

# Pregnancy and the Working Interventional Radiologist

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## Abstract

### Keywords

- ▶ interventional radiology
- ▶ pregnancy
- ▶ radiation exposure
- ▶ radiation safety
- ▶ occupational injury

The prevalence of women radiologists has risen in the past decade, but this rise is not reflected in interventional radiology. Women are grossly underrepresented, and this may be partly due to fear of radiation exposure, particularly during pregnancy. The simple fact is radiation exposure is minimal and the concern regarding the health of the developing fetus is unjustly aggrandized. Fully understanding the risks may help women to choose interventional radiology and practicing women interventionalists to stay productive during their child-bearing years. To date, little has been published to guide women who may become pregnant during their training and career.

**Objectives:** Upon completion of this article, the reader will be able to discuss the real risk of radiation to the pregnant working interventionalist and her fetus, and techniques to reduce radiation dose and work-related injuries.

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The latest statistics on the number of women physicians represents a milestone in history. In the 21st century, more than 30% of U.S. physicians are female. Between 1980 and 2010, the number of female physicians grew by 447%.<sup>1</sup> The prevalence of women radiologists has also grown; in 2012, women represent 22% of all radiologists, a rise from 16% in 2000.<sup>2</sup> This rise, however, is not reflected in interventional radiology (IR), where women represent merely 2% of all interventional radiologists.<sup>3</sup> The number of women choosing a career in IR trails far behind the influx of women

choosing specialties such as family medicine, pediatrics, and obstetrics and gynecology. This phenomenon has been linked to the attraction of these specialties having the traditional “family-friendly” reputation, where women can achieve the quintessential work–life balance. As women conventionally bear the childcare responsibility, they typically sacrifice career opportunities and limit their career choices.

In this era where modern women struggle less with gender equality, barriers still exist that might hinder women from choosing IR. Aside from the possible work–life disproportion and salary inequities, there is a paucity of female mentors and a misbelief that women should work part time to attend to childcare needs. Until more women enter IR and take on leadership positions, women will likely continue to be underrepresented. Some women may also be dissuaded by the “old boy’s club” mentality. But the challenges of the proverbial male-dominated practices and egos described in surgical subspecialties are not as pervasive in IR.

Women were among the pioneers of IR during its formative years, from the late 1960s to the mid-1980s. Arina van Breda was one of the first to perform catheter-directed thrombolysis and publish her results of using local streptokinase infusions in acute thrombosis.<sup>4</sup> Since the foundation of this field is rooted in innovation, women stand on equal ground where creative minds are valued and novel treatments are embraced. Gender disclosure has never been

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compulsory for Society of Interventional Radiology membership, but women remain under-represented.

One of the concerns is radiation exposure and its effect on childbearing. During pregnancy, working interventionalists are also at risk for occupational injuries from weight gain that become aggravated with prolonged standing. Understanding radiation exposure and radiation safety frequently gets lost in the physics. This article will simplify this aspect of radiation physics and allay the unfounded and perceived risks. It will also provide recommendations to reduce radiation dose and work-related injuries.

## Radiation Exposure

There are several different types and sources of radiation. Interventional radiologists are primarily exposed to photons (electromagnetic radiation) from X-ray tubes. Exposure to other types of radiation is beyond the scope of this paper.

Risks associated with radiation fall into two categories, stochastic risks and deterministic risks. *Stochastic risks* are those for which the probability of the effect increases with dose. Stochastic effects may occur with higher doses and longer exposures, and risks include genetic mutations and cancer. *Deterministic risks*, also referred to as *nonstochastic risks*, occur above a threshold dose. Therefore, if the threshold is not reached, the effect is not observed. The severity of deterministic effects increases with doses above the threshold.

Radiation exposure is strictly monitored for all radiation workers. Radiation doses are monitored monthly for interventional radiologists with a dosimeter worn outside the lead on their thyroid collar. Some facilities issue a second dosimeter to be worn under the lead apron. In the United States, the declaration of pregnancy is strictly voluntary and when a pregnant worker declares her pregnancy she is issued a fetal dosimeter to be worn at the level of the abdomen under any lead protective garments. The monthly dose readings are monitored by the radiation safety officer to verify that the regulatory fetal dose limits are not exceeded. The National Council for Radiation Protection (NCRP) has published recommended dose limits based on a careful review of the scientific literature and most states have adopted these recommendations in their regulations. The radiation dose limits are intended to prevent deterministic effects and minimize the risk of stochastic effects. The annual deep dose equivalent limit for occupational exposure is 5,000 mrem. The fetal dose limit is 500 mrem over the duration of the pregnancy, or 50 mrem per month.<sup>5</sup> What does this mean in lay terminology? An electronic search using the key phrases “radiation exposure” and “pregnancy” can produce over 100,000 results. Open any one of these articles and one may find radiation doses and exposures expressed in *mrem*, *mSv*, *rad*, and *mGy*. Even practicing radiologists with formal physics training sometimes have difficulty translating these units. Thus, it is not surprising that a female medical student or resident physician might be challenged to comprehend the real risks of radiation.

The use of different units for the same concept and the same unit for different concepts makes radiation doses more

difficult to understand. Rad and Gray (Gy) are used to express *absorbed dose*, which is the concentration of energy deposited in a material or the energy per unit mass. The conventional unit for absorbed energy is the rad, which is 100 ergs of energy per gram of the given material. The international system of units (SI) for absorbed energy is the Gy, which is one joule per kilogram. While many professional organizations favor discarding the conventional units in favor of SI units, regulations and dose reports are still often presented in the conventional units. Additionally, X-ray tube outputs are often given as the Air Kerma in Gy or mGy.

Rem and Sievert (Sv) are used to express *dose equivalent*, which accounts for differences in biological effectiveness of different types of radiation by incorporating a quality conversion factor. For X-rays and other photons, the quality factor is one, so a rad of absorbed dose is equivalent to a rem of dose equivalent. For X-rays, a Gy of absorbed dose delivers a Sv of dose equivalent.

*Effective dose* is used in radiation protection to equate the stochastic risks due to a nonuniform exposure to the risks associated with a uniform whole body exposure. Plainly speaking, effective dose is used to estimate cancer risk and the unit used is rem or Sv.

The unit conversions for rad, mGy, mrem, and mSv are as follows:

$$100 \text{ rad} = 1 \text{ Gy or } 1,000 \text{ mGy}$$

1 Gy (or 1 mGy) absorbed photon dose = 1 Sv (or 1 mSv) dose equivalent

$$1 \text{ mrem} = 0.01 \text{ mSv or } 100 \text{ mrem} = 1 \text{ mSv}$$

To keep this article relatively simple, *mGy* will be used to express absorbed dose in tissue and *mrem* will be used to measure occupational dose.

## Radiation Risks

Risks to the embryo or fetus are divided into preconception risks and perinatal risks. The risks associated with preconception exposures are genetic mutations leading to hereditary effects and sterility. The United Nations Scientific Commission on Effects of Atomic Radiation (UNSCEAR) has analyzed the scientific data from animal studies and survivors of the atomic bombings at Hiroshima and Nagasaki. The UNSCEAR 2001 report estimates the total risk of hereditary effects in humans, which increases by 0.41 to 0.46% per 1,000 mGy of exposure.<sup>6,7</sup> It would take 20 years of maximum occupational exposure to reach a dose of 1,000 mGy. Sterility is a deterministic effect for which the threshold dose in women ranges from 12 Gy or 12,000 mGy before puberty to 2 Gy or 2,000 mGy in premenopausal women.<sup>6</sup> These doses are well above the typical lifetime exposure in interventional procedures. In practice, the gonadal radiation dose from common IR procedures is less than 1 mrem,<sup>8</sup> which using the above conversion converts to merely 0.01 mGy. For interventionalists, the risks of hereditary effects or sterility are minimal.

Most perinatal risks are deterministic and are very dependent on the stage of gestation. ► **Table 1** summarizes the deterministic effects, the stage of gestation during which they

**Table 1** Deterministic effects

Radiation effect	Gestation (weeks)	Threshold dose (mGy)
Embryonic death	3–4	100–200
Major malformations	4–8	250–500
Growth retardation	4–8	200–500
Irreversible whole body growth retardation	8–15	250–500
Severe mental disability	8–15 > 16	60–500 > 1,500
Microcephaly	8–15	> 20,000
Decrease in intelligence quotient	> 16	> 100

may be induced, and the threshold doses.<sup>9</sup> During the period before the embryo is implanted, radiation exposure may increase the risk of embryo death, but if the embryo survives to implant, it is expected to grow normally. Because the background rate of miscarriage at this stage is not well known and the woman is often unaware she is pregnant, the actual risk of miscarriage due to radiation exposure during the early weeks is unknown. The embryo is most sensitive to the effects of radiation during the stage of organogenesis (weeks 2–8). Radiation doses above the threshold can result in major malformations and growth retardation. Between 8 and 15 weeks of gestation, the primary risks are growth retardation and severe mental disability. After 16 weeks, there is a risk of mental disability and decrease in IQ if the mother is exposed to high doses. The stochastic risk associated with perinatal radiation exposure is an increased risk of childhood cancer. The estimated excess absolute risk is approximately 6% per 1,000 mGy of fetal radiation exposure.

To put all of these risk numbers into perspective, for a fetus exposed to 50 mrem in utero, the probability of a live birth without malformation or cancer is reduced from 95.93 to 95.928% based on a conservative model from the NCRP.<sup>10</sup>

Practically speaking, to attain any of these risks, a woman needs to be directly exposed to the radiation beam for a continuous length of time without wearing personal protective equipment. Again, according to regulations the maximum total dose for the pregnancy is 500 mrem, and the monthly limit is 50 mrem. Pregnant interventionalists are not exposed to the direct beam, but exposed to scatter radiation, most of which is attenuated by a 0.5-mm lead apron. According to a prospective study performed by Marx et al,<sup>11</sup> the mean projected monthly deep dose equivalent measured by a thermoluminescent dosimetry under 0.5-mm lead at the waist was 9 mrem. A double lead 1.0-mm apron attenuates the dose by an additional two-thirds, to approximately 3 mrem. Therefore, the average dose to a pregnant interventionalist who works for her entire 40-week pregnancy wearing double lead is approximately 30 mrem. This dose is well below the NCRP occupational fetal dose limit of 500 mrem.

## Recommendations to Reduce Radiation Dose

The radiation dose to the patient should be optimized and the radiation dose to personnel should be minimized regardless

of pregnancy status. Reducing the patient dose leads to lower operator and staff doses. The principle of “as low as reasonably achievable” should guide decisions during fluoroscopically guided procedures. The radiation safety officer or medical physicist can help implement techniques to minimize radiation dose.

The key radiation protection concepts are time, distance, and shielding. The fluoroscopy beam-on time is one of the primary factors that can be controlled to reduce both patient and staff doses. Positioning the patient as far as possible from the X-ray tube and as close as possible to the image receptor reduces patient skin dose and improves image quality. Increasing the distance between the source of patient scatter and the interventionalist can also reduce operator dose. For lateral projections, the scatter is higher on the X-ray tube side of the table. Be aware of the location of the X-ray field and move away from it whenever practical.

Proper use of shielding is a very effective way to minimize dose to the interventionalist. For personal protective equipment, the pregnant interventionalist should wear a minimum of 0.5-mm lead equivalent protection over the abdomen. The ideal configuration is a lead skirt that overlaps in front in combination with a vest overlapping in front. Wearing an additional apron offers very little additional protection but considerably increases risk of back injury due to the increased weight. Lighter weight protective aprons are now available and may be worth the higher cost.

The majority of dose to personnel in a fluoroscopically guided procedure is due to scatter from the patient. Any additional shielding available in the room should be utilized as protection against this scatter. Tableside lead drapes should be positioned between the X-ray tube and the fluoroscopy operator to shield against scatter from the bottom of the table. If there is an overhead leaded acrylic shield, it should be placed close to the patient between the patient and the operator. Additionally, proper collimation of the X-ray field to the region of interest reduces both the volume of patient tissue irradiated and the amount of scatter.

Equipment settings should be adjusted to optimize the patient dose by delivering the lowest dose needed to meet the clinical objectives. The fluoroscopy unit may have high, standard, and low dose modes; the high dose mode can deliver twice the dose rate of standard mode, so it should only be used when necessary. The fluoroscopy frame rate can

also be adjusted. Continuous fluoroscopy and pulsed fluoroscopy with a frame rate of 30 frames per second deliver the same dose rate to the patient. Decreasing the frame rate to 15 frames per second cuts the dose rate in half. For many procedures, a frame rate of 7.5 frames per second provides sufficient image quality to meet the clinical objective while reducing patient dose by three-quarters. Magnification modes increase patient dose and thus should be used sparingly. Image acquisition using cine mode or single shot images also deliver higher doses than standard fluoroscopy, so minimizing the number of images acquired will also keep patient and staff doses lower.

Finally, interventional radiologists perform minimally invasive procedures using a variety of imaging modalities. A pregnant interventionalist can remain productive without using fluoroscopy by performing ultrasound-guided and CT-guided procedures (excluding CT fluoroscopy). Additionally, treatments using  $\beta$  particles, as in Y-90 selective intravascular radiation therapy, result in no additional known risks to the fetus.

### Reducing Injury on the Job

Several physiologic and anatomical changes occur during pregnancy that can affect a working interventionalist. A full service day can be 8 to 12 hours long with nearly half that time standing wearing radiation protective aprons, which typically adds an average of 10 pounds. Normal habits must be changed to minimize injury and discomfort.

The uterus lies within the pelvis up to the 12th week of pregnancy, then grows and becomes an abdominal organ for the remainder of the gestational period. This growth results in weight gain and changes in a woman's center of gravity.<sup>12</sup> The growing uterus displaces the abdomen posteriorly, resulting in posterior displacement of her center of gravity and potential balance issues. Lifting and bending forward should be minimized. Lifting is infrequent, but leaning or bending forward is not uncommon. Since interventional radiologists commonly work from the right side of the fluoroscopic table, leaning across the table is required when performing procedures on the patient's left side. When leaning forward cannot be avoided, simply raising the table and moving the control panel to the foot of the bed may help promote proper body mechanics.

Back pain is a frequent complaint throughout pregnancy, caused by a combination of the increase in lumbar lordosis, hormonal influence on the ligament insertion points of the lower spine, and muscular strain.<sup>13</sup> Back pain can be further exacerbated with the added weight of lead aprons. Lead aprons are now made with lighter nonlead or lead equivalent material, which effectively attenuates radiation as well as standard lead aprons. However, these lead-equivalent aprons come with a higher cost. To reduce back pain during long procedures, a two-piece apron consisting of a vest and skirt will distribute half of the weight to the woman's hips, rather than all the weight on her shoulders as a one-piece apron will do. Wearing double lead aprons is unnecessary, as a 0.5-mm lead equivalent apron is effective in reducing fetal exposure.

Should an interventionalist still elect to wear additional protection, a single maternity apron worn under the skirt is a good option as it weighs less than a full apron. Additional relief for back pain can be found in lumbar and abdominal support girdles.<sup>14</sup>

Leg swelling due to venous changes and increased circulatory volume,<sup>15</sup> particularly aggravated in the third trimester, can cause significant discomfort during procedures aggravated by prolonged standing. Compression stockings can apply external pressure on the legs, facilitating venous drainage. The most effective stockings have the greatest pressure around the ankles and gradually decrease the pressure up the leg. These stockings are available in a variety of lengths from knee-high, thigh length, and full pantyhose. Stockings also come in grades from 8 to 15 mm Hg to 40 to 50 mm Hg; the higher the grade, the tighter the application. Although randomized control trials confirm the effectiveness of compression stockings in diminishing the risk of deep vein thrombosis in prolonged immobilized patients,<sup>16</sup> there is insufficient high-quality evidence comparing the effectiveness of the different hose lengths and grades.<sup>17,18</sup> Partsch et al, however, recommend pressure ranges between 11 and 21 mm Hg for professions requiring prolonged standing and sitting.<sup>19</sup> In clinical practice, the decision on which type of stocking is ultimately determined by compliance; even lower-grade stockings provide benefit over no stockings.

Foot pain is another consequence of weight gain and prolonged standing. The changes in a pregnant woman's center of gravity alter her stance, resulting in additional pressure on the heel, arch, and forefoot.<sup>20</sup> Hormonal-induced ligamentous laxity in the foot may flatten the arch, provoke over pronation, and result in plantar fasciitis. Shoes and orthotic devices that provide appropriate heel and arch support can minimize the stress and help reduce pain.<sup>21</sup> There are numerous treatments for plantar fasciitis, but many modalities render relief in the long term. In a crossover study by Fong et al, custom-made rocker shoes and foot orthoses can provide more immediate relief.<sup>22</sup> Finally, any opportunity to sit adds further benefit to the above strategies in reducing injury. Some procedures such as biopsies and drainages can be performed sitting on an adjustable stool.

### Conclusion

Fluoroscopic-guided procedures are not limited to IR. In the past few decades, other specialties have shifted toward less invasive techniques using imaging guidance. Cardiologists, orthopedic surgeons, urologists, gastroenterologists, and more recently vascular surgeons are using fluoroscopy. Understanding radiation exposure and risks therefore apply more broadly to the physician population. For the childbearing interventionalist, fetal risk is negligible when appropriate shielding and radiation safety practices are applied. By taking additional measures to reduce injury related to the anatomic and physiologic changes of pregnancy, a practicing interventionalist can remain productive through her entire pregnancy. Safety should be universally emphasized by all



practicing radiologists, and excluding IR as a career for fears of radiation exposure is unfounded.

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