



Diagnostic and Interventional CT Shielding: A Dramatic Decrease in Scattered Radiation for Patients.

Poster: 181
Congress: SIR 2006
Type: Scientific Exhibit
Topic: 2006 SIR - VASCULAR IMAGING: / Angiography
Authors: D. Sudheendra; Bethesda/US

Keywords: Radiation Protection, Diagnostic CT, CT-Fluoroscopy

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS™ by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply SIR's endorsement, sponsorship or recommendation of the third party, information, product, or service. SIR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold SIR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

<http://www.sirweb.org>

1. Purpose

In attempt to reduce the scattered radiation to the patient during diagnostic CT scanning and CT fluoroscopy-guided procedures, a novel tungsten antimony shielding device was used, and its effects on scattered radiation to lens, thyroid, breast, and gonads were studied on both adult and pediatric phantoms.

2. Methods and Materials

MATERIALS

Using a 16 multi slice Phillips Mx8000 IDT CT scanner (Phillips Medical Systems, Cleveland, OH) scattered radiation to adult and pediatric anthropomorphic phantoms was measured with an electronic dosimeter to several organs that are sensitive to radiation scatter: the male and female gonads, thyroid gland, lens, and breast. For both adult and pediatric phantoms, scattered radiation measurements were taken with and without shielding during multiple routine diagnostic computed tomography (CT) protocols and four routine CT-fluoroscopy (CTF) interventional procedures (Tables 1 & 2).

TABLE 1: Diagnostic CT scan protocols in which scattered radiation was measured.

[see Mediafile \[2\]](#)

TABLE 2: Interventional CT-Fluoroscopy procedures for which scattered radiation was measured.

[see Mediafile \[6\]](#)

Phantom

The anthropomorphic RANDO® phantom (The Phantom Laboratory, Salem, NY) is a natural human skeleton that has been reconstructed with a proprietary urethane formulation that simulates muscle tissue with randomly distributed fat (Figure 2). For more info, visit <http://www.phantomlab.com>

Dosimeter

The dosimeter (Educational Direct Dosimeter, Unfors Instruments, Billdall Sweden) provides an immediate measurement of the radiation dose and dose rate to a body part via a small sensor that is attached to a cable. In order to provide more accurate measurements of scattered radiation to a specified body region, the sensor is small enough to be placed on the surface or between the body slices of the phantom. In addition, the sensor can measure scattered radiation from all angles and is easily resettable (Figures 3 & 4).

Shielding

The RadPad (Worldwide Innovations and Technologies, Overland Park, KS) shielding device is a tungsten antimony lead-free material weighing less than 3 lbs. and having dimensions of 2 x 6 feet and less than 5 mm in thickness. For each diagnostic and interventional modality, radiation dose measurements were performed first without shielding and then with the shield wrapped around the phantom in various geometries.

METHODS

Diagnostic CT Scanning

Scattered radiation was measured with and without shielding during the diagnostic CT scan protocols described above (Table 1). The phantom was shielded in four different geometries: one layer 180° (Figure 5), two layers 180°, one layer 360°, and two layers 360°. Commercially available CT scan parameters for head, chest, abdominal, and pelvic CT were used (Table 3).

Interventional CT-Fluoroscopy (CTF) Procedures

Similarly, scattered radiation was measured with and without shielding during adult and pediatric CTF procedures (Table 2 above) of variable length. In order to standardize the simulated procedures (1-30 frames at approximately 1.2 frames per second), the duration of the procedure was defined as the number of frames used, rather than an actual length of the procedure. Three different shielding configurations were used: one layer 180°, one layer 360°, and two layers 360°. A window of 5 cm was left in the plane of shielding (2.5 cm cranial to and 2.5 cm caudal to the area of interest).

3. Results

A reduction in scattered radiation was seen in all configurations of diagnostic CT scanning and interventional CTF procedures for both adult and pediatric phantoms (Tables 4-7). Although the reduction in scattered radiation varied depending on the organ and its proximity to the epicenter of the radiation field, increasing layers of the RadPad resulted in less scattered radiation for all diagnostic CT protocols and nearly all CTF procedures -- the most reduction seen with a double layer of 360° shielding.

Diagnostic CT Shielding

The most reduction from shielding was observed in the lens on all configurations of chest, abdomen, and pelvic CT scanning in both adult and pediatric phantoms. With double layered 360° shielding in the adult phantom during pelvic CT, the maximum scattered radiation reduction was 43%, 92%, 81% and 74% to the lens, gonads, thyroid, and breast, respectively. (Figures 6 & 7-- Note: In order to better delineate the reduction in radiation scatter to the lens, thyroid, and breast, Figure 7 presents the corresponding data in log scale.)

During diagnostic head CT in the pediatric phantom, the reduction in scattered radiation with single layer 180° shielding (Table 5A) was 24%, 15% and 22% to the female gonads, male gonads, and breast, respectively. With double layer 360° shielding, this reduction was maximized to 89%, 80%, and 55%, respectively, (Figure 8).

Interventional CT-Fluoroscopy (CTF) Procedures

Accordingly, as the number of frames per second increased during CTF procedures, the amount of scattered radiation also increased (Table 6). While a minimal reduction in scattered radiation was seen with 180° of one layer shielding, a double layer of 360° shielding did provide a significant decrease in scattered radiation to the

adult and pediatric phantoms. During adult and pediatric abdominal procedures, one layer of 180° shielding resulted in a 12.6% and 5.4% reduction in scattered radiation to the eye, respectively. When a double layer of 360° shielding was used, this reduction dramatically increased to 92.3% and 84.8%, respectively (Figure 9). Similar reductions in scattered radiation were seen during adult and pediatric chest procedures (Table 7).

4. Conclusion

Although vastly improved equipment and safety conditions have dramatically reduced patient and personnel exposure to high levels of ionizing radiation, recent technological advances have markedly enhanced the clinical application of diagnostic radiology, most notably CT.¹ Medical radiation is the largest source of man-made radiation and the second largest source of radiation exposure next to natural background radiation. In large hospitals, CT scanning can account for up to 15% of all radiology procedures and nearly 75% of the radiation dose received by patients.² As a result, radiation doses from CT have piqued much interest recently in regards to potential cancer risk and other health hazards.

The Beir VII report³, for example, finds that a "linear-no-threshold" risk model exists regarding ionizing radiation. It supports the hypothesis that the risk of cancer increases in a linear fashion at lower doses without a minimum threshold. More importantly, even the smallest dose of radiation has the potential to cause a slight increase in cancer risk. When taking the above risk model into account, the increasing use of diagnostic CT and the high radiation exposure of CT-fluoroscopy presents a concern to both the patient and radiology personnel.

In this study, attempts to reduce the amount of scatter radiation with a tungsten antimony shield were performed in keeping with the As Low As Reasonably Achievable (ALARA) principle. Diagnostic CT and interventional CT-fluoroscopy (CTF) procedures were studied in anthropomorphic phantoms. Because the breast, lens, and gonads are frequently in the CT beam pathway and have a lack of overlying tissue to partially absorb some of the dose, these organs are particularly radiosensitive.⁴

In the United States, the number of pediatric abdominal and pelvic CT examinations on children less than 15 years old has increased 92% between 1996 and 1999⁵, especially in pediatric patients and young adults. Hence, both adult and pediatric phantoms were used in this study.

Our data shows that the tungsten antimony shield appears to be an ideal, lightweight, and durable shielding material for diagnostic CT scanning and interventional CTF procedures. While a single layer of 180° shielding provides some protection from scattered radiation, using a double layer of 360° protection provides the most benefit. Some organs, most notably the gonads in temporal bone CT, experience a reduction of nearly 100% in scattered radiation exposure with maximal shielding. This reduction is significant in the context of the increasing use of diagnostic CT in the pediatric population and their increased sensitivity to radiation as compared to adults.⁶ Additionally, the significant reduction in scattered radiation with shielding during CTF procedures which inherently has higher radiation exposure is a prime example of achieving the ALARA concept.

The use of shielding significantly reduces scattered radiation to the patient in an easy, painless, and inexpensive manner. The sterile pad is currently commercially available for \$39 US dollars per pad [verbal communication Worldwide Innovations and Technologies].

This study supports the rationale that protection from scattered radiation can be improved significantly and at a relatively low cost and inconvenience to the patient. Ongoing studies looking at scattered radiation to radiology

personnel during fluoroscopic and interventional CT procedures have been presented.⁷

5. References

1. Payne JT. CT radiation dose and image quality. Radiol Clin N Am 2005; 43: 953-962
2. Wiest PW, Locken JA, Heintz PH, Mettler FA. CT scanning: a major source of radiation exposure. Sem Ultrasound, CT, and MRI 2002; 23 (5): 402-410
3. BEIR VII: Health risks from exposure to low levels of ionizing radiation. The National Academies. Report in Brief. June 2005. <http://www.nap.edu/reportbrief/11340/11340rb.pdf>
4. Rehani MM, Bongartz G, Kalender W, et al. Managing X-ray dose in computed tomography: ICRP Special Task Force report. Ann ICRP 2000; 30: 7-45
5. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR 2001; 176: 289-296.
6. National Cancer Institute. Radiation and Pediatric Computed Tomography: A guide for health care providers. August 2002. <http://www.cancer.gov/cancertopics/causes/radiation-risks-pediatric-CT>
7. Sarin Shawn, Bradford J. Wood, John Jacobus, Ziv Neeman. CT Fluoroscopy Shielding - A Dramatic Decrease in Scattered Radiation For Both Patient and Operator. Hot topic scientific paper at the Society of Interventional Radiology (SIR) annual meeting 2004, Phoenix, AZ.

6. Personal Information

Ziv Neeman, MD; Deepak Sudheendra, MD; Jay Oberoi, BS; John Jacobus, MS, CHP; Bradford J. Wood, MD

Special Procedures

Department of Radiology

National Institutes of Health

Building 10, Rm 1C-660

Bethesda, MD 20892

7. Mediafiles

Mediafile 1:



FIGURE 2: Phantom with dosimeter displayed

Mediafile 2:

Diagnostic CT Scan Protocols	
•	<i>Sinuses-Orbits CT</i>
•	<i>Inner Ear-Temporal Bone CT</i>
•	<i>Head CT</i>
•	<i>Neck CT</i>
•	<i>Chest CT</i>
•	<i>High Resolution Chest CT</i>
•	<i>Chest-Abdomen CT</i>
•	<i>Chest-Abdomen-Pelvis CT</i>
•	<i>Abdomen CT</i>
•	<i>Abdomen-Pelvis CT</i>
•	<i>Pelvis CT</i>

Mediafile 3:

High Resolution Chest	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Exam	1027	71.28	40.09	41.67	52.90	48%
Thorax	1971	971.4	564.2	555.7	917.1	4%
Male Gonad	4.893	4.632	3.857	2.672	2.173	47%
Female Gonad	70.8	71.02	41.01	14.20	13.06	21%
Chest CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Exam	403.6	157.2	90.55	143.2	80.46	82%
Thorax	2228	2065	1970	1946	1889	15%
Male Gonad	71.29	23.66	20.11	16.33	12.18	83%
Female Gonad	147.7	136.3	128.2	94.40	87.72	42%
Chest-Abdomen CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Exam	480.2	352.3	164.7	154.0	164.4	76.76%
Thorax	2764	2215	2119	2181	2118	8.973%
Male Gonad	114.8	87.03	77.25	79.42	76.97	38.82%
Female Gonad	714.0	713.9	700.4	696.6	681.1	24.27%
Chest-Abdomen-Pelvis	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Exam	491.1	186.1	122.8	146.1	112.3	75.11%
Thorax	2608	2601	2512	2509	2312	13.02%
Male Gonad	178.4	138.9	120.1	1253	120.1	38.74%

TABLE 4B: Amount of Scattered Radiation During Diagnostic CT With and Without Shielding in Adults (cont.)

Mediafile 4:

Head CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Thorax	1711	822	1955	1163	1085	36%
Left Breast	129.0	62.36	30.74	25.21	14.66	89%
Male Gonad	2.687	1.378	1.188	0.530	0.326	87%
Female Gonad	3.868	3.319	2.611	1.011	0.831	82%
Lower ExtTB CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Thorax	1481	1199	1009	1156	1087	25.89%
Left Breast	71.51	23.68	16.79	20.90	13.05	81.73%
Male Gonad	1.874	0.790	0.497	0	0	100%
Female Gonad	1.877	1.187	0.843	0.614	0	100%
Sinuses/Orbits CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Thorax	1845	1793	1647	1663	1280	38.62%
Left Breast	99.91	32.55	24.86	31.18	17.18	82.74%
Male Gonad	2.373	1.120	0.763	0.471	0.315	86.73%
Female Gonad	2.046	1.801	1.200	0.613	0.335	83.62%
Spine CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Left Breast	112.9	260.7	268	274.8	268	20.96%
Right Breast	621.4	290.1	292.1	273.3	246.9	41.66%
Male Gonad	4.729	2.498	1.631	2.191	1.635	78.11%
Female Gonad	8.935	5.978	6.872	2.225	1.627	88.69%

TABLE 4A: Amount of Scattered Radiation During Diagnostic CT With and Without Shielding in Adults (cont.)

Mediafile 5:

Reference CT	Scan	Single IAP	Double IAP	Single IAP	Double IAP	Max. Decrease
Line	76.44	26.58	12.24	26.85	10.68	85%
Thorax	284.3	219.9	211.2	224.3	181.5	36%
Left Breast	2141	2134	2011	2033	1860	13.17%
Right Breast	2116	2147	2142	2158	2102	2.96%
Male Gonad	153.5	127.5	117.0	104.9	102.1	24%
Female Gonad	1567	1560	1197	1012	1003	6%

Reference PkA/C CT	Scan	Single IAP	Double IAP	Single IAP	Double IAP	Max. Decrease
Line	112.4	47.54	17.41	44.47	12.14	89.98%
Thorax	312.7	300.5	226.1	212.8	169.0	45.88%
Left Breast	2241	2240	2087	2090	1992	11.11%
Right Breast	2219	2248	2104	2162	2042	8.94%
Male Gonad	1390	1389	1394	1381	1227	34.88%

Table CT	Scan	Single IAP	Double IAP	Single IAP	Double IAP	Max. Decrease
Line	18.79	5.713	1.819	1.861	1.512	92%
Thorax	22.00	19.75	9.437	9.077	8.106	83%
Left Breast	148.4	56.34	49.99	59.41	34.98	74%
Right Breast	136	45.84	46.71	58.01	37.83	72.09%
Male Gonad	1493	1720	1613	1167	1084	43%

TABLE 4C: Amount of Scattered Radiation During Diagnostic CT With and Without Shielding in Adults (cont.)

Mediafile 6:

Interventional CT-Fluoroscopy (CTF) Procedures
• Adult Chest Procedure
• Adult Abdominal Procedure
• Pediatric Chest Procedure
• Pediatric Abdominal Procedure

Mediafile 7:

	Length (mm)	Collimation	Flashes (mm)	Increment (mm)	Scan Time (sec)	Vol (ATY)	mAs	FIL (°)
Head CT	144	16 x 1.5	5	21		120	350	22
Chest CT	220	16 x 1.5	5	5	6.79	120	150	
Abdominal CT	275	16 x 1.5	5	5	8.22	120	200	
Pelvic CT	210	16 x 1.5	5	5	6.53	120	200	

TABLE 3: Commercially available diagnostic CT scan parameters.

Mediafile 8:



FIGURE 2: Adult Anthropomorphic Phantom (The Phantom Laboratory, Salem, NY)

Mediafile 9:



FIGURE 3: Dosimeter (Educational Direct Dosimeter, Unfors Instruments, Billdall Sweden)

Mediafile 10:



FIGURE 4: Phantom with dosimeter displayed.

Mediafile 11:



FIGURE 5: One layer of shielding wrapped 180° around phantom.

Mediafile 12:

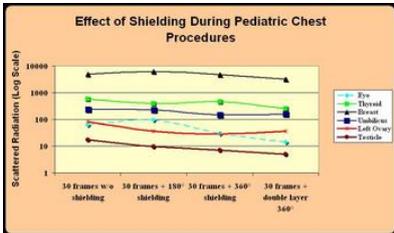
	1 Frame	3 Frames	15 Frames	30 Frames
Adult Chest Procedures				
Eye	1.970 µCv	15.04 µCv	76.37 µCv	151.54 µCv
Thyroid	6.481 µCv	32.39 µCv	96.81 µCv	185.2 µCv
Breast	1.974 µCv	7.663 µCv	22.52 µCv	43.87 µCv
Testicles	1.336 µCv	4.618 µCv	13.17 µCv	26.30 µCv
Left Ovary	0.292 µCv	1.432 µCv	4.301 µCv	8.606 µCv
Testis	0.132 µCv	0.633 µCv	1.936 µCv	3.876 µCv
Adult Abdomen Procedures				
Eye	6.176 µCv	3.851 µCv	2.476 µCv	1.570 µCv
Thyroid	0.239 µCv	1.184 µCv	3.566 µCv	7.130 µCv
Breast	2.149 µCv	10.75 µCv	32.28 µCv	64.66 µCv
Testicles	1.867 µCv	7.618 µCv	22.11 µCv	43.86 µCv
Left Ovary	0.133 µCv	0.679 µCv	2.023 µCv	4.047 µCv
Testis	1.057 µCv	5.279 µCv	15.81 µCv	31.78 µCv
Pediatric Chest Procedures				
Eye	2.296 µCv	10.71 µCv	34.47 µCv	63.61 µCv
Thyroid	19.46 µCv	97.52 µCv	293.1 µCv	583.5 µCv
Breast	166.1 µCv	833.6 µCv	2,506 µCv	5,007 µCv
Testicles	1.971 µCv	39.39 µCv	109.3 µCv	218.7 µCv
Left Ovary	2.757 µCv	13.8 µCv	41.81 µCv	82.76 µCv
Testis	0.57 µCv	2.834 µCv	8.522 µCv	17.04 µCv
Pediatric Abdominal Procedures				
Eye	8.401 µCv	2,208 µCv	6,423 µCv	13,317 µCv
Thyroid	1,769 µCv	8,835 µCv	26,55 µCv	53,17 µCv
Breast	7,572 µCv	37,39 µCv	113,3 µCv	226.8 µCv
Testicles	220.3 µCv	1,110 µCv	3,332 µCv	6,664 µCv
Left Ovary	29.26 µCv	146.6 µCv	439.3 µCv	878.7 µCv
Testis	4,118 µCv	20,57 µCv	61.7 µCv	123.64 µCv

TABLE 6: Scattered Radiation in Adult & Pediatric Phantoms WITHOUT Shielding During Interventional CT-Fluoroscopy Procedures.

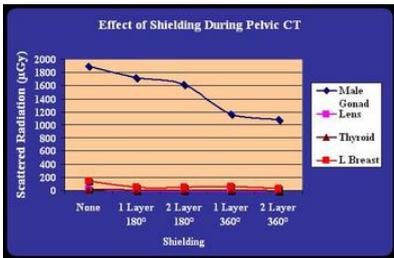
Mediafile 13:



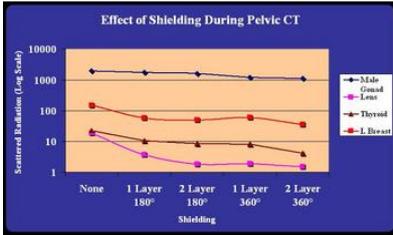
Mediafile 14:



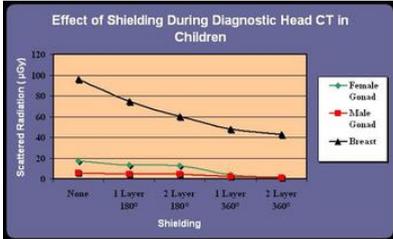
Mediafile 15:



Mediafile 16:



Mediafile 17:



Mediafile 18:

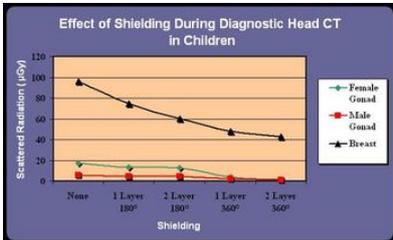


FIGURE 8: Effect of Shielding During Diagnostic Head CT in Children. A reduction in scattered radiation by 22.3% to the breast was seen with one layer of 180°. This reduction increased to 55% when a double layer of 360° shielding was used.

Mediafile 19:

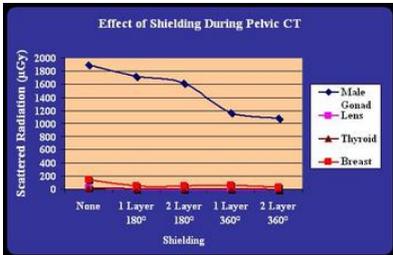


FIGURE 6: Effect of Shielding During Pelvic CT

Mediafile 20:

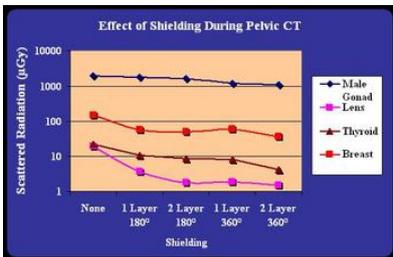


FIGURE 7: Logarithmic Graph of the Effect of Shielding During Pelvic CT. A reduction in scattered radiation by 92% was seen to the thyroid with increased shielding.

Mediafile 21:

Adult Chest Procedures	1 frame	5 frames	15 frames	30 frames
Eye	1.975 µSv	1.514 µSv	50.37 µSv	151.24 µSv
Thyroid	4.481 µSv	32.39 µSv	96.41 µSv	185.2 µSv
Breast	1.874 µSv	7.61 µSv	2.252 mSv	4.567 mSv
Testicles	1.335 µSv	4.643 µSv	11.27 µSv	31.89 µSv
Left Ovary	0.292 µSv	1.432 µSv	4.301 µSv	8.466 µSv
Testicle	0.152 µSv	0.433 µSv	1.376 µSv	3.9 µSv
Adult Abdomen Procedures	1 frame	5 frames	15 frames	30 frames
Eye	4.176 µSv	1.469 µSv	2.79 µSv	5.159 µSv
Thyroid	0.239 µSv	1.184 µSv	3.566 µSv	7.139 µSv
Breast	2.149 µSv	18.75 µSv	32.26 µSv	144.66 µSv
Testicles	1.863 µSv	7.84 µSv	2.214 mSv	4.543 mSv
Left Ovary	0.133 µSv	40.79 µSv	123.3 µSv	244.7 µSv
Testicle	1.057 µSv	5.273 µSv	15.81 µSv	31.78 µSv
Paediatric Chest Procedures	1 frame	5 frames	15 frames	30 frames
Eye	2.966 µSv	10.51 µSv	34.47 µSv	113.61 µSv
Thyroid	19.46 µSv	97.52 µSv	293.1 µSv	581.5 µSv
Breast	166.1 µSv	833.4 µSv	2.566 mSv	5.067 mSv
Testicles	1.97 µSv	86.79 µSv	189.3 µSv	289 µSv
Left Ovary	2.575 µSv	13.8 µSv	16.44 µSv	82.7 µSv
Testicle	0.57 µSv	2.834 µSv	8.322 µSv	17.64 µSv
Paediatric Abdominal Procedures	1 frame	5 frames	15 frames	30 frames
Eye	8.463 µSv	2.208 µSv	4.673 µSv	13.37 µSv
Thyroid	1.769 µSv	4.835 µSv	26.55 µSv	53.17 µSv
Breast	7.572 µSv	37.79 µSv	113.3 µSv	226.8 µSv
Testicles	220.3 µSv	1.118 mSv	3.563 mSv	4.433 mSv
Left Ovary	29.28 µSv	1.616 µSv	426.3 µSv	873.3 µSv
Testicle	4.118 µSv	20.47 µSv	61.5 µSv	123.64 µSv

TABLE 7: Scattered Radiation in Adult & Pediatric Phantoms WITH Shielding During Interventional CT-Fluoroscopy Procedures

Mediafile 22:

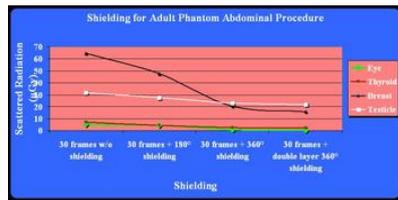


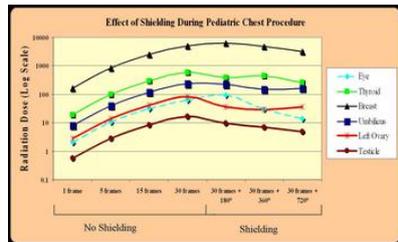
FIGURE 9: Shielding in Adult Phantom During Abdominal Procedure

Mediafile 23:

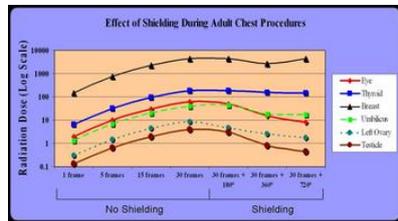
Adult Chest Procedures	30 frames + 180°	30 frames + 360°	30 frames + 360° (double layer)
Eye	14.62 µSv	16.93 µSv	8.2 µSv
Thyroid	153.4 µSv	154 µSv	148.7 µSv
Breast	4.442 mSv	2.735 mSv	4.473 mSv
Testicles	143.16 µSv	117.79 µSv	114.66 µSv
Left Ovary	4.543 µSv	2.802 µSv	1.748 µSv
Testicle	2.487 µSv	0.819 µSv	0.428 µSv
Adult Abdomen Procedures	30 frames + 180°	30 frames + 360°	30 frames + 360° (double layer)
Eye	1.413 µSv	2.916 µSv	6.11 µSv
Thyroid	4.474 µSv	2.805 µSv	2.112 µSv
Breast	47.39 µSv	20.4 µSv	15.89 µSv
Testicles	4.346 mSv	4.227 mSv	4.226 mSv
Left Ovary	1.984 µSv	1.003 µSv	1.01 µSv
Testicle	27.81 µSv	22.89 µSv	21.81 µSv
Paediatric Chest Procedures	30 frames + 180°	30 frames + 360°	30 frames + 360° (double layer)
Eye	146.0 µSv	202.0 µSv	14.12 µSv
Thyroid	388.4 µSv	454.1 µSv	298.9 µSv
Breast	6.204 mSv	4.748 mSv	3.285 mSv
Testicles	228.4 µSv	148.1 µSv	181.8 µSv
Left Ovary	36.13 µSv	28.23 µSv	38.1 µSv
Testicle	9.427 µSv	7.117 µSv	4.823 µSv
Paediatric Abdominal Procedures	30 frames + 180°	30 frames + 360°	30 frames + 360° (double layer)
Eye	1.81 µSv	4.822 µSv	2.566 µSv
Thyroid	18.31 µSv	20.97 µSv	16.38 µSv
Breast	158.4 µSv	137.8 µSv	134.2 µSv
Testicles	6.712 mSv	6.517 mSv	5.879 mSv
Left Ovary	166.2 µSv	218.4 µSv	154.1 µSv
Testicle	67.31 µSv	119.8 µSv	87.61 µSv

TABLE 7: Scattered Radiation in Adult & Pediatric Phantoms WITH Shielding During Interventional CT-Fluoroscopy Procedures

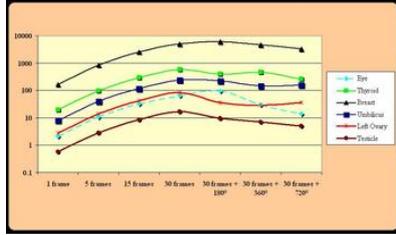
Mediafile 24:



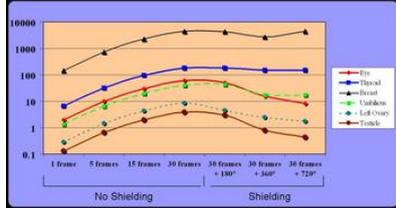
Mediafile 25:



Mediافile 26:



Mediافile 27:

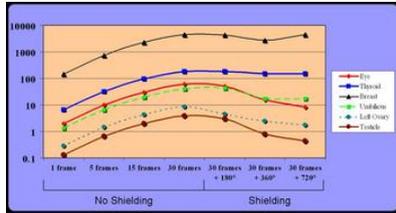


Mediافile 28:

Adult Chest Procedure	1 Frame	5 Frames	15 Frames	30 Frames	30 Frames + 180°	30 Frames + 360°	30 Frames + 720°
Eye	1.976 µSv	10.54 µSv	30.37 µSv	61.24 µSv	10.82 µSv	18.55 µSv	8.21 µSv
Thyroid	6.481 µSv	32.30 µSv	96.61 µSv	183.2 µSv	118.9 µSv	134 µSv	148.7 µSv
Breast	1.874 µSv	7.86 µSv	2.232 µSv	4.507 µSv	4.440 µSv	2.738 µSv	4.473 µSv
Uddicles	1.331 µSv	4.668 µSv	13.97 µSv	30.88 µSv	63.16 µSv	117.79 µSv	172.6 µSv
Left Ovary	0.792 µSv	1.432 µSv	4.361 µSv	8.698 µSv	4.943 µSv	2.802 µSv	1.748 µSv
Testicle	0.132 µSv	0.653 µSv	1.976 µSv	3.9 µSv	2.887 µSv	0.810 µSv	0.429 µSv

TABLE 6: Amount of Scattered Radiation During Interventional CT Procedures With and Without Shielding in Adults and Children

Mediافile 29:



Mediافile 30:

Head CT	Name	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Thyroid	1729	1484	1655	1515	1444	15%
Breast	26.02	24.53	40.33	48.22	43.01	60%
Male Gonad	4.528	4.475	4.330	2.642	1.022	80%
Female Gonad	17.86	13.27	12.30	3.926	1.875	90%

Pediatric CT table 1

Mediafile 31:

High Resolution Cerv	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Lens	61.94	51.94	20.79	32.67	22.80	63.86%
Thyroid	70.83	70.22	40.83	48.6	43.22	38.86%
Male Gonad	11.20	7.121	6.626	5.930	4.603	56.28%
Female Gonad	17.54	11.43	9.432	43.16	36.78	32.48%

Low	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Lens	202.8	122.2	93.46	132.2	89.67	79%
Thyroid	2403	2211	2543	2273	2380	9%
Male Gonad	46.43	26.95	34.49	39.20	31.31	54%
Female Gonad	488.2	345.8	371.9	279.2	243.1	39%

Cerv. Abdomen CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Lens	401.8	196.8	125.7	103.2	110.1	72.99%
Thyroid	2717	2734	2680	2523	2488	11.27%
Male Gonad	222.4	223.8	244.2	250.0	181.0	43.86%
Female Gonad	1670	1001	1018	1356	1383	17.19%

Cerv. Abdomen Pelvic CT	None	Single 180°	Double 180°	Single 360°	Double 360°	Max. Decrease
Lens	440.7	182.2	149.0	150.2	116.3	73.73%
Thyroid	2932	2761	2685	2508	2480	15.68%
Male Gonad	2857	2763	2746	2689	2606	8.786%

Pediatric Ct table 2

Mediafile 32:



FIGURE 6: Shielding in Adult Phantom During Pelvic CT

Mediafile 33:

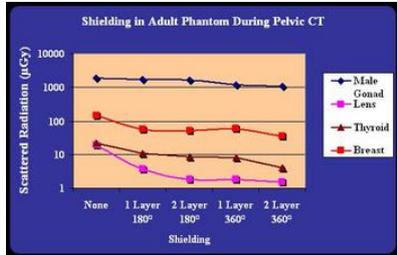


FIGURE 7: Shielding in Adult Phantom During Pelvic CT (Log Scale).

Mediafile 34:

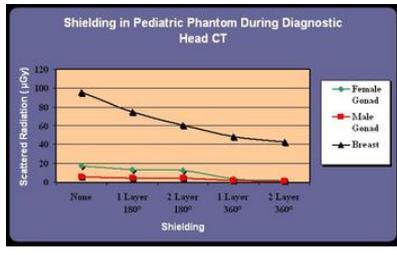


FIGURE 8: Shielding in Pediatric Phantom During Diagnostic Head CT. A reduction in scattered radiation by 22.3% to the breast was seen with one layer of 180°. This reduction increased to 55% when a double layer of 360° shielding was used.

Mediafile 35:

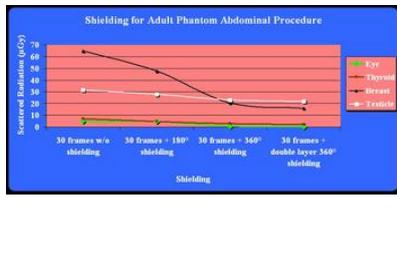


FIGURE 9: Shielding in Adult Phantom During Abdominal Procedure

Mediafile 36:

Exam	Name	Single 10P	Double 10P	Single 30P	Double 30P	Max. Decrease	
Thorax CT	Thorax	1729	1084	1675	1515	13%	
	Right Breast	16.02	14.55	40.33	40.32	43.01	55%
	Male Gonad	5.528	4.675	4.550	2.042	1.102	80%
Female Gonad							
Lower Ext/TH CT	Lower Ext/TH CT	1374	1372	1340	1326	1.8%	
	Right Breast	1495	1310	1280	1310	1192	24.08%
	Male Gonad	72.96	46.70	40.38	40.41	27.50	62.13%
Female Gonad							
Abdominal CT	Abdominal CT	1747	1091	1023	992.2	44.61%	
	Right Breast	40.16	40.87	32.89	33.25	25.56	48.13%
	Male Gonad	4.107	1.839	1.402	1.215	0.605	83.13%
Female Gonad							
Neck CT	Neck CT	1516	1223	1115	1227	1021	22.47%
	Right Breast	116.4	1205	1040	1200	108.5	32.11%
	Male Gonad	21.34	12.87	11.12	5.332	2.906	86.43%
Female Gonad							
Child Abdomen CT	Child Abdomen CT	11.62	17.60	19.10	17.36	11.81	57.67%
	Leas	41.84	31.84	20.59	32.67	22.80	63.96%
	Thorax	332.9	332.2	409.0	408.0	418.2	16.99%
Male Gonad							
Female Gonad							

TABLE 5A: Amount of Scattered Radiation During Diagnostic CT With and Without Shielding in Children

Mediafile 37:

Exam	Name	Single 10P	Double 10P	Single 30P	Double 30P	Max. Decrease	
Leas	Leas	282.0	192.0	192.0	152.1	46.8%	
	Thorax	2403	2211	2343	2273	2180	9%
	Male Gonad	48.43	38.95	54.49	39.20	31.30	54%
Female Gonad							
Child Abdomen CT	Child Abdomen CT	10.70	16.01	16.10	14.86	10.01	57.08%
	Leas	441.1	342.3	149.0	159.2	116.4	73.79%
	Thorax	2932	2991	2685	2508	2400	15.08%
Male Gonad							
Female Gonad							
Abdomen CT	Abdomen CT	1123.1	61.69	20.20	16.72	21.73	81%
	Leas	494.0	373.4	322.8	404.4	422.7	39%
	Male Gonad	377.7	278.0	260.8	236.0	174.0	54%
Female Gonad							
Abdomen Pelvis CT	Abdomen Pelvis CT	152.0	45.81	31.49	54.08	25.46	83.28
	Leas	301.8	275.2	492.8	498.4	425.3	47.48
	Male Gonad	260.1	160.7	270.2	238.2	213.3	9.468
Female Gonad							
Pelvis CT	Pelvis CT	27.38	22.09	8.82	8.68	11.51	90%
	Thorax	42.03	35.91	37.06	29.12	18.42	76%
	Male Gonad	412.1	154.8	137.9	174	143.9	65%
Female Gonad							

TABLE 5B: Amount of Scattered Radiation During Diagnostic CT With and Without Shielding in Children (cont.)

Mediafile 38:

Adult Chest Procedures	4 frames	5 frames	12 frames	30 frames
Eye	1.970 µCy	10.04 µCy	30.37 µCy	48.24 µCy
Thorax	4.481 µCy	32.39 µCy	96.11 µCy	193.2 µCy
Osary	0.292 µCy	1.432 µCy	4.361 µCy	8.406 µCy
Testis	0.132 µCy	0.453 µCy	1.096 µCy	3.9 µCy
Adult Abdomen Procedures	4 frames	5 frames	12 frames	30 frames
Eye	0.170 µCy	0.820 µCy	2.490 µCy	5.550 µCy
Thorax	0.239 µCy	1.111 µCy	3.560 µCy	7.130 µCy
Breast	2.149 µCy	10.75 µCy	32.26 µCy	64.66 µCy
Osary	8.139 µCy	40.79 µCy	122.3 µCy	244.7 µCy
Testis	1.042 µCy	5.219 µCy	15.69 µCy	31.38 µCy
Pediatric Chest Procedures	4 frames	5 frames	12 frames	30 frames
Eye	2.080 µCy	10.31 µCy	31.47 µCy	43.44 µCy
Thorax	10.40 µCy	47.52 µCy	144.3 µCy	281.3 µCy
Osary	2.770 µCy	13.8 µCy	41.44 µCy	82.76 µCy
Testis	0.97 µCy	2.834 µCy	8.322 µCy	17.64 µCy
Pediatric Abdomen Procedures	4 frames	5 frames	12 frames	30 frames
Eye	0.460 µCy	2.300 µCy	6.922 µCy	13.81 µCy
Thorax	1.769 µCy	8.835 µCy	26.59 µCy	53.17 µCy
Breast	7.572 µCy	37.78 µCy	113.3 µCy	226.8 µCy
Osary	29.26 µCy	147.8 µCy	436.3 µCy	873.5 µCy
Testis	4.110 µCy	20.47 µCy	61.74 µCy	123.48 µCy

TABLE 6: Scattered radiation in adult & pediatric phantoms WITHOUT shielding during interventional CT-Fluoroscopy procedures. Scattered radiation increased as the numbers of frames increased.

Mediafile 39:

Adult Chest Procedures	30 frames + 10P	30 frames + 30P	30 frames + 30P (double layer)
Eye	46.02 µCy	11.97 µCy	3.21 µCy
Thorax	192.9 µCy	134 µCy	108.7 µCy
Osary	4.543 µCy	2.582 µCy	1.748 µCy
Testis	2.267 µCy	0.830 µCy	0.627 µCy
Adult Abdomen Procedures	30 frames + 10P	30 frames + 30P	30 frames + 30P (double layer)
Eye	4.693 µCy	0.916 µCy	0.41 µCy
Thorax	44.73 µCy	2.889 µCy	2.112 µCy
Breast	27.79 µCy	23.4 µCy	15.36 µCy
Osary	198.3 µCy	120.3 µCy	101.9 µCy
Testis	27.81 µCy	12.99 µCy	11.18 µCy
Pediatric Chest Procedures	30 frames + 10P	30 frames + 30P	30 frames + 30P (double layer)
Eye	96.9 µCy	16.01 µCy	11.12 µCy
Thorax	381.4 µCy	254.1 µCy	229.9 µCy
Osary	36.13 µCy	20.23 µCy	16.7 µCy
Testis	19.47 µCy	7.137 µCy	6.023 µCy
Pediatric Abdomen Procedures	30 frames + 10P	30 frames + 30P	30 frames + 30P (double layer)
Eye	13.1 µCy	4.232 µCy	2.189 µCy
Thorax	38.41 µCy	29.57 µCy	18.38 µCy
Breast	156.4 µCy	137.8 µCy	134.2 µCy
Osary	364.8 µCy	234.8 µCy	174.4 µCy
Testis	87.31 µCy	110.8 µCy	87.61 µCy

TABLE 7: Scattered radiation in adult & pediatric phantoms WITH shielding during interventional CT-Fluoroscopy procedures. Maximum shielding was seen with a double layer 360° shield.