OT[1], Smith A[1], Modarai B[2]; Guy's and St Thomas' Cardiovascular Research Collaborative.

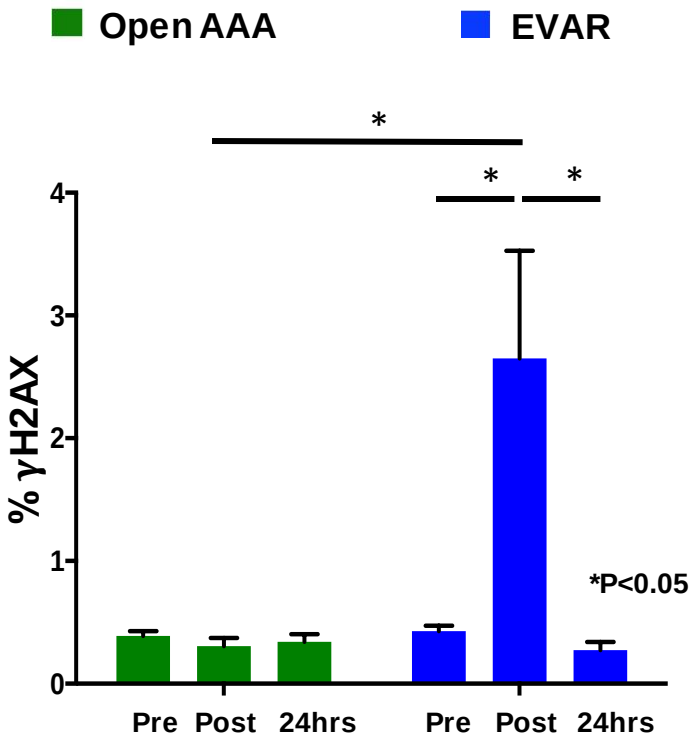
Radiation → Double Stranded DNA Break → H2AX → Gamma H2AX

Pre-op



Post-op





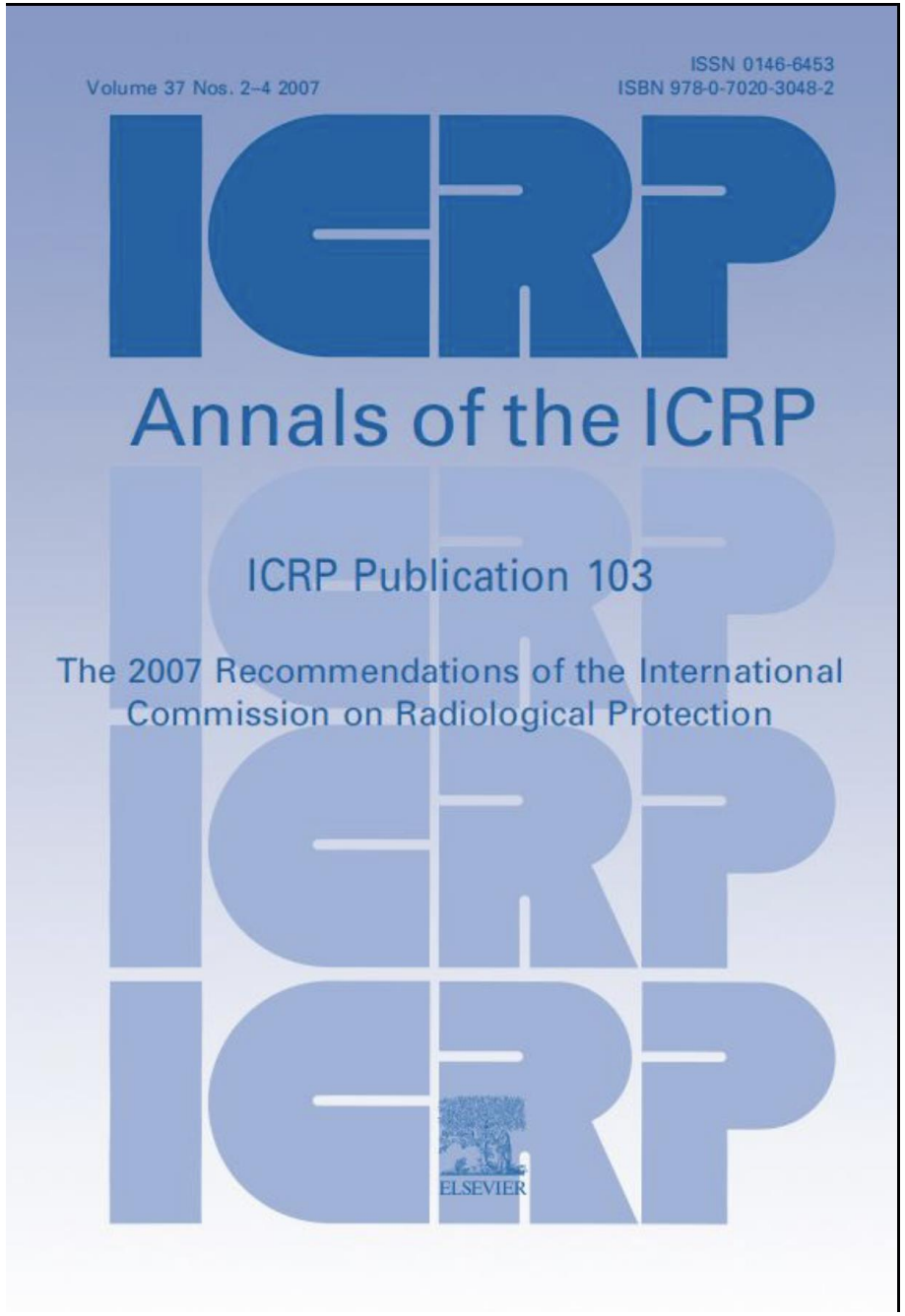
Effects of ionising radiation on micronucleus formation and chromosomal aberrations in Chinese radiation workers

Qing-Zeng Qian,[1,*] Xiang-Ke Cao,[2] Fu-Hai Shen,[1] and Qian Wang[1]

Groups	Cases (*N*)	MN		
		Numbers (*N*)	MN numbers (*N*)	MN rate (‰)
Exposed group	1392	1 392 000	3395	2.44[a]
Control group	143	143 000	246	1.72

Exposure time (y)	Cases (*N*)	MN	
		MN number (*N*)	MN rate (‰)
<10	723	1597	2.21
10–20	532	1316	2.47[a]
>20	137	482	3.52

Qian et al. Radiat Prot Dosimetry 2016


Volume 37 Nos. 2–4 2007
ISSN 0146-6453
ISBN 978-0-7020-3048-2
ICRP
Annals of the ICRP
ICRP Publication 103
The 2007 Recommendations of the International Commission on Radiological Protection
ELSEVIER

"Genetic susceptibility to radiation-induced cancer involving strongly expressed genes is judged to be too rare to appreciably distort estimates of population risk; the potential impact of common but weakly expressing genes remains uncertain"

CrossMark

Antioxidants Taken Orally prior to Diagnostic Radiation Exposure Can Prevent DNA Injury

Nivethan Velauthapillai, MSc, Joe Barfett, MD, Hussein Jaffer, MD, David Mikulis, MD, PhD, and Kieran Murphy, MD, FRCPC, FSIR

- Cancer staging: 99mTc MDP bone scans
- Anti-oxidant formulation:

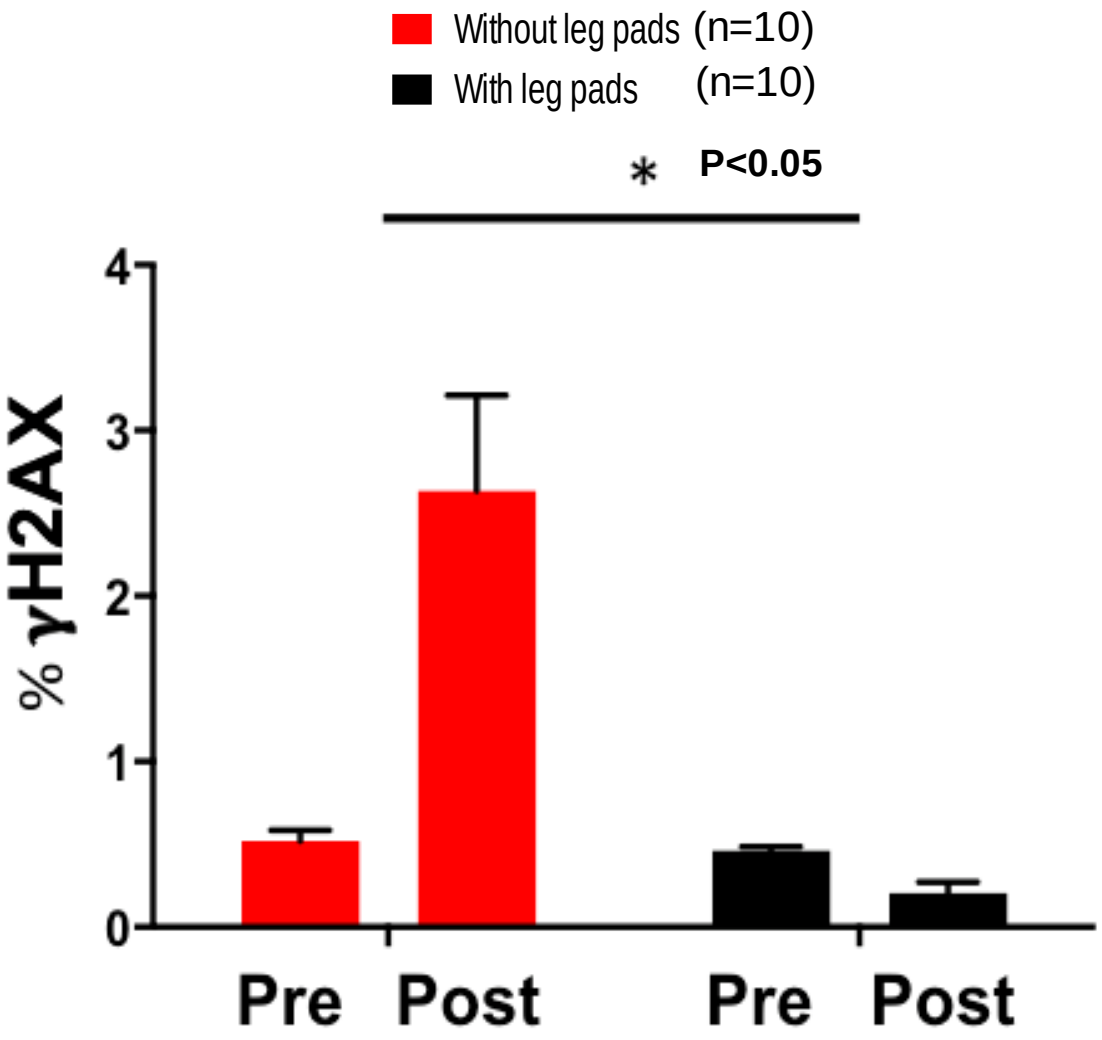
  1.2g N-acetylcysteine,

  600mg lipoicacid

  30mg betacarotene
- Reduction in DNA damage (gamma H2AX)

Velauthapillai et al. J Vasc Interv Radiol 2017

Leg lead shielding is protective



Towards X-ray free endovascular interventions – using HoloLens for on-line holographic visualisation

Ivo Kuhlemann[1] ✉, Markus Kleemann[2], Philipp Jauer[1], Achim Schweikard[1], Floris Ernst[1]

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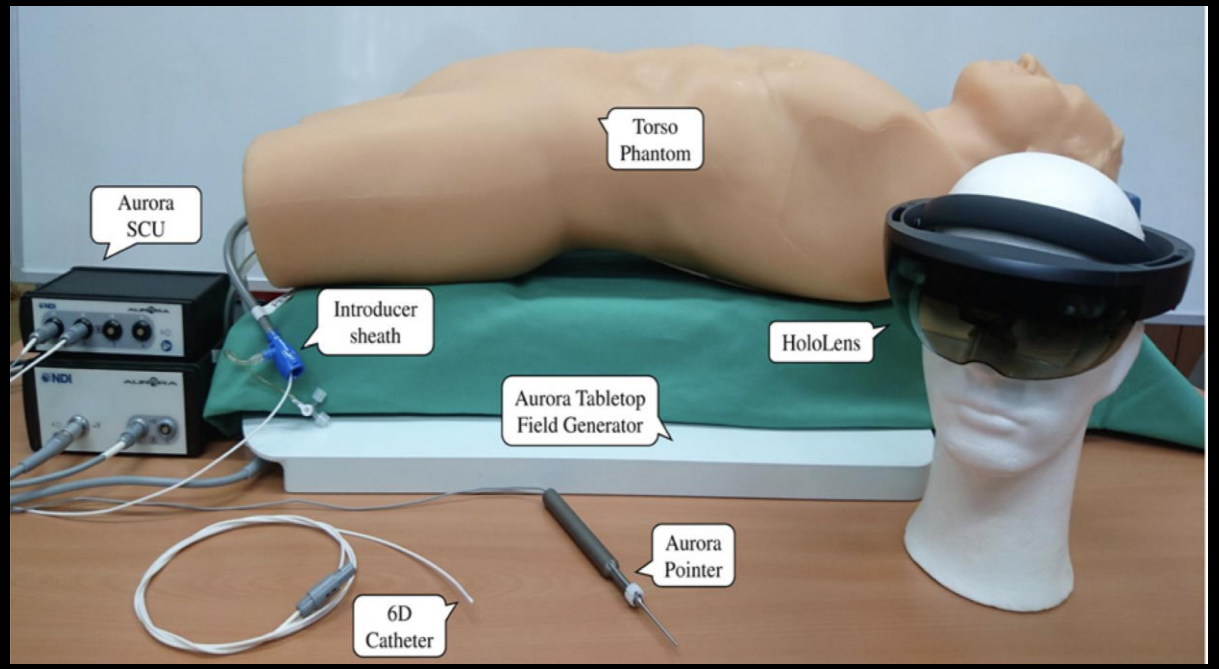

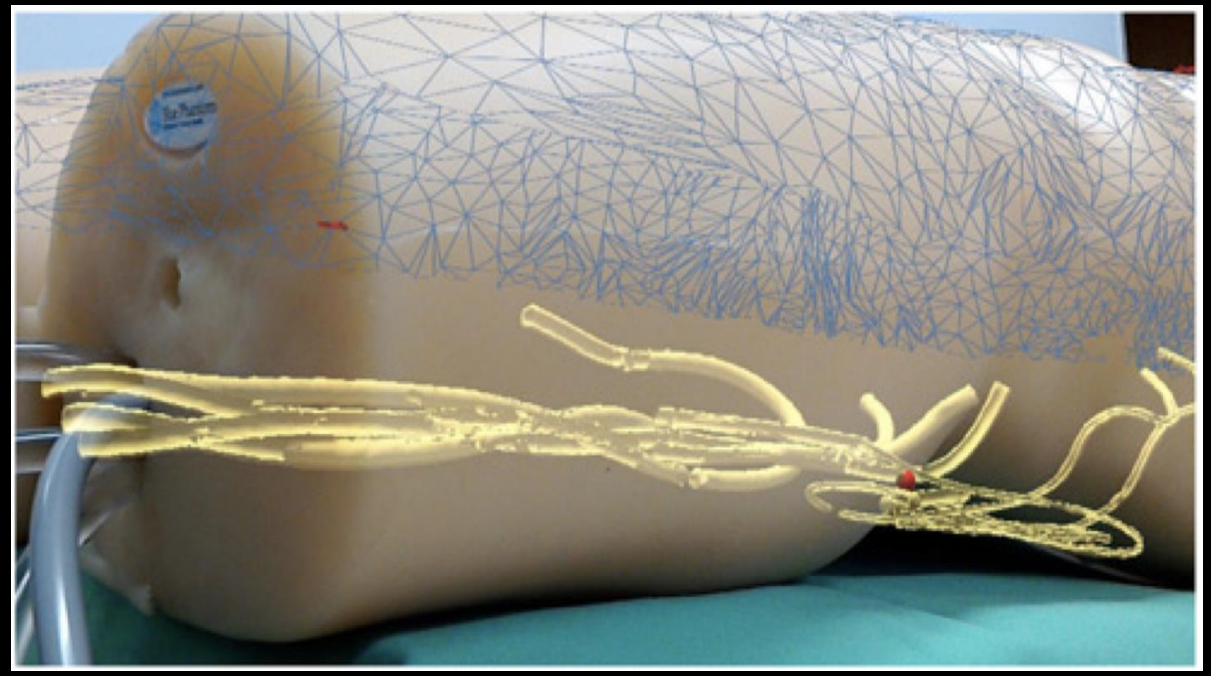

As Low As Reasonably Achievable

- Elevated markers of DNA damage after EVAR
- Know your dose
- Real time dosimetry +/- alert
- Role for ”spotter” in theatre
- Insist on maximal shielding

- Intermittent fluoroscopy
- Reduce pulse rate
- Reduce frame rate
- Limit number of DSA runs
- Step away during DSA runs
- Magnification
- Collimation
- Avoid angulation C-arm
- Reduce “air gap”