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# Baby on Board: Managing Occupational Radiation Exposure During Pregnancy

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**This article reviews the issue of occupational radiation exposure as a deterrent to recruitment of women into the field of interventional radiology and provides the reader with three strategies to optimize radiation protection during fluoroscopically guided procedures. These include personal protective shielding, use of ancillary shielding, and techniques that limit fluoroscopy x-ray tube output. When optimal radiation safety practices are implemented as the norm in the IR suite, very little extra needs to be done to ensure that fetal dose of a pregnant interventionalist is negligible.**


**KEYWORDS** occupational radiation exposure, pregnant worker

## Introduction

Concerns related to occupational radiation exposure during pregnancy are commonly thought to be a significant deterrent to the recruitment of women into fields that involve fluoroscopically guided interventions (FGI) such as interventional radiology and interventional cardiology.[1,2] These two specialties have fewer women practitioners and trainees than do the fields of general surgery, cardiothoracic surgery and orthopedic surgery, traditionally very male dominated specialties.[3] The recruitment issue stems from the fact that ionizing radiation is known to affect the health and development of fetal tissue. The doses that have been associated with measurable deleterious effects are exponentially higher than those measured on dosimeters of physicians who do FGI.[4] However, no study has stated in its conclusion that all fetal ill effects of radiation have a distinct threshold dose. Therefore, no written material advising women on management of occupational radiation exposure can say that low exposure carries no risk. They say the risk is "minimal", but none say that the risk is zero.

The problem this creates for women is that in our current culture, we are not supposed to do anything that carries any risk to the fetus during pregnancy. Every activity we engage in should have zero risk. Published advice of risks to avoid during pregnancy is extremely broad and far reaching (see BabyCenter.com or pregnancy.org). In addition, complete strangers are apt to provide their unsolicited opinions regarding pregnancy risks to pregnant women in ways that are remarkably judgmental and intrusive. In this environment, who can blame women for avoiding careers that include occupational exposure to ionizing radiation?

The result of this career avoidance is significant. Interventional Radiology needs diversity to provide the best care to patients and the broadest creativity of thought. Half of all medical students are women. If IR does not recruit from the full breadth of medical school graduates, the specialty will miss out on its share of half of the best minds.

The goal of this article is to provide information and work strategies to support the view that minimal risk is, in practical terms, the same as no risk. IR can be, and should be, a safe profession for everyone with respect to occupational radiation exposure. I include my personal experience in the discussion.

## Background

Pregnancy is inherently not a safe undertaking. Background risk of a negative outcome is high. In all, 15% of known pregnancies end in spontaneous abortion. Approximately 3/100 babies are born with a major congenital malformation, while 4/100 have minor congenital abnormalities.[5]

It is known that the developing fetus is radiation sensitive, based primarily on mammalian animal studies.[5]

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Studies have shown that embryonal/fetal dose less than 0.1 Gy (100 mGy) does not increase the risk of ill effect in humans.[5] Extrapolating that number to the dose unit used in occupational dosimetry, a dose equivalent of 100 mSv is not known to cause ill effect in the developing fetus.

The United States sets the limit on fetal dose at 5 mSv/pregnancy, and 0.5 mSv/month after declaration of pregnancy.[6,7] These limits are well below the 100 mSv dose noted above. In Europe, fetal dose limit is set at 1 mSv/pregnancy, which is the same as the dose limit for a member of the general public.[8]

Published data regarding occupational dose under lead indicate that occupational dose among IRs at waist level under lead are within the regulatory limit. My study, published in 1992, found that IRs wearing 0.5 mm Pb eq thickness aprons had average recorded under-lead doses of 1.3 mSv/year which translates to ~0.1 mSv/month.[9] In the same study, IRs wearing 1 mm Pb eq thickness aprons had an average yearly dose at waist level under lead of 0.4 mSv/year, or 0.03 mSv/month (a dose not detectable by standard dosimeters).[9] More recent studies in interventional radiology and interventional cardiology have similar results.[10,11] One of these demonstrated significant reduction in operator dose following implementation of radiation safety training and routine use of boom-mounted shielding.[11] A study that included 32 pregnant vascular surgeons involved with endovascular work, found that the average fetal dose tracked by dosimetry was minimally above background.[12]

All this data is reassuring and indicates that working in the fluoroscopy environment during pregnancy is safe and can be done within regulatory dose limits. However, regulatory dose limits do change. For example, the regulatory limit for lens of eye has been decreased in Europe due to the increased information related to radiation-induced cataracts in physicians.[13] This type of regulatory evolution contributes to a widely accepted view that fetal radiation exposure should be kept well below levels that regulations require. Strategies to help women achieve that goal are reviewed below and include: using dosimetry data as a guide, tailoring use of personal and ancillary lead shielding, and active fluoroscopy practices that can minimize occupational dose.

## Dosimetry Data: Know Yourself

The first step to developing an evidence-based strategy of managing occupational dose during pregnancy is to know dosimetry data. The dosimetry study I published in 1992 was in part motivated by a drive to learn about occupational dose in planning my own work strategy during pregnancy.[9] By measuring over-lead and under-lead dosimetry data prospectively on 30 IRs for 2 months, the study established that average under-lead doses for this group of busy practitioners was below regulatory limit for fetal exposure, and especially low for IRs wearing 1 mm Pb eq thickness aprons. I found this information very reassuring, and made plans to manage my occupational radiation exposure based on it. More recent dosimetry work has demonstrated similar results, despite the increased complexity of modern FGIs.[10–12] I am hopeful that increased awareness of published dosimetry data will encourage more women to enter the field of IR.

Knowledge of personal dosimetry data is a powerful tool in allowing us to manage our work practices during pregnancy. I encourage all IRs to use under-lead dosimeters, in addition to over-lead dosimeters for at least some period of time to get personalized information about occupational dose. The dose reports will tell you two things: (1) what your monthly under-lead dose is, and (2) indirectly, how well your lead apron attenuates the radiation in your work environment. This latter piece of information is particularly relevant given the information provided in one of the articles in this journal.[14] A few months of accurate dosimetry data will allow you to decide if you need/want to change your personal shielding system during pregnancy. Another option to learn about personal dosimetry is to wear a dosimeter for a short period of time that provides realtime feedback; this method has been demonstrated to lead to behaviors that reduce occupational dose.[15] The best way to make sure you have access to 2 dosimeters and to the data they provide, as well as to investigate the realtime feedback option, is to work with your medical physicist and/or institutional radiation safety officer on an ongoing basis.

## Personal Shielding: the "Lead" Apron

The standard type of shield used to protect the most radiation sensitive organs (lungs, GI tract, bone marrow, and gonads) from occupational radiation exposure during fluoroscopy is the 0.5 mm lead equivalent (Pb eq) thickness apron. Most IRs currently use 2 piece wrap-around style aprons for comfort. These aprons typically have 0.25 mm Pb eq thickness and provide 0.5 mm Pb eq protection in the front where they overlap. Based on published and personally recorded dosimetry data, this standard level of shielding is extremely likely to be sufficient to keep fetal exposure below regulatory limits. However, as mentioned in the introduction, women are likely to prefer to add a higher level of shielding during pregnancy. Women are also likely to be very mindful of the current conversation related to lack of standardization of protection provided by lead aprons materials[14] and want the highest quality product to wear during pregnancy.

Multiple options exist to achieve the goal of increasing abdominal shielding. One option is to wear a 2 piece wrap-around lead apron that is made of 0.5 mm thick Pb eq material. This provides 1 mm Pb eq thickness across the portion of overlap, which should be wider than is typical to accommodate not only the front of the abdomen but also the sides. This might require buying multiple aprons

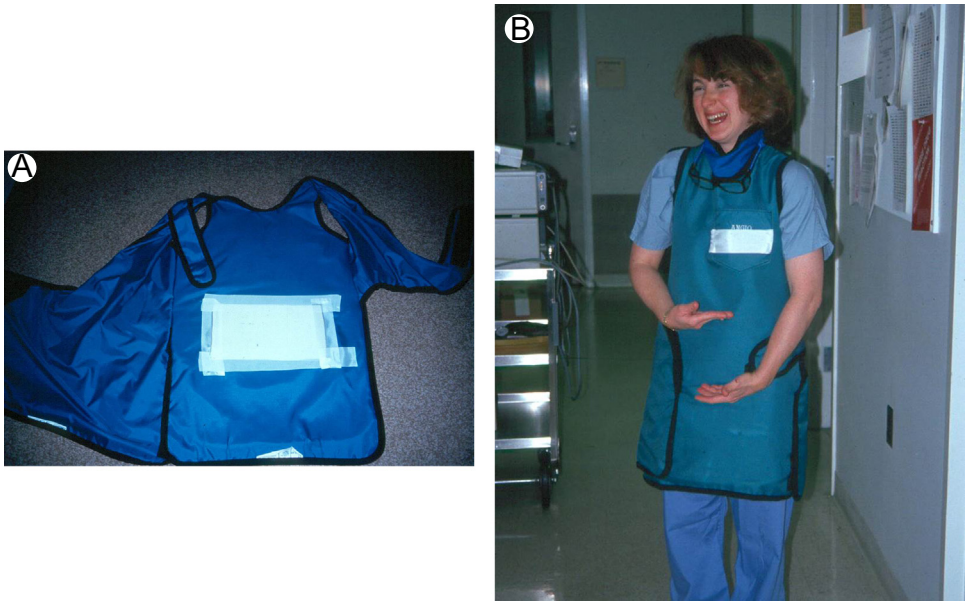


**Figure 1** These images demonstrate the extra lead shield taped to the inside of my apron (A) and the position of that additional shielding while I wore the apron (B). Note that I was not concerned about needing additional shielding in the back to supplement the 0.5 mm Pb eq protection provided by the apron alone because I was typically in control of the fluoroscopy pedal during cases, given my role as the most senior IR in the room. (Color version of figure is available online.)

over the course of pregnancy to accommodate increase in abdominal size. Another option is to wear 2 standard (0.25 mm Pb eq thickness) wraparound aprons, which together provide 1 mm Pb eq shielding in the region of overlap. Again, for optimal coverage, the size of the aprons being worn needs to provide a broad area of overlap, which will need to increase in size over the course of pregnancy.

I took a slightly different approach in 1992. I wore a 0.5 mm Pb eq wraparound apron that did not overlap in the front. I taped an extra piece of flexible lead (taken from a shield we had previously used to collimate the lower extremities during peripheral angiography on a long leg changer) to the inside of my apron over my pelvis (Fig. 1). Obviously, that modification was suitable only for a few months. I subsequently wore a custom-fitted maternity apron for the rest of my pregnancy (Fig. 2). It had 1 mm Pb eq thickness coverage from the xyphoid to the knees and provided front and side shielding. My under-lead dosimetry throughout pregnancy demonstrated negligible under-lead dose.

Timing any modification of lead shielding related to fetal protection is a personal decision. If you have decided to increase your level of shielding during pregnancy, when do you start that? Before you are pregnant? After you know you are pregnant? Before you tell people you are pregnant? After you have declared your pregnancy to your institution? One option is to simply make a change before you even contemplate pregnancy and say nothing about the reason for it. That keeps any information about pregnancy separate and private. I decided that planning a pregnancy would not be a secret for me in my workplace (as is obvious from Fig. 1). I found that this transparency led to a community of support among all the IR physicians, technologists, and nurses I worked with, and an overall increase in radiation safety consciousness that persisted after my pregnancy. I was a good role model.

**Figure 2** Here I am in the third trimester getting ready to do a drainage tube change. The apron was less uncomfortable than it looks—but my posture does illustrate the concept that utilizing ancillary shielding rather than operator-mounted shielding is more ergonomic! Note that standards for operator hair coverage and body fluid protection were less stringent in those days than is currently the standard. (Color version of figure is available online.)

## Ancillary Shielding

Boom-mounted, table-mounted, patient-mounted and/or floor-mounted barriers can be utilized to minimize scatter radiation during fluoroscopy. Ancillary shields that do not add a physical burden on the pregnant worker have significant ergonomic benefit. These types of shields are discussed elsewhere in this journal.[16] Use of ancillary shielding is relatively easy in an IR environment with a culture of safety-consciousness regarding fluoroscopic work practices. My experience has been that millennial IRs are inherently more safety conscious than practitioners of my generation (baby boomers) and that this has improved the utilization of best practices with respect to ancillary shielding for all practitioners in the IR suite. In work environments that are unaccustomed to incorporating ancillary shielding into fluoroscopy room preparation prior to a case, there will be a learning curve prior to seamless implementation of these devices during clinical cases. Be patient and insistent! A combination of a 0.5 mm Pb eq lead apron and ancillary shielding is likely to result in an undetectable occupational dose on an under-lead dosimeter.[17,18]

## Fluoroscopic Work Practices

Shielding yourself from occupational radiation exposure is fundamentally a reactive process—you are protecting yourself from the radiation in the environment. Two equally powerful, and arguably more important ways to limit occupational radiation exposure are to proactively limit the radiation emitted from the x-ray tube when you are doing a procedure and to limit the time you are at the patient's side when the x-ray beam is active. This is easiest for a pregnant IR to accomplish when she is the most senior IR in the room, as was the case for me. A pregnant trainee (student, resident, or fellow) has less control over the management of a case and is more reliant on optimal shielding and on the ability to communicate openly with the senior IR she is working under. It is the responsibility of the IR in charge to factor radiation safety for all members of the team into fluoroscopy work practices.

The most fundamental way to limit procedural radiation exposure is to limit the fluoroscopy time and field size. This can be done in multiple ways. One is to use alternative imaging methods, such as ultrasound, to provide diagnostic information or to guide a task when appropriate. A second is to utilize last image hold, rather than live fluoroscopy, while making decisions about technical issues. A third is to decrease the fluoroscopy frame rate from the current standard of 15 or 30 frames per second down to 7.5 or 4 frames per second. This frame reduction is most appropriate in regions of the body which have little motion, and during tasks that do not require fine visual detail. Finally, field collimation during fluoroscopy is an important way to decrease scatter radiation. This has the added benefit of improving image quality.

With respect to acquiring digital images for the patient medical record, use of a "fluoro save" option for image documentation rather than higher quality digital "spot" images will limit occupational exposure during acquisition of those images. For digital subtraction angiography, it is best to avoid doing DSA runs with hand-injection of contrast that require physician presence near the incident beam. The operator should use a power injector for contrast administration and step into the control room as images are acquired.

These fluoroscopy work practices are discussed in more detail in another article in this journal.[19] Note that use of these dose-saving fluoroscopy work practices should be implemented by all IRs all the time. They should be habits! Once implemented and practiced in a consistent fashion over time, these practices do not need to be modified (or learned) during pregnancy.

## Conclusion

Being pregnant is complicated and imposes a level of personal responsibility on women that is intense and unique. Being an interventional radiologist is complicated—and intense and unique. Being both amplifies the complexity, and not many of us have been both! Like the women who completed a recent SIR survey,[1] my pregnancies ended with healthy children. I have no regrets! I always am happy to provide support to other women IRs as you navigate this path.

My personal opinion is that it is completely possible to be a responsible pregnant woman and a dedicated interventional radiologist all at the same time. It takes some thoughtful decision making and consistent implementation of best radiation safety practices. It benefits from a collaborative work environment. My experience has been that open communication and planning of pregnancy in the IR environment leads to an overall increased awareness and implementation of good radiation safety practices by all members of the IR team. Women can be leaders in making this happen. The more of us there are, the more effective role models we will be for all IR physicians.

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