

AORN Guideline for Radiation Safety
Evidence Table

REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
1	Salvo, John P, Zarah, Jake Surgeon Radiation Exposure in Hip Arthroscopy 2016	Organizational Experience	280 hip arthroscopy procedures at one facility by one surgeon	n/a	n/a	n/a	Surgeons are exposed to an acceptable amount of radiation if doing 100 cases per year but recommend continued use of shielding.	VC
2	Sciahbasi, Alessandro, Ferrante, Giuseppe, Fischetti, Dionigi, et al Radiation dose among different cardiac and vascular invasive procedures: the RODEO study 2017	Nonexperimental	17,711 interventional operators.	n/a	n/a	Radiation dosage	The radiation dose received by the interventional operators varied by procedure.	IIIA
3	van den Haak, RFF, Hamans, B C, Zuurmond, K, Verhoeven, B A N and Koning, O H J Significant Radiation Dose Reduction in the Hybrid Operating Room Using a Novel X-ray Imaging Technology 2015	Quasi-experimental	138 patients having aortoiliac endovascular procedures in the hybrid operating room.			Radiation levels for patient and staff	The radiation levels were reduced after introduction of new technology	IIB
4	Hirshfeld, John W,Jr, Ferrari, Victor A, Bengel, Frank M, et al 2018 ACC/HRS/NASCI/SCAI/SCCT Expert Consensus Document on Optimal Use of Ionizing Radiation in Cardiovascular Imaging: Best Practices for Safety and Effectiveness, Part 1: Radiation Physics and Radiation Biology: A Report of the American College of Cardiology Task Force on Expert Consensus Decision Pathways Developed in Collaboration With Mended Hearts 2018	Consensus	n/a	n/a	n/a	n/a	Provides definitions for tissue reactions and stochastic effects and recommendations for patient education.	IVA
5	Richardson, David B, Cardis, Elisabeth, Daniels, Robert D, et al Site-specific Solid Cancer Mortality After Exposure to Ionizing Radiation: A Cohort Study of Workers (INWORKS) 2018	Nonexperimental	308,297 nuclear workers	n/a	n/a	Rate of cancers	Exposure to ionizing radiation is associated with the formation of cancer in nuclear workers	IIIA
6	Haylock, Richard G E, Gillies, Michael, Hunter, Nezhahat, Zhang, Wei and Phillipson, Mary Cancer mortality and incidence following external occupational radiation exposure: an update of the 3rd analysis of the UK national registry for radiation workers 2018	Nonexperimental	167,003 persons who occupational low level radiation exposure	n/a	n/a	Rate of cancers	Exposure to low level radiation is related to the incidence of cancer	IIIA
7	Andreassi, Maria G, Piccaluga, Emanuela, Guagliumi, Giulio, Del Greco, Maurizio, Gaita, Fiorenzo and Picano, Eugenio Occupational Health Risks in Cardiac Catheterization Laboratory Workers 2016	Qualitative	746 questionnaires completed by IR personnel or unexposed persons	n/a	n/a	n/a	Certain health problems are more prevalent in people exposed to radiation.	IIIB
8	Guesnier-Dopagne, Melanie, Boyer, Louis, Pereira, Bruno, Guersen, Joel, Motreff, Pascal and D'Incan, Michel Incidence of Chronic Radiodermatitis after Fluoroscopically Guided Interventions: A Retrospective Study 2019	Nonexperimental	55,782 patients having fluoroscopically guided interventions	n/a	n/a	Presence of radiodermatitis	Radiodermatitis is a frequent side effect in fluoroscopically guided interventions in high-risk patients.	IIIB
9	Wei, Kai-Che, Yang, Kuo-Chung, Mar, Guang-Yuan, et al STROBE--Radiation Ulcer: An Overlooked Complication of Fluoroscopic Intervention: A Cross-Sectional Study 2015	Nonexperimental	2,124 patients have cardiac catheterization	n/a	n/a	Presence of radiation burns	Radiation burns occur and patient education is required before, during and after the procedure.	IIIC
10	Caird, Michelle S Radiation Safety in Pediatric Orthopaedics 2015	Expert Opinion	n/a	n/a	n/a	n/a	Radiation comes from many different sources and shielding should be used.	VB

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11	Preston, D L, Kitahara, C M, Freedman, D M, et al Breast cancer risk and protracted low-to-moderate dose occupational radiation exposure in the US Radiologic Technologists Cohort, 1983-2008 2016	Nonexperimental	66 915 female technologists,	n/a	n/a	Incidence of breast cancer	Incidence of breast cancer increases with an increased radiation dose.	IIIA
12	OSHA Health Effects	Expert Opinion	n/a	n/a	n/a	n/a	Lists health effects of radiation	VA
13	Basheerudeen, Safa A S, Kanagaraj, Karthik, Jose, M T, et al Entrance surface dose and induced DNA damage in blood lymphocytes of patients exposed to low-dose and low-dose-rate X-irradiation during diagnostic and therapeutic interventional radiology procedures 2017	Quasi-experimental	75 patients having interventional radiology procedures	2 & 24 hours after exposure	Before exposure	DNA damage	There was early DNA damage present in the subjects	IIB
14	Kanagaraj, Karthik, Abdul Syed Basheerudeen, Safa, Tamizh Selvan, G, et al Assessment of dose and DNA damages in individuals exposed to low dose and low dose rate ionizing radiations during computed tomography imaging 2015	Quasi-experimental	27 patients having CT scans	CT exam	No CT exam	DNA damage	There was DNA damage present in some of the subjects having the exam	IIB
15	Wiesel, Awi, Stolz, Gabriela and Queisser-Wahrendorf, Annette Evidence for a teratogenic risk in the offspring of health personnel exposed to ionizing radiation?! 2016	Nonexperimental	30 pregnant women	n/a	n/a	congenital anomalies	Congenital anomalies occurred as the result of exposure to radiation in medical workers	IIIB
16	Parikh, Jay R, Geise, Richard A, Bluth, Edward I, et al Potential Radiation-Related Effects on Radiologists 2017	Literature Review	n/a	n/a	n/a	n/a	Education on biological effects of radiation should be provided	VB
17	Kalem, Mahmut, BaÅ...Ä, arÄ, Ä±r, Kerem, KocaoÄ, Ä, lu, Hakan, Ä...Ä¼ahin, Ercan and KÄ, Ä±nÄ, Ä±k, Hakan The Effect of C-Arm Mobility and Field of Vision on Radiation Exposure in the Treatment of Proximal Femoral Fractures: A Randomized Clinical Trial 2018	RCT	17 patient having femur fracture repairs with device B and with device A	Device A	Device B	Radiation dose	The radiation dose varies with the device used.	IB
18	Georges, J-L, Boueri, Z, Mailler, B, et al Reduction of radiation exposure associated with renewal of the radiologic systems in coronary interventions 2018	Quasi-experimental	2,771 patients have interventional cardiology procedures before and 940 after new equipment installed	New equipment used	Old equipment used	Radiation dose	The radiation dose was decreased after new equipment was installed	IIA
19	Casella, Michela, Dello Russo, Antonio, Russo, Eleonora, et al X-Ray Exposure in Cardiac Electrophysiology: A Retrospective Analysis in 8150 Patients Over 7 Years of Activity in a Modern, Large-Volume Laboratory 2018	Nonexperimental	8150 patients having electrophysiologic al/device implant procedures	n/a	n/a	Radiation dose	There has been a reduction in radiation exposure between 2010 to 2016.	IIIA
20	Goldswieg, Andrew M, Kennedy, Kevin F, Kolte, Dhaval, et al Predictors of patient radiation exposure during transcatheter aortic valve replacement 2018	Nonexperimental	294 patients having TAVRs	n/a	n/a	Radiation dose	Radiations does was increased with an increase in BMI	IIIA
21	Cushman, Daniel, Mattie, Ryan, Curtis, Bradley, Flis, Alexandra and McCormick, Zachary L The effect of body mass index on fluoroscopic time and radiation dose during lumbar transforaminal epidural steroid injections 2016	Nonexperimental	419 normal, 572 overweight, and 557 obese patients having transforaminal epidural steroid injections	n/a	n/a	Fluoroscopy time and radiation dose	Fluoroscopy time and radiation dose increased with increased BMI	IIIA

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22	Cushman, Daniel, Flis, Alexandra, Jensen, Ben and McCormick, Zachary The Effect of Body Mass Index on Fluoroscopic Time and Radiation Dose During Sacroiliac Joint Injections 2016	Nonexperimental	359 patients having sacroiliac joint injections	n/a	n/a	Radiation dose	The radiation dose increased with increased BMI.	IIIB
23	Canham, Colin D, Williams, Richard B, Schiffman, Scott, Weinberg, Eric P and Giordano, Brian D Cumulative Radiation Exposure to Patients Undergoing Arthroscopic Hip Preservation Surgery and Occupational Radiation Exposure to the Surgical Team 2015	Nonexperimental	52 patients undergoing arthroscopic hip preservation surgery at an ambulatory surgical center by a single surgeon	n/a	n/a	Patient and staff radiation dose.	Radiation dose is increased with an increase in BMI therefore does to staff is also increased with increase BMI	IIIB
24	Dalglish, S, Hince, A and Finlayson, D F Peri-operative radiation exposure: Are overweight patients at increased risks? 2015	Nonexperimental	81 patients having femoral neck fracture repair	n/a	n/a	Radiation dose	Radiation dose increases with increased BMI.	IIIB
25	Maempel, J F, Stone, O D and Murray, A W Quantification of radiation exposure in the operating theatre during management of common fractures of the upper extremity in children 2016	Nonexperimental	248 patients with arm fractures	n/a	n/a	Radiation doses	The radiation dose varies by procedure.	IIIB
26	Madder, Ryan D, VanOosterhout, Stacie, Mulder, Abbey, et al Patient Body Mass Index and Physician Radiation Dose During Coronary Angiography 2019	Nonexperimental	1119 patients having coronary angiograms	n/a	n/a	DAP	Dosage is increased with an increased BMI	IIIB
27	Farah, Jad, Rouchaud, Aymeric, Henry, Theophraste, et al Dose reference levels and clinical determinants in stroke neuroradiology interventions 2019	Nonexperimental	319 stroke patients having thrombectomy	n/a	n/a	Patient's dose area product, cumulative air Kerma , fluoroscopy time, and number of images	Male gender, number of passages, and success of recanalization were key parameters affecting patient dose	IIIB
28	Pravata, Emanuele, Presilla, Stefano, Roccatagliata, Luca and Cianfoni, Alessandro Operator radiation doses during CT-guided spine procedures 2018	Nonexperimental	26 CT-guided spine procedures	n/a	n/a	Operator and patient radiation dose	The operator radiation dose received by the operator correlates with the patient dose	IIIC
29	Faroux, Laurent, Blanpain, Thierry, Nazeyrollas, Pierre, et al Trends in Patient Exposure to Radiation in Percutaneous Coronary Interventions Over a 10-Year Period 2017	Nonexperimental	416 patients having percutaneous coronary interventions during October 2005 to March 2006 and 807 during November 2015 to October 2016.	n/a	n/a	Radiation dose	The dose of radiation for he same procedure has decreased in the ten years between the two groups.	IIIA
30	Rumanek, Jake, Kudlas, Myke Shielding in Medical Imaging and Radiation Therapy 2018	Expert Opinion	n/a	n/a	n/a	n/a	General overall information on radiation safety	VA
31	Patet, Camille, Ryckx, Nick, Arroyo, Diego, Cook, Stephane and Goy, Jean-Jacques Efficacy of the SEPARPROCATH R radiation drape to reduce radiation exposure during cardiac catheterization: A pilot comparative study 2019	RCT	51 patients having cardiac interventional procedures	Shielding drape plus standard prevention	Standard Prevention	Operator and nurse radiation exposure	Operator and nurse radiation exposure were decreases with the use of a shielding drape	IB

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32	Gilligan P, Lynch J, Eder H, et al. Assessment of clinical occupational dose reduction effect of a new interventional cardiology shield for radial access combined with a scatter reducing drape. <i>Catheter Cardiovasc Interv.</i> 2015;86(5):935-40.	Quasi-experimental	325 interventional cardiac procedures	With enhanced shield	Without enhanced shield	Radiation dose	The cardiologists, nurses, radiation technologists, radiologists, all received varying amounts of radiation during the same procedure	IIB
33	Leyton, Fernando, Nogueira, Maria S, Gubolino, Luiz A, Pivetta, Makyson R and Ubeda, Carlos Correlation between scatter radiation dose at height of operator's eye and dose to patient for different angiographic projections 2016	Nonexperimental	Laboratory using different angiographic projections and a phantom	n/a	n/a	Radiation dose	The radiation dose differs with the angiographic projection	IIIC
34	Principi, S, Farah, J, Ferrari, P, Carinou, E, Clairand, I and Ginjaume, M The influence of operator position, height and body orientation on eye lens dose in interventional radiology and cardiology: Monte Carlo simulations versus realistic clinical measurements 2016	Quasi-experimental	Monte Carlo simulation	Turned toward the source	Turned away from the tube.	Radiation dose to the eye.	Taller operators received a lower dose to the eye and use of eye protection decreased the radiation dose to the eye.	IIB
35	Wilson-Stewart, Kelly, Shanahan, Madeleine, Fontanarosa, Davide and Davidson, Rob Occupational radiation exposure to nursing staff during cardiovascular fluoroscopic procedures: A review of the literature 2018	Literature Review	n/a	n/a	n/a	n/a	Supports lack of evidence on radiation exposure to nurses and need for nursing education on radiation protection	VA
36	Van Wicklin, Sharon, Conner, Ramona Guideline for Specimen Management 2020	Guideline	n/a	n/a	n/a	n/a	Provides guidance on the handling of specimens.	IVA
37	Fearon MC, Conner R. Guideline for minimally invasive surgery. In: Conner R, ed. <i>Guidelines for perioperative practice.</i> e-Guidelines+ ed. Denver, CO: AORN; 2020. [IVA].	Guideline	n/a	n/a	n/a	n/a	Provides guidance on use of MRI	IVA
39	10 CFR 20: Standards for Protection Against Radiation 2019	Regulatory	n/a	n/a	n/a	n/a	Provides minimum doses and requirement for a radiation safety program	n/a
38	Burlingame B. Guideline for laser safety. In: Wood A, ed. <i>Guidelines for perioperative practice.</i> e-Guidelines+ ed. Denver, CO: AORN; 2020.	Guideline	n/a	n/a	n/a	n/a	Provides guidance on use of lasers.	IVA
40	State Operations Manual Appendix A: Survey Protocol, Regulations and Interpretive Guidelines for Hospitals 2020	Regulatory	n/a	n/a	n/a	n/a	Contains the Medicare requirements for radiology	n/a
41	State Operations Manual Appendix L: Guidance for Surveyors: Ambulatory Surgical Centers 2020	Regulatory	n/a	n/a	n/a	n/a	Contains the Medicare requirements for radiology	n/a
42	10 CFR 35: Medical Use of Byproduct Material 2019	Regulatory	n/a	n/a	n/a	n/a	Regulations on the radiation safety program	n/a
43	10 CFR 3041: Transfer of byproduct material 2019	Regulatory	n/a	n/a	n/a	n/a	Provides guidance on laws covering brachytherapy	n/a
44	Camper, L W, Schlueter, J, Woods, S, et al Management of Radioactive Material Safety Program at Medical Facilities: Final Report 1997	Expert Opinion	n/a	n/a	n/a	n/a	Overall guidance on radiation safety program and responsibilities of the RSO and Radiation safety committee.	VA
45	42 CFR 41649: Condition for coverage-Laboratory and radiologic services 2019	Regulatory	n/a	n/a	n/a	n/a	Need a radiation safety officer	n/a
46	42 CFR 48226 Condition of participation: Radiologic services 2019	Regulatory	n/a	n/a	n/a	n/a	Legal requirements for radiological services	n/a
47	29 CFR 19101096: Toxic and hazardous substances: Ionizing radiation 2011	Regulatory	n/a	n/a	n/a	n/a	Provides requirements for radiation protection from OSHA	n/a

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48	Rehani, M M, Ciraj-Bjelac, O, Vano, E, et al ICRP Publication 117: Radiological Protection in Fluoroscopically Guided Procedures outside the Imaging Department 2010	Guideline	n/a	n/a	n/a	n/a	Personnel need education commensurate with job responsibilities, should use x-ray shielding	IVB
49	NRC: Iodine-125 and Palladium-103 Low Dose Rate Brachytherapy Seeds Used for Localization of Non-Palpable Lesions 2017	Regulatory	n/a	n/a	n/a	n/a	Provides regulations for handling radioactive seeds	n/a
50	Ortiz Lopez, P O, Dauer, L T, Loose, R, et al ICRP Publication 139: Occupational Radiological Protection in Interventional Procedures 2018	Guideline	n/a	n/a	n/a	n/a	Provides on radiation safety measures in interventional suites.	IVB
51	Choi, Moon H, Jung, Seung E, Oh, Soon N and Byun, Jae Y Educational Effects of Radiation Reduction During Fluoroscopic Examination of the Adult Gastrointestinal Tract 2018	Quasi-experimental	779 examinations before and 1547 after education			Fluoroscopy time and DAP	Education on the risks of radiation exposure decreased the fluoroscopy time and the DAP	IIB
52	Vano, E, Rosenstein, M, Liniecki, J, Rehani, M, Martin, C J and Vetter, R J ICRP Publication 113: Education and Training in Radiological Protection for Diagnostic and Interventional Procedures 2009	Guideline	n/a	n/a	n/a	n/a	Provides guidance on educational content.	IVC
53	Jensen, Nicole, Janssen, Meganne Quality Improvement: Staff Radiation Exposure Reduction While Maintaining Patient Safety 2017	Organizational Experience	13 nursing staff	n/a	n/a	n/a	Radiation dose was reduced after receiving education on protection measures	VA
54	Khong, P-L, Ringertz, H, Donoghue, V, et al ICRP Publication 121: Radiological Protection in Paediatric Diagnostic and Interventional Radiology 2015	Guideline	n/a	n/a	n/a	n/a	Provides recommendations on caring for the pediatric patient.	IVB
55	Federal Guidance Report No 14: Radiation Protection Guidance for Diagnostic and Interventional X-Ray Procedures 2014	Guideline	n/a	n/a	n/a	n/a	Provides guidance on overall radiation safety.	IVB
56	AST standards of practice for ionizing radiation exposure in the perioperative setting. Association of Surgical Technologists; 2010.	Guideline	n/a	n/a	n/a	n/a	Provides guidance on all aspects of radiation exposure prevention.	IVC
57	NCRP Report 168 Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures 2010	Guideline	n/a	n/a	n/a	n/a	Provides guidance for use during for fluoroscopy procedures	IVB
58	Fidalgo Domingos, Liliana, San Norberto Garcia, Enrique, M, Gutierrez Castillo, Diana, Flota Ruiz, Cintia, Estevez Fernandez, Isabel and Vaquero Puerta, Carlos Radioprotection Measures during the Learning Curve with Hybrid Operating Rooms 2018	Quasi-experimental	170 interventional vascular procedures before education and 142 after education	Education on radiation protection	No education	Radiation dose	Education on the risks of radiation exposure decreased the radiation dose but it did not reach significance	IIB
59	Gendelberg, David, Hennrikus, William, Slough, Jennifer, Armstrong, Douglas and King, Steven A Radiation Safety Training Program Results in Reduced Radiation Exposure for Orthopaedic Residents Using the Mini C-arm 2016	Quasi-experimental	53 ulnar fracture repairs before education and 45 after.	Education program on mini C-arm use and radiation safety	No education	Radiation dose	The radiation dose decreased after the education program.	IIB
60	Sarkozy, Andrea, De Potter, Tom, Heibuchel, Hein, et al Occupational radiation exposure in the electrophysiology laboratory with a focus on personnel with reproductive potential and during pregnancy: A European Heart Rhythm Association (EHRA) consensus document endorsed by the Heart Rhythm Society (HRS) 2017	Consensus	n/a	n/a	n/a	n/a	provides guidance on protection for pregnant personnel	IVB
61	Radiation risks of diagnostic imaging and fluoroscopy 2011 Revised: February 2019	Expert Opinion	n/a	n/a	n/a	n/a	Provides recommendations for the role of the radiation safety officer and guidance for education	VB

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62	Ghodadra, Anish, Bartoletti, Stefano Reducing Radiation Dose in Pediatric Diagnostic Fluoroscopy 2016	Quasi-experimental	9 radiologists performing 945 diagnostic procedures pretraining and 530 post-training	Training	No training	Fluoroscopy time and radiation dose area product (DAP)	Fluoroscopy time and DAP were reduced after education on methods to reduce radiation exposure	IIB
63	Koth, Jana, Hess Smith, Marcia Radiation Safety Compliance 2016	Expert Opinion	n/a	n/a	n/a	n/a	Provides guidance on the radiation safety program and safety committee and other general stuff	VB
64	Johnstone, Esther M, Conner, Ramona Guideline for Medical Device and Product Evaluation 2020	Guideline	n/a	n/a	n/a	n/a	Provides guidance for selecting new products	IVA
65	<i>Management of radionuclide therapy patients.</i> Bethesda, MD: National Council on Radiation Protection & Measurements; 2006; No. 155.	Guideline	n/a	n/a	n/a	n/a	Provides overall guidance for caring for the patient receiving a radionuclide.	IVC
66	Kachaamy, Toufic, Harrison, Edwyn, Pannala, Rahul, Pavlicek, William, Crowell, Michael D and Faigel, Douglas O Measures of patient radiation exposure during endoscopic retrograde cholangiography: beyond fluoroscopy time 2015	Nonexperimental		n/a	n/a	Fluoroscopy time and DAP		IIIB
67	Lazarus, Matthew S, Taragin, Benjamin H, Malouf, William, et al Radiation dose monitoring in pediatric fluoroscopy: comparison of fluoroscopy time and dose-area product thresholds for identifying high-exposure cases 2019	Nonexperimental	1,011 pediatric fluoroscopy cases	n/a	n/a	Relationship between DAP and fluoroscopy time	Limited correlation exists between fluoroscopy time and DAP	IIIA
68	Bonilha, Heather S, Wilmskoetter, Janina, Tipnis, Sameer, Horn, Janet, Martin-Harris, Bonnie and Huda, Walter Relationships Between Radiation Exposure Dose, Time, and Projection in Videofluoroscopic Swallowing Studies 2019	Nonexperimental	200 adults having barium swallows	n/a	n/a	DAP, radiation exposure time, and projection	Radiation time and DAP do not correlate the DAP should be the unit used for measuring radiation exposure	IIIB
69	Ghelani, Sunil J, Glatz, Andrew C, David, Sthuthi, et al Radiation dose benchmarks during cardiac catheterization for congenital heart disease in the United States 2014	Nonexperimental	2,713 pediatric patient having interventional catheterization for congenital heart disease	n/a	n/a	Radiation dose and fluoroscopy time	Fluoroscopy time should not be used for calculation of radiation dose.	IIIA
70	Skripochnik, Edvard, Loh, Shang A Fluoroscopy time is not accurate as a surrogate for radiation exposure 2017	Nonexperimental	145 patients having lower extremity endovascular interventions	n/a	n/a	Fluoroscopy time, DAP, air Kerma	Fluoroscopy time is not a good substitute to DAP or air Kerma for measuring radiation dose/	IIIB
71	Wilson, Sharon M, Prasan, Ananth M, Virdi, Amy, et al Real-time colour pictorial radiation monitoring during coronary angiography: effect on patient peak skin and total dose during coronary angiography 2016	Quasi-experimental	589 patient having coronary angiography and intervention procedures with real time skin does measurement and 488 without.	Use of real time skin dose monitoring	No monitoring	Radiation dose	Patient dose was decreased with the use of a real time skin dose measurement system	IIB

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72	Baumann, Frederic, Katzen, Barry T, Carelsen, Bart, Diehm, Nicolas, Benenati, James F and Pena, Constantino S The Effect of Realtime Monitoring on Dose Exposure to Staff Within an Interventional Radiology Setting 2015	Quasi-experimental	Intervention radiology procedures (88 control, 50 learning, 114 intervention)	Use or real time dosimetry	No real time dosimetry	Radiation dose	Real time dosimetry decreases the radiation dose received by staff.	IIB
73	Muller, M C, Welle, K, Strauss, A, et al Real-time dosimetry reduces radiation exposure of orthopaedic surgeons 2014	Quasi-experimental	68 patients having various orthopedic procedures using fluoroscopy in both control and experimental group	Real time dosimetry	No real time dosimetry	Radiation dose	Real time dosimetry decreases the radiation dose received by staff.	IIB
74	Sailer, Anna M, Vergoossen, Laura, Paulis, Leonie, et al Personalized Feedback on Staff Dose in Fluoroscopy-Guided Interventions: A New Era in Radiation Dose Monitoring 2017	Quasi-experimental	27 physicians and technicians	Weekly individual dose feedback	No feedback	Radiation dose	Radiation dose was decreased with weekly reporting of dosimeter readings.	IIB
75	Heilmaier, Christina, Kara, Levent, Zuber, Niklaus, Berthold, Christian and Weishaupt, Dominik Combined Use of a Patient Dose Monitoring System and a Real-Time Occupational Dose Monitoring System for Fluoroscopically Guided Interventions 2016	Quasi-experimental	2 interventionalists performing 365 fluoroscopy guided procedures without real time and 355 with real time monitoring	Fluoroscopy guided procedures with real time monitoring	Fluoroscopy guided procedures without real time monitoring	Radiation dose	The radiation dose decreased when the real time monitoring system was used	IIB
76	Baumgartner, Rita, Libuit, Kiley, Ren, Dennis, et al Reduction of Radiation Exposure From C-Arm Fluoroscopy During Orthopaedic Trauma Operations With Introduction of Real-Time Dosimetry 2016	Quasi-experimental	39 patients without and 44 with real time monitoring.	Real time dosimetry	No real time dosimetry	Radiation dose.	The use of real time dosimetry decreases the dose received by the personnel measured.	IIB
77	Miller, Claire, Kendrick, Daniel, Shevitz, Andrew, et al Evaluating strategies for reducing scattered radiation in fixed-imaging hybrid operating suites 2018	Quasi-experimental	72 cardiovascular interventional procedures without real time monitoring. 34 with	Real time dosimetry	No real time dosimetry	Room radiation dose	The room radiation dose was reduced but not significantly	IIB
78	Racadio, John, Nachabe, Rami, Carelsen, Bart, et al Effect of real-time radiation dose feedback on pediatric interventional radiology staff radiation exposure 2014	Quasi-experimental	5 staff people during 97 IR procedures (control group) 148 IR procedures (experimental group)	Use of real time dosimetry	No real time dosimetry	Radiation dose	Real-time dosimetry decreased the radiation dose received by the staff	IIB
79	Adler, Douglas G, Lieb, John G, Cohen, Jonathan, et al Quality indicators for ERCP 2015	Guideline	n/a	n/a	n/a	n/a	Provides guidance for establishing a quality program	IVB

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80	Cousins, C, Miller, D L, Bernardi, G, et al ICRP Publication 120: Radiological Protection in Cardiology 2013	Guideline	n/a	n/a	n/a	n/a	Provides guidance for education, documentation and PPE.	IVB
81	ACR-AAPM Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures 2018	Guideline	n/a	n/a	n/a	n/a	Provides guidance on documentation, patient education,	IVB
82	Cupp, Scott L Radiation Protection in Computed Tomography 2016	Expert Opinion	n/a	n/a	n/a	n/a	Provides definition of deterministic and stochastic effects	VA
83	Phelps, Andrew S, Gould, Robert G, Courtier, Jesse L, Marcovici, Peter A, Salani, Christina and MacKenzie, John D How Much Does Lead Shielding during Fluoroscopy Reduce Radiation Dose to Out-of-Field Body Parts? 2016	Quasi-experimental	Laboratory using a phantom model	use of a flat or curved shield	no shield	Radiation dose	Use of a curved shield decreased the radiation dosage from	IIB
84	ACR-SPR Practice Guideline for General Radiography 2018	Guideline	n/a	n/a	n/a	n/a	Provides guidance on patient shielding and use of assistive devices for restraint and positioning.	IVB
85	Martus, Jeffrey E, Hilmes, Melissa A, Grice, Jared V, et al Radiation Exposure During Operative Fixation of Pediatric Supracondylar Humerus Fractures: Is Lead Shielding Necessary? 2018	Nonexperimental	18 pediatric patients have humerus fractures repaired	n/a	n/a	Radiation exposure at thyroid and gonads	Radiation exposure at thyroid and gonads is minimal with the use of shielding	IIIB
86	Kaplan, Summer L, Magill, Dennise, Felice, Marc A, Xiao, Rui, Ali, Sayed and Zhu, Xiaowei Female gonadal shielding with automatic exposure control increases radiation risks 2018	Quasi-experimental	Phantom	With gonad shield	Without shield	Radiation dose	Use of the gonadal shield increased the radiation dose when automatic exposure is on.	IIB
87	Lee, Mark C, Lloyd, Jessica and Solomito, Matthew J Poor Utility of Gonadal Shielding for Pediatric Pelvic Radiographs 2017	Nonexperimental	84 boys and girls having radiographs for orthopedic conditions	n/a	n/a	Percent of correctly placed shields.	Use of pelvic shielding should be discontinued	IIIB
88	Karami, Vahid, Zabihzadeh, Mansour, Shams, Nasim and Saki Malehi, Amal Gonad Shielding during Pelvic Radiography: A Systematic Review and Meta-analysis 2017	Systematic Review w/ Meta-Analysis	n/a	n/a	n/a	n/a	Gonad protection should be discontinued in females and radiographers need to be educated on how to place it in males	IIA
89	AAPM position statement on the use of patient gonadal and fetal shielding. American Association of Physicists in Medicine; 2019.	Guideline	n/a	n/a	n/a	n/a	Provides guidance on use of patient shielding	IVC
90	Culp, Melissa P, Jackowski, Melissa B and Barba, James R Shield Placement: Effect on Exposure 2014	Quasi-experimental	Subject was a phantom	Protective garment on anterior near source	Protective garment on posterior side with source on anterior side	Radiation dose	The radiation dose to peripheral areas was less when the protective garment was placed on the same side of the body as the source.	IIB
91	Hirshfeld, John W,Jr, Ferrari, Victor A, Bengel, Frank M, et al 2018 ACC/HRS/NASCI/SCAI/SCCT Expert Consensus Document on Optimal Use of Ionizing Radiation in Cardiovascular Imaging-Best Practices for Safety and Effectiveness, Part 2: Radiological Equipment Operation, Dose-Sparing Methodologies, Patient and Medical Personnel Protection 2018	Consensus	n/a	n/a	n/a	n/a	Recommendations for patient and personnel radiation protection.	IVA
92	ACR -SPR Practice Guideline for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation 2018	Guideline	n/a	n/a	n/a	n/a	Provides recommendations for caring for a pregnant patient	IVB

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REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
93	Chatterson, Leslie C, Leswick, David A, Fladeland, Derek A, Hunt, Megan M, Webster, Stephen and Lim, Hyun Fetal shielding combined with state of the art CT dose reduction strategies during maternal chest CT 2014	Quasi-experimental	Laboratory phantom	Use of shield	No shield	Radiation dose to fetus	Fetal radiation dose is decreased with the use of a shield.	IIB
94	Moore, William, Bonvento, Michael J, Lee, Dwight, Dunkin, Jared and Bhattacharji, Priya Reduction of fetal dose in computed tomography using anterior shields 2015	Quasi-experimental	Laboratory phantom at 1 & 18 week gestation	Use of shield	No shield	Radiation dose to fetus	Fetal radiation dose is decreased with the use of a shield.	IIB
95	RSNA statement on safety of the developing fetus in medical imaging during pregnancy . Radiological Society of North America.	Guideline	n/a	n/a	n/a	n/a	Provides guidance on patient shielding	IVC
96	Al Kharji, Samah, Connell, Tanner, Bernier, Martin and Eisenberg, Mark J Ionizing Radiation in Interventional Cardiology and Electrophysiology 2019	Expert Opinion	n/a	n/a	n/a	n/a	Recommends documentation of radiation dose.	VB
97	Giarrizzo-Wilson, Sharon, Conner, Ramona Guideline for Patient Information Management 2020	Guideline	n/a	n/a	n/a	n/a	Provides guidance for documentation on the patients medical record.	IVA
98	Choi, Beatrix H, Yaya, Kamalou, Prabhu, Vinay, et al Simple preoperative radiation safety interventions significantly lower radiation doses during central venous line placement in children 2019	Quasi-experimental	59 pediatric patients having an insertion of a central line in the OR pre-implementation and 41 post implementation	Briefing and time out	No briefing or time out	Radiation dose and time	Implementation of the briefing and time out significantly decreased the radiation dose and the radiation time.	IIB
99	Aizer, Anthony, Qiu, Jessica K, Cheng, Austin V, et al Utilization of a Radiation Safety Time-Out Reduces Radiation Exposure During Electrophysiology Procedures 2019	Nonexperimental	1,040 Electrophysiology procedures	n/a	n/a	Dose area product, reference point dose, fluoroscopy time, use of additional shielding, and use of alternative imaging modalities	The time out reduced radiation exposure and increased use of protective shields and alternative imaging modalities.	IIIA
100	Yu, Elizabeth, Khan, Safdar N Does less invasive spine surgery result in increased radiation exposure? A systematic review 2014	Systematic Review	n/a	n/a	n/a	n/a	Standing on the contralateral side and increasing the distance from the source will decrease the amount of radiation exposure.	IIIB
101	Lee, Jae-Eun, Kim, Ju-Hyun, Lee, Su-Jin, et al Does nonexistent of your hands on the screen guarantee no radiation exposure to your body? - Study on exposure of the practitioner's hands to radiation during C-arm fluoroscopy-guided injections and effectiveness of a new shielding device 2019	Nonexperimental	Laboratory study using a phantom	n/a	n/a	Radiation dose		IIIB
102	Sailer, Anna M, Paulis, Leonie, Vergoossen, Laura, Wildberger, Joachim E and Jeukens, Cecile R L P N Optimizing Staff Dose in Fluoroscopy-Guided Interventions by Comparing Clinical Data with Phantom Experiments 2019	Quasi-experimental		Use of table lead curtain, tableside and ceiling suspended shielding. Dose on step back	No shielding. Dose at field	Radiation dose	The use of table lead curtain, tableside and ceiling suspended shielding and stepping back from the source decreased operator radiation dose	IIB
103	Schuetze, K, Kraus, M, Eickhoff, A, Gebhard, F and Richter, P H Radiation exposure for intraoperative 3D scans in a hybrid operating room: how to reduce radiation exposure for the surgical team 2018	Quasi-experimental	Laboratory study	Dose reduction protocol	Standard protocol	Radiation dose	There is a quadratic relation between distance and radiation dose. Greater distance less dose.	IIB

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104	Kendrick, Daniel E, Miller, Claire P, Moorehead, Pamela A, et al Comparative occupational radiation exposure between fixed and mobile imaging systems 2016	Nonexperimental	116 endovascular cases	n/a	n/a	Radiation dose	Personnel over 6 ft. from the source received a negligible dose of radiation.	IIIB
105	Urakov, Timur M Practical Assessment of Radiation Exposure in Spine Surgery 2018	Nonexperimental	Simulated spine surgery with fluoroscopy	n/a	n/a	Radiation exposure	Radiation values are decreased to baseline at 14 ft. in front of source and 8 ft. behind	IIIB
106	Heilmaier, C, Mayor, A, Zuber, N, Fodor, P and Weishaupt, D Improving Radiation Awareness and Feeling of Personal Security of Non-Radiological Medical Staff by Implementing a Traffic Light System in Computed Tomography 2016	Quasi-experimental	56 non-radiology staff members	Application of marking system to indicate radiation exposure amounts	No marking system	Feeling of personnel radiation safety	An increased sense of security was achieved with the use of the indicator system.	IIB
107	Rhea, E B, Rogers, T H and Riehl, J T Radiation safety for anaesthesia providers in the orthopaedic operating room 2016	Systematic Review w/ Meta-Analysis	n/a	n/a	n/a	n/a	The need for lead aprons to be worn by the anesthesia care professional is questionable if the person is at least 1.5 meters from the source.	IIIA
108	Valone, Lindsey C, Chambers, Monique, Lattanza, Lisa and James, Michelle A Breast Radiation Exposure in Female Orthopaedic Surgeons 2016	Quasi-experimental	Phantom of a female chest	Large and small garments	Proper fit garment	Radiation dose to upper outer quadrant and inner lower quadrant of the breast.	An apron that fits properly provides the greatest amount of protection and that manufacturers should devise an apron with wings to protect the breasts	IIB
109	Tavares, J B, Sacadura-Leite, E, Matoso, T, et al The importance of protection glasses during neuroangiographies: A study on radiation exposure at the lens of the primary operator 2016	Nonexperimental	4 neuroradiologists performing 7 diagnostic and 6 interventional neuroangiographies	with radioprotective glasses	without radioprotective glasses	Eye radiation dose.	The use of eye protection reduced does to the eye.	IIIC
110	Fetterly, Kenneth, Schueler, Beth, Grams, Michael, Sturchio, Glenn, Bell, Malcolm and Gulati, Rajiv Head and Neck Radiation Dose and Radiation Safety for Interventional Physicians 2017	Nonexperimental	Laboratory using a phantom			Radiation dose to brain and eyes	Reduction in dose was found with glasses but only minimal reduction to the brain with cap.	IIIB
111	Matsubara, Kosuke, Lertsuwunseri, Vorarit, Srimahachota, Suphot, et al Eye lens dosimetry and the study on radiation cataract in interventional cardiologists 2017	Nonexperimental	48 Interventional Cardiology staff	n/a	n/a	Radiation dose inside and outside of protective eye wear	Protective eye wear reduced that amount of radiation received by the eye.	IIIA
112	Waddell, Bradford S, Waddell, W H, Godoy, Gustavo and Zavatsky, Joseph M Comparison of Ocular Radiation Exposure Utilizing Three Types of Lead Glasses 2016	Quasi-experimental	Phantom model	With radiation protection glasses	No glasses	Radiation dose to eyes	Radiation protective glasses reduced the radiation received by the eyes	IIB
113	Ekpo, Ernest U, Bakhshi, Suleman, Ryan, Elaine, Hogg, Peter and McEntee, Mark F Operator eye doses during computed tomography fluoroscopic lung biopsy 2016	Quasi-experimental	Phantom model	With protective glasses	No protective glasses	Radiation dose	Protective glasses reduce radiation exposure to the eyes	IIB
114	Hoffler, C E, Ilyas, Asif M Fluoroscopic radiation exposure: are we protecting ourselves adequately? 2015	Quasi-experimental	Laboratory study			Radiation dose	Gloves and eye protection should be worn.	IIB

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115	Honorio da Silva, Edilaine, Vanhavere, Filip, Struelens, Lara, Covens, Peter and Buls, Nico Effect of protective devices on the radiation dose received by the brains of interventional cardiologists 2018	Quasi-experimental	Phantom model	Protective ceiling screens, lead glasses and lead caps	No protective ceiling screens, lead glasses and lead caps	Amount of radiation received	The best protection is provided by a ceiling suspended screen when compared to lead glasses and 3 different style lead hats.	IIB
116	Sans Merce, Marta, Korchi, Amine M, Kobzeva, Lisa, et al The value of protective head cap and glasses in neurointerventional radiology 2016	Quasi-experimental	4 physician performing 32 procedures	With protective glasses and cap	without protective glasses and cap	Radiation dose at eyes and brain	Eye dose and brain dose were decreased by use of protective cap and eyeglasses.	IIB
117	Haga, Yoshihiro, Chida, Koichi, Kaga, Yuji, Sota, Masahiro, Meguro, Taichiro and Zuguchi, Masayuki Occupational eye dose in interventional cardiology procedures 2017	Quasi-experimental	9 physicians with eye protection, 3 physicians without eye protection and 11 nurses.	With eye protection	Without eye protection	Radiation dose and correlation between neck and eye dosimeters	Eye protection should be worn and neck dosimeters may be used to estimate the dose to the eye in nurses but not physicians.	IIB
118	Pomeroy, Christopher L, Mason, J B, Fehring, Thomas K, Masonis, John L and Curtin, Brian M Radiation Exposure During Fluoro-Assisted Direct Anterior Total Hip Arthroplasty 2016	Nonexperimental	3 surgeons performing 30 anterior total hip replacements.	n/a	n/a	Eye radiation levels	The surgeon should decide if eye protection is necessary.	IIIC
119	Alazzoni, Ashraf, Gordon, Chris L, Syed, Jaffer, et al Randomized Controlled Trial of Radiation Protection With a Patient Lead Shield and a Novel, Nonlead Surgical Cap for Operators Performing Coronary Angiography or Intervention 2015	RCT	10 operators, 230 cardiac interventional procedures	With protective drape, inside of cap	No protective drape, outside of cap	Radiation dose	The drape and the cap decreased the amount of scatter radiation received by the operator	IB
120	Reeves, Ryan R, Ang, Lawrence, Bahadorani, John, et al Invasive Cardiologists Are Exposed to Greater Left Sided Cranial Radiation: The BRAIN Study (Brain Radiation Exposure and Attenuation During Invasive Cardiology Procedures) 2015	Nonexperimental	11 physicians conducting 66.2 interventional cardiology procedures per physician	n/a	n/a	Radiation level of the brain.	A protective cap decreases the amount of radiation received by the brain.	IIIB
121	Kirkwood, Melissa L, Arbiq, Gary M, Guild, Jeffrey B, et al Radiation brain dose to vascular surgeons during fluoroscopically guided interventions is not effectively reduced by wearing lead equivalent surgical caps 2018	Nonexperimental	29 physicians and assistants performing endovascular aortic aneurysm procedures and 1 phantom	n/a	n/a	Radiation attenuation	Protective caps provide minimal protection	IIIB
122	Chohan, Muhammad O, Sandoval, Daniel, Buchan, Andrew, Murray-Krezan, Cristina and Taylor, Christopher L Cranial radiation exposure during cerebral catheter angiography 2014	Nonexperimental	24 adult neuroradiology procedures	n/a	n/a	Radiation dose to head	Use of protective skull cap decreases radiation dose to head.	IIIB
123	Kosaka, Hiroyuki, Monzen, Hajime, Matsumoto, Kenji, Tamura, Mikoto and Nishimura, Yasumasa Reduction of Operator Hand Exposure in Interventional Radiology With a Novel Finger Sack Using Tungsten-containing Rubber 2019	Quasi-experimental	Laboratory study using a hand	radiation protective finger sack	tungsten functional paper	Radiation dose	Radiation gloves decrease the amount of radiation received.	IIC
124	Kamusella, Peter, Scheer, Fabian, Ludtke, Christopher W, Wiggermann, Philipp, Wissgott, Christian and Andresen, Reimer Interventional Angiography: Radiation Protection for the Examiner by using Lead-free Gloves 2017	Nonexperimental	50 patients having angiograms			radiation dose to fingers	The use of radiation protective gloved decreased the amount of scatter radiation but increased when used in the direct x-ray beam.	IIIB
125	Calderwood, Audrey H, Chapman, Frank J, Cohen, Jonathan, et al Guidelines for safety in the gastrointestinal endoscopy unit 2014	Guideline	n/a	n/a	n/a	n/a	Guidance on wall protective barriers	IVC

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126	Guidelines for design and construction of hospitals 2018	Guideline	n/a	n/a	n/a	n/a	Provides guidance for building radiology suites in hospitals.	IVC
127	Guidelines for design and construction of outpatient facilities 2018	Guideline	n/a	n/a	n/a	n/a	Provides guidance for building radiology suites in out patient facilities	IVC
128	Sciahbasi, Alessandro, Sarandrea, Alessandro, Rigattieri, Stefano, et al Extended Protective Shield Under Table to Reduce Operator Radiation Dose in Percutaneous Coronary Procedures 2019	RCT	205 percutaneous coronary procedures	With the under table drape	Without under table drape	Operator radiation exposure	Operator radiation dose to thorax and pelvic region was decreased with use of the under table drape.	IA
129	Inoue, Takaaki, Komemushi, Atsushi, Murota, Takashi, et al Effect of Protective Lead Curtains on Scattered Radiation Exposure to the Operator During Ureteroscopy for Stone Disease: A Controlled Trial 2017	RCT	62 patients undergoing ureteroscopy without shielding curtains and 61 with the curtains.	Shielding curtains.	Without shielding curtains	Radiation dose of operator	The application of the shielding curtains reduced the radiation dose received by the operator.	IB
130	Madder, Ryan D, LaCombe, Andrew, VanOosterhout, Stacie, et al Radiation Exposure Among Scrub Technologists and Nurse Circulators During Cardiac Catheterization: The Impact of Accessory Lead Shields 2018	Quasi-experimental	401 patients undergoing cardiac interventional without radiation protective shield and 363 with additional shield	With protective shield	Without protective shield	Radiation dose	The use of an additional shield decreased the radiation dose to the circulator and the scrub technician	IIB
131	Crowhurst, James A, Scalia, Gregory M, Whitby, Mark, et al Radiation Exposure of Operators Performing Transesophageal Echocardiography During Percutaneous Structural Cardiac Interventions 2018	Quasi-experimental	50 procedures with ceiling-suspended shielding and 98 without	With ceiling-suspended shielding	Without ceiling-suspended shielding	Radiation dose	The additional shielding decreased the radiation dose significantly	IIB
132	Etzel, Robin, Konig, Alexander M, Keil, Boris, Fiebich, Martin and Mahnken, Andreas H Effectiveness of a new radiation protection system in the interventional radiology setting 2018	Quasi-experimental	Laboratory study	Radiation protection garment	No protection garment	Radiation dose	The ceiling suspended radiation systems provided better protection than the two-piece apron suit plus thyroid collar and standard ancillary shields	IIB
133	Sciahbasi, Alessandro, Piccaluga, Emanuela, Sarandrea, Alessandro, et al Operator Pelvic Radiation Exposure During Percutaneous Coronary Procedures 2018	Nonexperimental	55 procedures with drape shield, 1973 without drape	n/a	n/a	radiation dose of operator	Use of a radiation drape decreased the radiation received by operator at thorax and pelvic region	IIIA
134	Hayre, C, Bungay, H, Jeffery, C, Cobb, C and Atutornu, J Can placing lead-rubber inferolateral to the light beam diaphragm limit ionising radiation to multiple radiosensitive organs? 2018	Quasi-experimental	Phantom patient model during an elbow exam.	With drape attached to source	Without drape	Radiation dose at radiosensitive organs	The use of the drape decreases the radiation dose significantly	IIB

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135	Madder, Ryan D, VanOosterhout, Stacie, Mulder, Abbey, et al Impact of robotics and a suspended lead suit on physician radiation exposure during percutaneous coronary intervention 2017	Quasi-experimental	Patients undergoing percutaneous coronary intervention with (n=123) and without (n=168) the application of a suspended radiation protective shield.	With a suspended radiation protective shield	Without a suspended radiation protective shield	Operator radiation dose	The application of the suspended radiation protective drape reduced the radiation dose received by the operator.	IIB
136	Ploux, Sylvain, Jesel, Laurence, Eschaliere, Romain, et al Performance of a radiation protection cabin during extraction of cardiac devices 2014	RCT	37 procedures involving extraction of a cardiac device	Use of the protective cabin	Without use of the protective cabin	Operator radiation exposure	The use of the cabin decreased the radiation dose to the operator	IB
137	Muniraj, Thiruvengadam, Aslanian, Harry R, Laine, Loren, et al A double-blind, randomized, sham-controlled trial of the effect of a radiation-attenuating drape on radiation exposure to endoscopy staff during ERCP 2015	RCT	100 patients having ERCP.	With shield applied	Without shield	Radiation dose to operator and assistant nurse	The drape significantly decreased the radiation dose to the operator and the assistant nurse	IB
138	Kohlbrener, Ryan, Lehrman, Evan D, Taylor, Andrew G, et al Operator Dose Reduction during Transjugular Liver Biopsy Using a Radiation-Attenuating Drape: A Prospective, Randomized Study 2018	RCT	31 patients with and without a radiation protective drape applied during transjugular liver biopsy	With radiation protective drape	Without radiation protective drape	Radiation dose of operator	The application of the radiation protective drape reduced the radiation dose received by the operator.	IB
139	Sciahbasi, Alessandro, Sarandrea, Alessandro, Rigattieri, Stefano, et al Staff radiation dose during percutaneous coronary procedures: Role of adjunctive protective drapes 2018	Quasi-experimental	79 patients without drape and 43 with drape	With protective drape	Without protective drape	Radiation dose to all staff in room	The application of the pelvic drape decreases the radiation dose to the entire staff in the room.	IIB
140	Jones, Michael A, Cocker, Mary, Khiani, Raj, et al The benefits of using a bismuth-containing, radiation-absorbing drape in cardiac resynchronization implant procedures 2014	Quasi-experimental	Patients having pacemaker insertion 16 with and 20 without radiation protective drape.	Protective drape applied	No protective drape	Radiation dose	Radiation protection drape should be used	IIB
141	Arrivi, Alessio, Pucci, G, Vaudo, G, et al Operators' radiation exposure reduction during cardiac catheterization using a removable shield 2020	Quasi-experimental	1610 cardiac cath without and 1670 with shield applied	Removable shield	No removable shield	Radiation exposure	The use of the shield decreased the dose to the operators arm	IIA
142	Dabin, Jeremie, Maeremans, Joren, Berus, Danielle, et al DOSIMETRY DURING PERCUTANEOUS CORONARY INTERVENTIONS OF CHRONIC TOTAL OCCLUSIONS 2018	Quasi-experimental	34 procedures without drape and 31 with drape.	Radioprotective drape	No drape	Radiation dose	The use of a radiation protective drape decreased the radiation dose to the operator	IIB
143	Corrigan, Frank E,3rd, Hall, Michael J, Iturbe, Jose M, et al Radioprotective strategies for interventional echocardiographers during structural heart interventions 2019	Nonexperimental	10 TAVR's with TTE-guidance	Use of a radioprotective shields	No shielding	Does to les, body and hand of interventional cardiologist and interventional echocardiographer	Dose was less when drape was used.	IIIB

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144	Power, S, Mirza, M, Thakorlal, A, et al Efficacy of a radiation absorbing shield in reducing dose to the interventionalist during peripheral endovascular procedures: a single centre pilot study 2015	Quasi-experimental	30 lower limb angioplasties with and without the radiation protection drape.	Application of protective drape	No protective drape, outside of cap	Radiation dose	The application of the drape decreased the radiation dose to the operator	IIB
145	Vlastra, Wieneke, Delewi, Ronak, Sjaauw, Krischan D, et al Efficacy of the RADPAD Protection Drape in Reducing Operators' Radiation Exposure in the Catheterization Laboratory: a Sham-Controlled Randomized Trial 2017	RCT	Interventional cardiac procedures 255 with shield, 255 without shield, 256 with sham shield	Shield	No shield, sham shield	Operator radiation dose	The use of the shield decreased the dose to the operator.	IB
146	Mayekar, Emily M, Bayrak, Aysel, Shah, Smiresh and Mejia, Alfonso Radiation Exposure to the Orthopaedic Surgeon and Efficacy of a Novel Radiation Attenuation Product 2017	Quasi-experimental	51 orthopedic cases	With bismuth and barium fabric	With lead protection	Radiation dose	The bismuth/barium lead alternative is effective at reducing the radiation dose.	IIB
147	Uthoff, Heiko, Benenati, Matthew J, Katzen, Barry T, et al Lightweight bilayer barium sulfate-bismuth oxide composite thyroid collars for superior radiation protection in fluoroscopy-guided interventions: a prospective randomized controlled trial 2014	RCT	135 operators with bilayer barium sulfate-bismuth oxide composite thyroid collars and 121 0.5 mm lead thyroid collars worn during fluoroscopy guided vascular procedures	bilayer barium sulfate-bismuth oxide composite thyroid collars	0.5 mm lead thyroid collars	Radiation dose	The bilayer barium sulfate-bismuth oxide composite thyroid collars are more effective than the lead collars	IB
148	Monzen, Hajime, Tamura, Mikoto, Shimomura, Kohei, et al A novel radiation protection device based on tungsten functional paper for application in interventional radiology 2017	Quasi-experimental	Laboratory study using multiple layers of tungsten			Scattered radiation dose	Radiation dose was decreased with the use of layers of tungsten	IIB
149	Kijima, Kenta, Krisanachinda, Anchali, Tamura, Mikoto, Monzen, Hajime and Nishimura, Yasumasa Reduction of Occupational Exposure Using a Novel Tungsten-Containing Rubber Shield in Interventional Radiology 2019	Quasi-experimental	Laboratory phantom	Tungsten drape	Lead drape	Radiation dose	The tungsten drape effectively lowered the radiation dose more than the lead drape.	IIB
150	Lichliter, Andrew, Weir, Victor, Heithaus, Robert E, et al Clinical Evaluation of Protective Garments with Respect to Garment Characteristics and Manufacturer Label Information 2017	Quasi-experimental	16 different protective garments from 3 different brands. Some lead and others not lead.	Non-lead garments	Lead based garments	Radiation dose to mannequin	Various manufacturer labels are not always consistent.	IIB
151	Fakhoury, Elias, Provencher, Jo-Ann, Subramaniam, Raja and Finlay, David J Not all lightweight lead aprons and thyroid shields are alike 2019	Quasi-experimental	6 types of radiation protection garments	Non-lead aprons	Lead aprons	Radiation penetration	Assess the amount of protection of a garment before purchase.	IIB
152	Lange, Victor R Eyewear contamination levels in the operating room: Infection risk 2014	Quasi-experimental	315 pieces of eyewear			Bacterial contamination	Eyewear is contaminated and can be a source for cross-contamination	IIB

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153	Jain, Sameer, Rajfer, Rebecca A, Melton-Kreft, Rachel, et al Evaluation of bacterial presence on lead X-ray aprons utilised in the operating room via IBIS and standard culture methods 2019	RCT	20 radiation protective aprons	After cleaning	Before cleaning	Presence of bacteria	Aprons should be cleaned immediately before use because of the presence of certain bacteria recurring after 6 hours	IC
154	Boyle H, Strudwick RM. "Do lead rubber aprons pose an infection risk?". Radiography. 2010;16(4):297-303.	Nonexperimental	19 aprons each cultured at 4 sites	n/a	n/a	Positive cultures	Shields should be cleaned per policy and procedure	IIIC
155	Grogan BF, Cranston WC, Lopez DM, et al. Do protective lead garments harbor harmful bacteria? Orthopedics. 2011;34(11):e765-7.	Nonexperimental	182 swabs of vests, skirts and thyroid shield	n/a	n/a	Positive cultures	Shields should be cleaned at least weekly	IIIB
156	La Fauci V, Riso R, Facciola A, Merlina V, Squeri R. Surveillance of microbiological contamination and correct use of protective lead garments. <i>Ann Ig</i> . 2016;28(5):360-366. [IIIB].	Nonexperimental	19 thyroid shields, 45 over-the shoulder vests and 45 wrap-around skirts	n/a	n/a	Positive cultures	Shields should be cleaned	IIIB
157	Feierabend S, Siegel G. Potential infection risk from thyroid radiation protection. <i>J Orthop Trauma</i> . 2015;29(1):18-20. [IIIC].	Nonexperimental	32 thyroid shields	n/a	n/a	Positive cultures	Shields should be cleaned between cases	IIIC
158	<i>Best practices for environmental cleaning in healthcare facilities: In resource-limited settings. version 2.</i> US Department of Health and Human Services, CDC; Infection Control Africa Network; 2019.	Guideline	n/a	n/a	n/a	n/a	Protective garments should be cleaned daily.	IVB
159	deKay, Karen Guideline for Environmental Cleaning 2020	Guideline	n/a	n/a	n/a	n/a	Provides guidance for environmental cleaning.	IVA
160	Downes, Jessica, Rauk, Philip N and Vanheest, Ann E Occupational hazards for pregnant or lactating women in the orthopaedic operating room 2014	Expert Opinion	n/a	n/a	n/a	n/a	Pregnant employees should wear protective aprons and possibly wear double thickness aprons.	VB
161	Ghatan, Christine E Understanding and Managing Occupational Radiation Exposure for the Pregnant Interventional Radiology Nurse 2020	Literature Review	n/a	n/a	n/a	n/a	Provides guidance on precautions for pregnant employees.	VA
162	Marx, M V Baby on Board: Managing Occupational Radiation Exposure During Pregnancy 2018	Expert Opinion	n/a	n/a	n/a	n/a	Wear correctly sized aprons and even extra radiation protection when pregnant and wear dosimeter also in the abdomen	VB
163	Chen, Stephanie H, Brunet, Marie-Christine Fetal radiation exposure risk in the pregnant neurointerventionalist 2020	Nonexperimental	758 cases	n/a	n/a	Radiation dose under the apron	It is safe for pregnant women to perform interventional radiology cases if proper are taken.	IIIC
164	Gerasia, Roberta, Ligresti, Dario, Cipolletta, Fabio, et al Endoscopist's occupational dose evaluation related to correct wearing of dosimeter during X-ray-guided procedures 2019	Quasi-experimental	62 radiology procedures on adults and pediatric patients	Dosimeter placed on back or side	Dosimeter on chest	Radiation dose	The level of radiation is highest on the side of the body that is closest to the source.	IIB

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165	Funao, Haruki, Ishii, Ken, Momoshima, Suketaka, et al Surgeons' exposure to radiation in single- and multi-level minimally invasive transforaminal lumbar interbody fusion; a prospective study 2014	Nonexperimental	Finger of surgeon involved in 31 minimally invasive transforaminal lumbar interbody fusion	n/a	n/a	Radiation dose of right middle finger	Hand radiation dose should be measured because it has the highest radiation dose when compared to eye, thyroid, chest, and genitals,	IIIB
166	Betti, Margherita, Mazzoni, Lorenzo N, Belli, Giacomo, et al Surgeon eye lens dose monitoring in catheterization lab: A multi-center survey: Invited for ECMP 2018 Focus Issue 2019	Nonexperimental	15 physician operators in a Cath lab	n/a	n/a	Lens dose measured with temporal dosimeter	Eye dosimeters should be worn	IIIA
167	10 CFR 20.1802 control of material not in storage. Washington, DC: Government Publishing Office [for] Nuclear Regulatory Commission; 2020.	Regulatory	n/a	n/a	n/a	n/a	Regulation on controlling material not in storage.	n/a
168	Kimura, Fuyo, Yoshimura, Mana, Koizumi, Kiyoshi, et al Radiation exposure during sentinel lymph node biopsy for breast cancer: effect on pregnant female physicians 2015	Nonexperimental	146 medical staff members (surgeons, anesthesiologists, 1st & 2nd assistant and scrub persons)	n/a	n/a	Radiation levels	The principals of time, distance, and shielding decrease the amount of exposure during a procedure a sentinel lymph node biopsy using a radionuclide	IIIB
169	ACRâ€”SPR Technical Standard for Diagnostic Procedures Using Radiopharmaceuticals 2016	Guideline	n/a	n/a	n/a	n/a	Provides guidance for use of radiopharmaceuticals	IVC
170	Bruchmann, Iris, Szermerski, Bastian, Behrens, Rolf and Geworski, Lilli Impact of radiation protection means on the dose to the lens of the eye while handling radionuclides in nuclear medicine 2016	Quasi-experimental	Laboratory study	Leaded glasses	Laboratory glasses	Radiation doses to the eye when Tc-99, I-131, Y-90, F-18 and Ga-68 were administered	The radiation doses to the eye when Tc-99, I-131, Y-90, F-18 and Ga-68 were administered varied with the agent used.	IIB
171	Yonekura, Y, Mattsson, S, Flux, G, et al ICRP Publication 140: Radiological protection in therapy with radiopharmaceuticals 2019	Guideline	n/a	n/a	n/a	n/a	Provides guidance for administration of radionuclides	IVB
172	Common radioactive isotopes. Radiation Emergency Preparedness and Response Web site. https://www.osha.gov/SLTC/emergencypreparedness/radiation/radioactive_isotopes.html .	Expert Opinion	n/a	n/a	n/a	n/a	Provides guidance for protections with multiple radionuclides.	VA
174	Miller, Donald L Make Radiation Protection a Habit 2018	Expert Opinion	n/a	n/a	n/a	n/a	Provides guidance on handling radionuclides	VB
176	Conner, Ramona, Kyle, Erin and Wood, Amber Guideline for Sterilization 2020	Guideline	n/a	n/a	n/a	n/a	Provides recommendations for sterilization of seeds	IVA
173	Michel R, Hofer C. Radiation safety precautions for sentinel lymph node procedures. <i>Health Phys</i> . 2004;86(2):S35-7. [VB].	Expert Opinion	n/a	n/a	n/a	n/a	provides guidance on safety precautions during a sentinel lymph node procedure using radionuclides	VB
177	Khan, Shoukat, Syed, At, Ahmad, Reyaz, Rather, Tanveer A, Ajaz, M and Jan, Fa Radioactive waste management in a hospital 2010	Expert Opinion	n/a	n/a	n/a	n/a	Describes different methods for disposing of radioactive waste.	VB
175	Wood A, Conner R. Guideline for prevention of retained surgical items. In: Conner R, ed. Guidelines for perioperative practice. e-Guidelines+ ed. Denver, CO: AORN; 2020.	Guideline	n/a	n/a	n/a	n/a	Provides guidance on procedure for accounting of items in surgery	IVA
178	10 CFR 201905: Exemptions to labeling requirements 2019	Regulatory	n/a	n/a	n/a	n/a	Provides guidance for labeling of containers of radioactive materials	n/a

AORN Guideline for Radiation Safety
Evidence Table

REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
179	10 CFR 20 subpart K: Waste disposal. 1-1-20 ed. Washington, DC: Government Publishing Office [for] Nuclear Regulatory Commission; 2020.	Regulatory	n/a	n/a	n/a	n/a	Provides guidance for disposal of radioactive waste.	n/a
180	Spry C, Conner R. Guideline for cleaning and care of surgical instruments. In: Conner R, ed. <i>Guidelines for perioperative practice</i> . e-Guidelines+ ed. Denver, CO: AORN; 2020. [IVA].	Guideline	n/a	n/a	n/a	n/a	Provides guidance on cleaning of instruments	IVA
181	Miner TJ, Shriver CD, Flicek PR, et al. Guidelines for the safe use of radioactive materials during localization and resection of the sentinel lymph node. <i>Annals of Surgical Oncology</i> . 1999;6(1):75-82.	Quasi-experimental	24 tissue specimens and 318 lymph nodes	Radiation readings of tissue, dosimeter chips in gloves, and of OR items (eg, sponges, garments, linen).	Compared against nonreactivity and 0.002 µCi/g of excised tissue radioactivity minimum level set by the US Department of Transportation.	Amount of radiation in the specimen and length of time to become nonreactive. Radiation readings from sterilized dosimeter chips placed in surgical gloves and readings from sponges, linen, and garments from the OR.	No significant dose was found on the hands of surgeons. Dosimeters are not required for surgical staff performing these procedures. No evidence was found for contamination of the OR or in OR waste, no special waste disposal is required. Education of personnel is helpful to reduce concerns.	IIB
182	Safety is No Accident: A Framework for Quality Radiation Oncology Care 2019	Consensus	n/a	n/a	n/a	n/a	Provides guidance on educational content for brachytherapy	IVC
183	Erickson, Beth A, Demanes, D J, Ibbott, Geoffrey S, et al American Society for Radiation Oncology (ASTRO) and American College of Radiology (ACR) Practice Guideline for the Performance of High-Dose-Rate Brachytherapy 2011	Guideline	n/a	n/a	n/a	n/a	Provides guidance on safe administration of brachytherapy.	IVC
184	Keller BM, Pignol J, Rakovitch E, Sankreacha R, O'Brien P. A radiation badge survey for family members living with patients treated with a 103Pd permanent breast seed implant. <i>International Journal of Radiation Oncology*Biophysics*Physic</i> . 2008;70(1):267-271	Nonexperimental	61 family members or spouses of patients having breast seed implants.	n/a	n/a	Radiation dose received by family and friends	Breast patches should be worn when the patient having a radioactive breast implant is in the presence of toddlers or pregnant women.	IIIB
185	Kaulich TW, Bamberg M. Radiation protection of persons living close to patients with radioactive implants. <i>Strahlentherapie und Onkologie</i> . 2010;186(2):107-112.	Nonexperimental	Calculations of distance and radiation dose when wearing protective shorts	n/a	n/a	Proposed radiation dose	Wearing x-ray protective clothing decreases the radiation dose to family and caregivers of a patient with a radionuclide implant.	IIIC
186	Yondorf, Menachem Z, Schwartz, Theodore H, Boockvar, John A, et al Radiation Exposure and Safety Precautions Following 131Cs Brachytherapy in Patients with Brain Tumors 2017	Nonexperimental	20 patients with Cesium-131 seeds placed in the brain.	n/a	n/a	Radiation dose at surface, 35 cm and 100 cm away from patient	Dose varies by the number of seeds implanted and dace received by family is safe.	IIIB