

# Cumulative Radiation Exposure and Your Patient

This document, developed by Intermountain Healthcare's Cardiovascular Clinical Program and Imaging Clinical Service, provides information on the cumulative radiation exposure reported in HELP2: the limitations of this information, why Intermountain is measuring and reporting it, tips on interpreting this information, and factors to consider when choosing an imaging procedure.

## ► Information in this document

*(click each item below to skip to that section):*

- 1 What's included — and not included — in your patient's cumulative radiation exposure as reported in HELP2
- 2 Why Intermountain is measuring and reporting cumulative radiation exposure
- 3 The risks of radiation exposure
- 4 Factors to consider when choosing an imaging test
- 5 Discussing this information with your patient
- 6 Estimated radiation exposures and lifetime risks from common procedures — a quick reference with resources

## 1 ► WHAT'S INCLUDED IN MY PATIENT'S REPORTED CUMULATIVE RADIATION EXPOSURE?

The number reported for each patient:

- **Includes four types of relatively higher-dose procedures:** CT studies, angiography, nuclear cardiology, and cardiac catheterization procedures.
- **Begins in mid-2012:** Earlier exposures are not included.
- **Does NOT include:** Procedures performed at non-Intermountain facilities, other procedures besides the four listed above, or radiation (oncology) treatments.

**Please note that reported exposures are only estimates.** The accuracy of these estimates depends on a number of factors, including patient size, equipment, and exam type.

*Please note that while this document provides evidence-based information to consider in making treatment decisions for most patients, your approach should be adapted to meet the needs of individual patients and situations, and should not replace clinical judgment.*

**A brief overview of this topic is also available.**

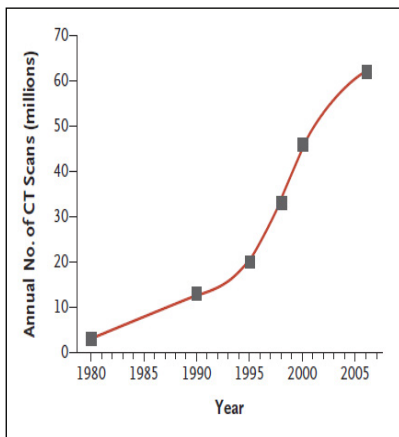
For basic, concise information on radiation exposure and risk, see the brief [Physician's Guide to Radiation Exposure](#).



## 2 ► WHY IS INTERMOUNTAIN MEASURING AND REPORTING CUMULATIVE RADIATION EXPOSURES?

Key points (click each link for more details):

- Medical radiation exposure has dramatically increased, as a function of increased imaging. ([See Section 2.1.](#))
- Media coverage, government initiatives, and professional organizations have focused on radiation exposure ([See Section 2.2.](#))
- Intermountain has set a major goal focused on reducing cumulative radiation exposure. ([See Section 2.3.](#))



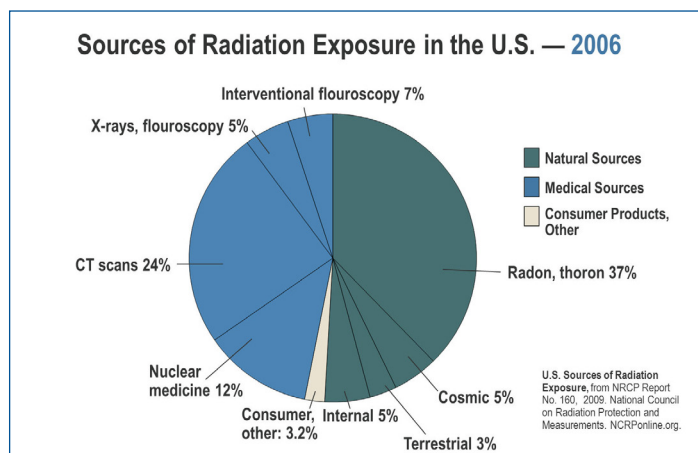
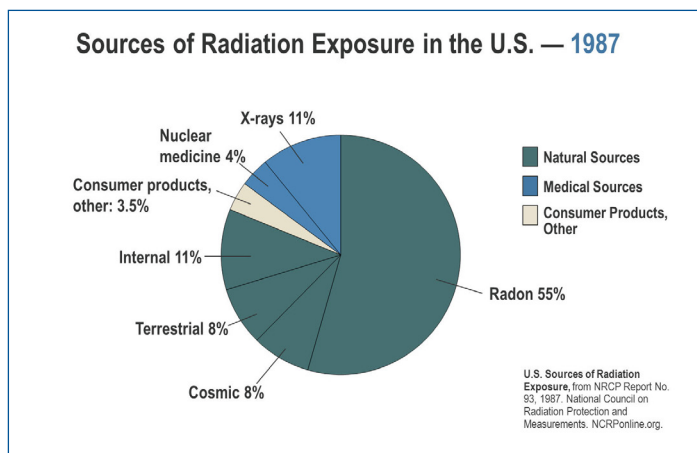
### 2.1 The increase in medical radiation exposure

In the past few decades, there has been amazing growth in the use of medical imaging, particularly procedures with significant radiation (CT scans, nuclear scans, angiography). For example, between 1980 and 2006, the annual number of CT scans in the U.S. grew from 3 million to 60 million<sup>1</sup> (see Figure 1 at left).

Another example of this increase is the rising use of CT scans in emergency department pediatric visits (infants to 18 years). A recent review<sup>2</sup> based on data from the 1995–2008 National Hospital Ambulatory Medical Care Survey showed that in this time period, the percentage of pediatric ED visits that included CT examination had an almost five-fold increase, with a compound annual growth rate of 12.8%.

Largely due to this increase in medical radiation exposure, the U.S. population’s total exposure to ionizing radiation has nearly doubled over the past two decades, based on annual reports from the National Council on Radiation Protection and Measurements (NCRP).<sup>3,4</sup> In 1987, the annual average radiation exposure was approximately 3 millisieverts (mSv). By 2006, this number had risen to approximately 6 mSv. In 1987, medical exposure accounted for 15% of overall radiation exposure, but in 2006 it accounted for 48% of this total. Compare the blue sections (medical exposure) in Figure 2.

**Figure 1.** Growth of annual CT use in the U.S. From Brenner DJ, Hall EJ. Computed tomography — an increasing source of radiation exposure. *New England Journal of Medicine.*<sup>1</sup>



**Figure 2.** Exposure to Medical Radiation in 1987 and 2006, based in annual NCRP reports.<sup>3,4</sup>

## 2.2 Media coverage, government initiatives, and professional initiatives

This increase in medical radiation exposure has resulted in increased media attention, and a variety of initiatives aimed at reducing unnecessary exposure.

- **Media coverage.** In the past decade and particularly starting in 2010, many major media outlets have reported on the increase in medical radiation, including a “[Radiation Boom](#)” series in the New York Times and coverage in [Newsweek](#), [Time Magazine](#), and the [Washington Post](#). Some of this coverage has been accurate and balanced, some has not — regardless, this media attention has raised public awareness of medical radiation and the idea that it may carry potential health risks.
- **Federal initiatives.** In 2010, the FDA launched an [initiative](#)<sup>5</sup> to reduce unnecessary radiation exposure by promoting safe use of medical imaging devices, supporting informed clinical decision making, and increasing patient awareness. The FDA launched a special focus on [pediatric imaging](#) in 2012.
- **Legislative initiatives.** In 2010, the California state legislature passed a law ([SB1237](#)) requiring all facilities to record the radiation exposure from every CT study (if equipment is able to display the exposure) and report it to providers and patients, starting in July 2012. Starting in July 2013, the law also requires facilities to report unintended radiation exposures to California’s health department (such as CT to the wrong patient or site, CT or therapeutic exposure to an embryo or fetus over 50 mSv, etc.). This law may become a model for other states.
- **Professional initiatives.** Professional initiatives focused on safe imaging and the reduction of unnecessary radiation exposure include:
  - **Image Wisely** ([www.imagewisely.org](http://www.imagewisely.org)), focused on radiation safety in adult medical imaging, sponsored by [four major professional organizations](#), including the American College of Radiology.
  - **Image Gently** ([www.imagegently.org](http://www.imagegently.org)), focused on pediatric radiation. This initiative is sponsored by the [Alliance for Radiation Safety in Pediatric Imaging](#) (founded by four major professional organizations, including the American College of Radiology, and in partnership with 65 other professional groups).

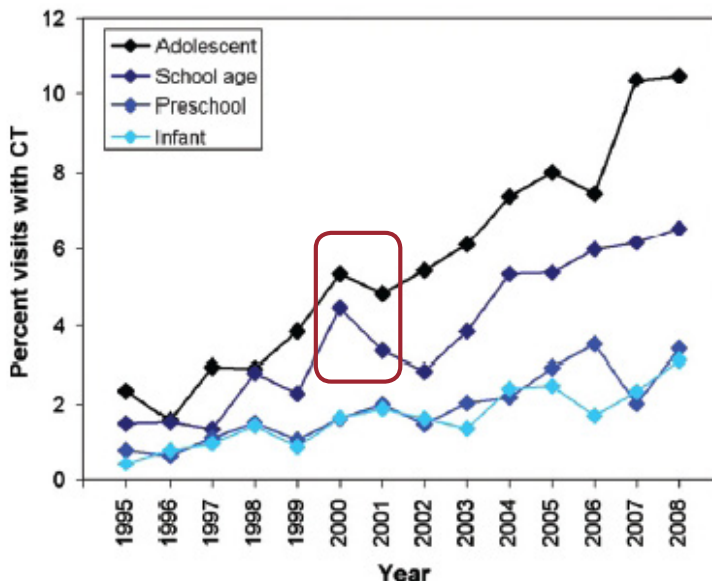
Intermountain has long focused on radiation safety and effectiveness — implementing [ALARA](#) (radiation as low as reasonably achievable) in our facilities, training staff in radiation safety, regularly inspecting and updating equipment, and consulting with referring providers about imaging procedures. Based on the national increase in medical radiation exposure and our desire to improve our imaging processes, Intermountain has set a goal to become one of the first healthcare systems in the country to compile and report cumulative radiation exposure for its patients and implement other initiatives to facilitate better decision-making about imaging procedures.

### 2.3 Intermountain’s goal: compile, report, educate, and improve

Intermountain has set a goal to compile cumulative radiation exposures from a subset of procedures, report the exposure to patients and providers and provide education on radiation exposure, and improve our processes by implementing appropriate use criteria for certain procedures.

<b>Compile</b>	The cumulative exposure incorporates the following procedures, if performed at Intermountain facilities in 2012 or later: CT studies, angiography, nuclear cardiology, and cardiac catheterization procedures. The long-term goal is to expand this procedure list, and over time the cumulative exposure will cover a longer period. Collecting and analyzing cumulative exposures will help us to improve our imaging processes as a system overall.
<b>Report and educate</b>	<ul style="list-style-type: none"> <li>• Reporting cumulative exposure for each patient in HELP2 gives providers more information to use in weighing the risk and benefits of an imaging procedure. (See <a href="#">section 3</a> for more on radiation risks and <a href="#">section 4</a> for guidance on choosing imaging strategies.)</li> <li>• Reporting exposure to patients in their MyHealth record is one way Intermountain can be transparent about our initiatives and efforts for their safety. The MyHealth screen that displays the exposure describes the limits of the information and links to an <a href="#">Intermountain patient education fact sheet</a> that gives an introduction to medical radiation and places the risk in context. (See <a href="#">section 5</a> for tips on talking with patients.)</li> </ul>
<b>Improve our processes</b>	<ul style="list-style-type: none"> <li>• Collecting and analyzing cumulative exposures will help us to improve our imaging processes as a system overall.</li> <li>• Implementing appropriate use guidelines will reduce exposure to unnecessary radiation. Currently, Intermountain has adapted and is implementing the following guidelines:                     <ul style="list-style-type: none"> <li>– <a href="#">CTPA for Suspected Pulmonary Embolism</a>. This guideline represents a collaborative effort including Intermountain’s Cardiovascular and Intensive Medicine Clinical Programs, Intermountain’s Imaging Service, and Intermountain Medical Center’s Thrombosis Clinic, Department of Medicine, and Department of Emergency Medicine.</li> <li>– <a href="#">Cardiac radionuclide imaging</a>. This guideline is based on criteria by the <a href="#">American College of Cardiology</a>, and is designed as an easy-to-use form.</li> </ul> </li> </ul>

**Why set a goal like this? Because education and awareness can make a difference.** For example, while the growth rate of pediatric CT scan use in the ED increased from 1995–2008 for all age groups, this rate actually decreased in 2001 for two subgroups (infants and preschoolers) — see the highlight on Figure 3 below.<sup>2</sup> What changed? In 2001, there were many reports and initiatives focusing on radiation in infants and young children. Continued awareness efforts have minimized the increase in CT use for these two subgroups.



**Figure 3.** Pediatric CT use in U.S. Emergency Departments. From Larson DB, et al. Rising use of CT in child visits to the emergency department in the United States, 1995-2008. Radiology<sup>2</sup>

### 3 ► WHAT IS THE RISK FROM RADIATION EXPOSURE?

Key points (click each item for more details):

- Radiation can cause **deterministic** effects (immediate symptoms) or **stochastic** effects (genetic changes that can increase long-term cancer risk). ([See Section 3.1.](#))
- Cancer risks are generally determined using atomic bomb survivor data, a well-accepted hypothesis (the Linear No-Threshold Hypothesis), and other data. ([See Section 3.2.](#))
- The estimated risk of developing cancer from a single CT or angiogram is very low. ([See Section 3.3.](#))
- Factors that affect an individual's cancer risk from radiation exposure include age at the time of exposure, body part exposed, genetics, their cumulative exposure, and other carcinogenic risk factors for that patient. ([See Section 3.4.](#))

#### 3.1 Terms used to describe radiation effects

Two terms are used when discussing the effects of radiation:

**Deterministic effects:** Cell death at radiation exposures far higher than those used in most imaging studies. These effects are predictable, and can include permanent skin burns and hair loss.

**Stochastic effects:** Genetic changes that may lead to the eventual development of cancer. These effects are probabilistic — they cannot be predicted accurately for an individual, and the risk must be estimated.

#### 3.2 How cancer risks from radiation exposure are determined

The best data available on cancer risk and radiation exposure comes from atomic bomb survivor data, which has shown a statistically significant association between developing cancer and a radiation exposure above 100 mSv.<sup>6</sup> (Note: This exposure is approximately 30 times higher than the average annual environmental radiation exposure and is significantly higher than exposures from individual diagnostic tests.) There is also other data from medical or occupational exposures that support the relationship between radiation exposure and increased risk of developing cancer.

In atomic bomb survivors, the rate of solid cancers varied linearly with the amount of exposure. This linear relationship has led to the formation of the **Linear No-Threshold (LNT) hypothesis**. This hypothesis states that the risk of developing cancer secondary to radiation exposure varies in proportion to the size of the exposure, and there is no exposure threshold below which there is no risk. In other words, exposure to even a single x-ray photon carries a risk, albeit an extremely small risk. While it is important to understand that any exposure carries some risk, it is equally important to remember that nearly all radiation exposures from diagnostic tests and interventional procedures are well below the exposures that have a proven association with cancer development.

It must also be understood that the values we can report for individual radiation exposures are truly estimates. The only way to measure radiation doses precisely would be to implant dosimeters into every organ of the body and take individual measurements for each organ during the exposure. Since that is clearly not possible, other methods to estimate dose have been developed. These methods differ with each imaging modality. For example, acrylic phantoms (plastic cylinders with implanted dosimeters that simulate patient body size) are used to measure the radiation dose at various settings for a CT scanner. These values are then used to estimate exposure for a patient who is scanned with the same settings. Once the radiation exposure estimate is calculated, this number can be multiplied by a conversion factor that takes into account the radiation sensitivity of the organs exposed in the scan. The result is an **effective dose**, measured in **millisieverts (mSv)**. This effective dose can then be used to give a risk estimate, as is given in the tables in [section 6](#). While this method has recognized limitations based on assumptions and estimates (the risk estimates may be off by up to 300%),<sup>7</sup> it is currently the best method available.

### 3.3 Estimated risk from a single CT or angiogram

The estimated risk of developing fatal cancer from a single CT scan or angiogram is low. This risk will vary based on the body area scanned and the technique used. The risk for fatal cancer is estimated at 1 in 10,000 to 1 in 2,500, depending on the nature of the diagnostic study<sup>8</sup> (see [section 6](#) for a list of estimated exposures and associated estimated risks).

To put this risk in perspective, the background lifetime risk of fatal cancer is 1 in 5, or 20%. Therefore, one CT scan with an increased fatal cancer risk of 1 in 2,500 would increase the probability of developing fatal cancer during a patient's lifetime from 20% to 20.04%.<sup>9</sup> With such a small increase in risk, in the vast majority of cases the benefit from an indicated diagnostic or therapeutic study will far outweigh the risk.

### 3.4 Factors that affect an individual patient's cancer risk

Many factors can affect an individual patient's cancer risk. Some of these are easily measured, while others are largely theoretical. Because of the varied nature of these factors, calculating an absolute risk is a very complicated and likely impossible exercise. Therefore, it's important to understand the estimates and theories involved in discussing risk, and take a conservative approach with a focus on patient safety.

The factors that affect the risk from radiation exposure include (but are not limited to):

- **Age at exposure.** Age matters in two different ways. First, some tissues (gonads and thyroid) show increased radiosensitivity at young ages. This decreases with age until adulthood. Also, because there is a significant lag time between the time of exposure and the advent of a new cancer (up to 20 years), the younger a patient is at the time of exposure, the more likely it is that the individual will live long enough for a neoplasm to manifest. Therefore, a significant exposure in a 5-year-old has higher risk than in a 35-year-old, and a similar exposure in a 75-year-old may have very little associated risk.

- **Sex.** Overall, women have a higher risk of malignancies from radiation exposure, due to breast tissue.
- **Body part exposed to radiation.** The gonads, breast tissue, and thyroid are the most sensitive to radiation exposure, while skin, muscle, and bone are the least sensitive. Therefore, a CT scan of the pelvis holds significantly greater risk than a CT scan of the foot. This variability in sensitivity of organs is accounted for as measures of x-ray tube output are converted to an effective dose.
- **Genetics.** Genetic factors can have both a positive and a negative effect on risk. Like many other carcinogens, radiation causes cancer by altering DNA, so a patient with strong DNA repair mechanisms may not have as much risk from exposure. There are also genetic syndromes, such as Li-Fraumeni Syndrome, that are believed to make an individual more sensitive to the carcinogenic effects of radiation.
- **Cumulative radiation dose.** This is a poorly understood but likely significant risk factor. From the existing data, it is clear that a large single dose of radiation (>100 mSv) carries a significant risk of carcinogenesis.<sup>6</sup> However, it is unclear if that level of risk is the same if a patient reaches this same lifetime exposure from several smaller doses (10 to 15 CT scans or 5 to 10 angiographic procedures). Recent evidence would suggest that a high cumulative dose does carry an increased risk,<sup>10</sup> but it remains unclear if this risk is the same as receiving the equivalent amount of radiation all in one dose. The Linear No-Threshold hypothesis would suggest that any dose, no matter the size, does carry a risk; the size of the risk depends on the size of the dose.
- **Other carcinogenic risk factors.** This is likely the most difficult factor to measure. There are many other carcinogenic factors (tobacco, ultraviolet light, viral infection, etc.) to which patients are exposed during their lifetime. Since these are mostly environmental factors, patients may not realize their exposure; measuring their effect on risk and how these effects interact with the risk from radiation exposure is not possible.

As you can see, determining risk from radiation exposure is a complicated and not yet completely understood subject. Because of this, making absolute risk estimates from radiation exposure is very tricky and should be done with great caution. However, two guiding principles can help us to keep this process in perspective:

- 1 **A conservative approach to patient safety is always a reasonable approach.** Therefore, following the principles of the Linear No-Threshold hypothesis is a sound way of dealing with radiation safety.
- 2 **The risks from any one imaging test are likely to be far outweighed by the diagnostic advantages of the test, given that the study is indicated.** The next section summarizes ways to ensure that the test is indicated.

## 4 ► FACTORS TO CONSIDER WHEN CHOOSING AN IMAGING STRATEGY

Justification of imaging is an important strategy in controlling radiation exposure from medical testing, both in individuals as well as in the population as a whole. This is the area where referring clinicians can do the greatest good in terms of helping to control radiation exposure. Key points (click each item for more details):

- **Evaluate the need:** Is the test necessary? Is the information already available? What are the risks of not imaging? ([See Section 4.1.](#))
- **Think about the patient's unique factors:** What is the patient's disease state? Age? Is the patient pregnant? ([See Section 4.2.](#))
- **Evaluate the proposed procedure:** Is it appropriate for the need? ([See Section 4.3.](#))
- **Check the exposure:** Look at the patient's cumulative radiation exposure. ([See Section 4.4.](#))
- **Check available guidelines and resources:** These can help in choosing the best imaging procedure. ([See Section 4.5.](#))

### 4.1 The need

The following questions are helpful to ask yourself when determining the need for a diagnostic test:

- **Has this same test been performed recently?** If yes, what has changed with the patient since the last time the test was performed?
- **How will the test results affect your management of the patient?**
- **What is the risk to the patient if I don't image?**

An imaging test may be absolutely necessary — and the risk of not imaging may far outweigh any risk from the test. In other situations, providers are faced with a request from the patient or a patient representative to perform a diagnostic test that is not necessary and exposes the patient to radiation. This is an area where difficult conversations may need to happen for the good of the patient. For more information, see [section 5](#).

### 4.2 The patient

As stated above, a patient's risk from a radiation exposure depends on many factors, which should be considered when choosing an imaging strategy.

- **Disease state.** Factors unique to a specific disease process may also influence your choice of imaging. For example, in evaluating Crohn's disease, MR enterography may be a better choice than CT enterography, when you consider that the patient is likely to undergo multiple imaging evaluations of the abdomen and pelvis over the course of the disease. In some patients, this could require 5 to 10 abdominal imaging studies over a several-year period. If all these studies are performed by CT, a patient's estimated effective dose could reach considerable levels. On the other hand, if MR enterography is used, there is no radiation exposure.



- **Age.** The younger a patient is at the time of exposure, the higher the associated cancer risk. The younger the patient, the more important it is to spend extra effort evaluating the need for the procedure or considering a diagnostic test that doesn't use radiation.
- **Sex.** Because women have a higher risk of malignancies from radiation exposure, female sex may prompt you to consider alternatives to tests that involve significant exposure, if available.
- **Pregnancy.** There are higher risks from radiation exposure in a developing fetus. Always ask if your female patient might be pregnant, and look for non-radiation alternatives for pregnant patients if possible.

### 4.3 The procedure

The choice of a diagnostic imaging modality and the way it is used can vary greatly with the clinical question. Potential radiation exposure should be a part of this decision.

- **Non-radiation alternatives that are just as effective, or even more effective, are often available.** Ultrasound and MRI are very good imaging modalities that do not involve any radiation exposure. For example, either CT or MRI of the brain can be used in the course of a workup for seizures. While CT has the advantage of being fast and readily available, MRI gives better tissue detail and is more sensitive in revealing structural brain abnormalities which could be the cause of seizures. Evidence shows that if there is no neurologic deficit associated with the seizure, emergent intervention is rarely necessary. It is often tempting to order the test with faster results, but in the case of a seizure without neurologic deficit, an MRI gives better information and doesn't expose the patient to radiation. See section [4.5 Guidelines and Resources](#) to find resources that will help you choose between imaging procedures.
- **Procedures that involve radiation can be tailored for specific clinical indications to incorporate the lowest radiation exposure possible.** The history and indications you provide with your order can make this tailoring possible. For example, x-ray tube output can be lowered for certain indications such as renal stones, resulting in lower radiation exposure. Multiphase scans can be avoided in many cases, and scan length can be limited if the area of interest is clear, based on the history. For example, a CT scan to evaluate an adrenal gland mass may be limited to the adrenal gland instead of extending through the abdomen. Finally, in most cases CT scanning with and without contrast is not indicated.

#### What's in my patient's number?

The cumulative number in HELP2 incorporates the estimated exposure for all CT scans, cardiac nuclear medicine studies, interventional radiology studies, and cardiac catheterization procedures performed for the patient at Intermountain facilities, 2012 and later. These were chosen because they tend to have the highest radiation exposures. Eventually, exposures from all diagnostic tests involving radiation will be included.

### 4.4 The patient's cumulative radiation exposure

**How do I use my patient's cumulative exposure number?** These data may be helpful in deciding if a certain test is necessary. A patient's cumulative exposure should not be used to restrict the performance of a diagnostic test, but it may be useful in assessing the risk/benefit ratio of a particular test in a specific patient.

**In general, what's the risk from cumulative radiation exposure?** As concerns over radiation exposure grow, questions about cumulative exposures also grow. This is especially important for patients with diseases that require repeated diagnostic imaging. As multiple imaging tests are performed, it is possible that a patient's cumulative radiation dose may exceed 100 mSv.

The lifetime risk model in the BEIR VII report<sup>6</sup> states that approximately **1 individual in 100** would be expected to develop cancer due to an exposure of **100 mSv** above the background exposure from natural sources. However, it is not clear how this risk is affected by the **dose rate** — the amount of time it takes to accumulate a total exposure. There is clearly an increased risk from a one-time 100 mSv exposure due to a nuclear bomb or radiation accident. However, is there a difference in risk between a 100 mSv exposure from 5 to 10 long cardiac catheterization procedures over a 5-year period, versus 20 abdominal CT scans over a 10-year period? At the current time there is not sufficient data to support an answer.

Three facts further complicate the question of risk from cumulative medical radiation exposure. Everyone in Utah is exposed to approximately 4 mSv annually from natural background radiation, so we accumulate around 200 mSv by the age of 50 — regardless of medical exposure. Also, 40 out of 100 individuals will develop cancer anyway — regardless of medical radiation exposure. Finally, each person's individual cancer risk is affected by age, other carcinogens, genetics, and other factors as discussed earlier.

Nevertheless, according to the Linear No-Threshold Hypothesis, every radiation exposure (no matter how small) does carry a small inherent risk. Because of the estimates and assumptions involved in measuring radiation exposure and the nature of the data on the health effects of radiation, making absolute risk estimates is nearly impossible. It remains unclear how a single added radiation exposure will interact with a lifetime exposure to affect an individual's overall risk.

Despite these uncertainties, Intermountain recognizes the importance of tracking cumulative radiation exposures as a way to audit our processes, further optimize our imaging protocols, and improve our treatment algorithms. In the long term, tracking cumulative radiation exposures may generate data that can help us better understand the risks.

## 4.5 Guidelines and resources

Many resources are available to you when considering an imaging strategy:

- **Guidelines:** The [American College of Radiology](#) and the [American College of Cardiology](#) provide guidelines and appropriate use criteria to help you decide when imaging is necessary and if so, which procedure is best.
- **Associations:** The websites [imagegently.org](#), [imagewisely.org](#), and [choosingwisely.org](#) have helpful information on radiation safety and evaluating imaging procedures.
- **Radiologist:** Your local radiologist is also a great resource for advice on the utility of various imaging studies.

Please use these resources and give careful consideration to the imaging strategies that you use.

## 5 ► DISCUSSING THIS INFORMATION WITH YOUR PATIENT

Key points:

- **Cumulative radiation exposure:** Provide basic information and use Intermountain patient education resources to answer patient questions about cumulative radiation exposure. (*See Section 5.1.*)
- **An indicated imaging procedure:** If patients are worried about proposed imaging procedures that are necessary and indicated, reassure them by explaining how you will use the information, provide comparisons to give context for the level of radiation, and use Intermountain and web-based patient education resources. (*See Section 5.2.*)

### 5.1 Discussing cumulative radiation exposure

If patients ask about the cumulative radiation exposure number on their MyHealth screen, consider this approach:

- **Explain Intermountain's reasons for collecting the number.** Intermountain is collecting this information for reference and to help us improve overall processes related to procedures that use radiation.
- **Explain that the number is limited just to certain procedures, if done at Intermountain facilities from mid-2012 onward.** While the MyHealth page displaying the number says that it includes only CT scans, angiograms, nuclear cardiology, and cardiac catheterization procedures, you may want to explain this again.
- **Explain Intermountain's reasons for reporting the number to patients.** Intermountain is providing this information to help patients check their own imaging exposure and inform them about Intermountain's efforts to increase radiation safety.
- **Provide some context** for the number in one of two ways, depending on the situation:
  - **Compare it to exposure from natural sources.** This strategy may be useful for patients who are worried about an indicated procedure. In Utah and Colorado, we're exposed to 4 mSv per year from natural sources. A cumulative exposure of 20 mSv is equivalent to living in one's natural surroundings for 5 years.
  - **Compare it to the equivalent number of chest x-rays.** This strategy may be useful for patients who insist on a test that isn't indicated.
    - An adult with a cumulative exposure of 20 mSv has had the equivalent of 200 chest x-rays, since the average 2-view CXR exposes the patient to 0.1 mSv of radiation. For an adult, multiply any cumulative exposure (in mSv) by 10 to get the equivalent number of chest x-rays.
    - A five-year-old child with a cumulative exposure of 20 mSv has had the equivalent of 400 chest x-rays, since the average 2-view CXR exposes a five-year-old child to 0.05 mSv of radiation.

- **Be cautious about interpreting the cancer risk posed by a patient's cumulative exposure.** Remember that reported radiation exposures are all estimates, and all risk estimates involve significant assumptions. If a patient wants to discuss this topic, consider making the following points with your patient:
  - The added lifetime cancer risk posed by imaging radiation is not proven, but must be estimated. This estimate is based on assumptions that focus on safety and caution, and it's very small when compared to the overall cancer risk we all face from a variety of sources.
  - Our overall lifetime risk of cancer is 40%, and some experts feel that 100 mSv of medical radiation can increase this lifetime risk by 1%.
  - If a procedure using radiation is necessary to diagnose or treat a health problem, in most cases the added tiny risk is not as important as the benefit you will receive from the procedure.
  - The key, regardless of your cumulative exposure, is making sure that each procedure is necessary and will provide information used in your treatment
- **Use Intermountain patient education resources and web-based resources.** See the links below:
  - Intermountain's patient fact sheet [Radiation Exposure in Medical Tests](#) (also in [Spanish](#)).
  - [Image Wisely](#) — the Patient tab contains handouts, medical imaging record sheets, and other resources.
  - [Image Gently](#) — the Parent tab contains similar information, with a pediatric focus.
  - [RadiologyInfo](#) — provides information on radiation risks/benefits and a table for patients with radiation exposures from common procedures. (Note: The exposure information is a bit older and may differ from the numbers in [section 6](#) of this document.)

## 5.2 Discussing an indicated imaging procedure

See the tips below on discussing an indicated procedure with a patient:

- **Describe benefits of the procedure.** Explain the information you will gain and how that information will affect your treatment decisions.
- **Provide context and information about risk.** Provide information that is geared toward the level of effective radiation dose (see [section 6](#) below):
  - **For a test with minimal or low effective radiation dose (1 mSv or less),** compare the radiation from the procedure to background radiation. A chest radiograph involves the same effective dose as a cross-country flight. A mammogram involves the same effective dose as about 7 weeks in natural surroundings.

- For a procedure with moderate effective dose (1 to 10 mSv), explain that the procedure involves more radiation than a basic x-ray and use Intermountain’s fact sheet [Radiation Exposure in Medical Tests](#) to guide a conversation about the risks and benefits of radiation in medical procedures. You can consult the tables in [section 6](#) to provide information about the estimated effective dose from the procedure.
- For a procedure with more than 10 mSv effective radiation dose, explain the risks from NOT having the procedure, in addition to providing the information discussed above.

## 6 ► ESTIMATED EFFECTIVE RADIATION DOSES AND LIFETIME RISKS FROM COMMON PROCEDURES

The tables in this section are based on information from the published literature, many from the article “Effective Doses in Radiology and Nuclear Medicine: a Catalog” by Mettler et al<sup>1</sup> and mammographic dose/risk estimates from recent articles by Hendrick et al.<sup>12, 13</sup> This information was compiled by the Department of Radiology, University of Colorado – Denver.<sup>8</sup>

The tables include national estimates for adults — they do not represent exact exposure for every patient in every circumstance, and they may not represent ongoing efforts by Intermountain and others to further reduce exposure rates. For each procedure, the approximate additional risk of fatal cancer for an adult is shown, with risk based on the Linear No-Threshold Hypothesis and the BIER VII report.<sup>6</sup> The risks are color-coded, and the table below places exposure and risk levels in context with other estimated lifetime risks of death. (Keep in mind that risk estimates for radiation exposures involve significant assumptions.)

**Table 1. Average Annual Effective Doses**

Average Annual Effective Dose from Natural Background Radiation	
United States	3.1 mSv
State of Colorado	4.0 mSv
Color Code for Risk Levels	
Approximate additional risk of fatal cancer for an adult	Risk Level
Less than 1 in 1,000,000	Negligible
1 in 1,000,000 to 1 in 100,000	Minimal
1 in 100,000 to 1 in 10,000	Very Low
1 in 10,000 to 1 in 1,000	Low
1 in 1,000 to 1 in 500	Moderate
Estimated Lifetime Risks of Death	
Lightning strike	1 in 100,000
Bicycle accident	1 in 10,000
Drowning	1 in 1,000
Motor vehicle accident	1 in 100
Cancer (from natural causes)	1 in 5

*The tables are organized in two ways — by modality and by body region.*

*Adapted from data obtained by the Department of Radiology, University of Colorado School of Medicine – Denver.<sup>8</sup>*

Table 2. Estimated effective radiation dose and lifetime risk — by modality

Procedure	Estimated Effective Radiation Dose	Estimated lifetime risk of fatal cancer
<b>Radiographs</b>		
Lower GI tract x-ray (small-bowel series)	3 mSv	1 in 8,000
Upper GI tract x-ray (with fluoro)	6 mSv	1 in 4,000
Barium enema	8 mSv	1 in 3,000
Spinal x-ray: cervical spine	0.2 mSv	1 in 120,000
Spinal x-ray: thoracic or lumbar spine	1.25 mSv	1 in 20,000
Chest x-ray (PA + lateral)	0.1 mSv	1 in 240,000
Chest x-ray, low dose (PA only)	0.02 mSv	1 in 1.2 million
Abdomen/hip/pelvis x-ray	0.7 mSv	1 in 35,000
Extremity x-ray (hand, foot, etc.)	0.005 mSv	1 in 5 million
Bone densitometry-DEXA scan (dual x-ray absorptiometry)	0.001 mSv	1 in 24 million
Bilateral mammography	0.48 mSv	Age 70: 1 in 500,000
		Age 60: 1 in 250,000
		Age 50: 1 in 125,000
		Age 40: 1 in 70,000
Endoscopic retrograde cholangiopancreatography	4 mSv	1 in 6,000
<b>CT scans</b>		
CT: abdomen	8 mSv	1 in 3,000
CT: pelvis	6 mSv	1 in 4,000
CT: head	2 mSv	1 in 12,000
CT: spine	6 mSv	1 in 4,000
CT: chest	7 mSv	1 in 3,500
Coronary CT angiography	12 mSv	1 in 2,000
Cardiac CT for calcium scoring	3 mSv	1 in 8,000
Virtual colonoscopy	10 mSv	1 in 2,400
CTPA: chest for pulmonary embolism	15 mSv	1 in 1,600
3-phase liver study	15 mSv	1 in 1,600
<b>Nuclear medicine</b>		
Lung ventilation ( <sup>99m</sup> Tc-DTPA)	0.2 mSv	1 in 120,000
Lung ventilation ( <sup>113</sup> Xe)	0.5 mSv	1 in 50,000
Lung perfusion ( <sup>99m</sup> Tc-MAA)	2 mSv	1 in 12,000
GI emptying ( <sup>99m</sup> Tc-labeled solids)	0.4 mSv	1 in 60,000
GI Bleeding ( <sup>99m</sup> Tc-labeled RBCs)	7.8 mSv	1 in 3,100
Renal ( <sup>99m</sup> Tc-DTPA)	1.8 mSv	1 in 14,000
Renal ( <sup>99m</sup> Tc-glucoheptonate)	2 mSv	1 in 12,000
Renal ( <sup>99m</sup> Tc-MAG3)	2.6 mSv	1 in 9,400
Renal ( <sup>99m</sup> Tc-DMSA)	3.7 mSv	1 in 7,400
Thyroid scan (Sodium iodine-123)	1.9 mSv	1 in 13,000
Thyroid scan ( <sup>99m</sup> Tc-pertechnetate)	4.8 mSv	1 in 5,000
Parathyroid scan ( <sup>99m</sup> Tc-sestamibi)	6.7 mSv	1 in 3,600
Liver-spleen ( <sup>99m</sup> Tc-sulfur colloid)	2.1 mSv	1 in 12,000
Biliary tract ( <sup>99m</sup> Tc-disofenin)	3.1 mSv	1 in 7,900
Brain ( <sup>99m</sup> Tc-ECD-neurolite)	5.7 mSv	1 in 4,000
Brain ( <sup>99m</sup> Tc-HMPAO-exametazine)	6.9 mSv	1 in 3,500

Adapted from data obtained by the Department of Radiology, University of Colorado School of Medicine – Denver.<sup>8</sup>

Procedure	Estimated Effective Radiation Dose	Estimated lifetime risk of fatal cancer
Brain ( <sup>18</sup> F-FDG)	14.1 mSv	1 in 1,700
Bone ( <sup>99m</sup> Tc-MDP)	6.3 mSv	1 in 4,000
White blood cells ( <sup>111</sup> In)	6.7 mSv	1 in 3,600
White blood cells ( <sup>99m</sup> Tc)	8.1 mSv	1 in 3,000
Breast-specific gamma imag ( <sup>99m</sup> Tc-sestamibi)	9.4 mSv	1 in 2,600
Cardiac ventriculography ( <sup>99m</sup> Tc-labeled RBC)	7.8 mSv	1 in 3,100
Cardiac rest-stress, 1-day ( <sup>99m</sup> Tc-sestamibi)	9.4 mSv	1 in 2,600
Cardiac rest-stress, 2-day ( <sup>99m</sup> Tc-sestamibi)	12.8 mSv	1 in 1,900
Cardiac rest-stress ( <sup>99m</sup> Tc-tetrofosman)	11.4 mSv	1 in 2,100
Cardiac stress-rest (thallium 201 Cl)	40.7 mSv	1 in 600
Cardiac ( <sup>18</sup> F-FDG)	14.1 mSv	1 in 1,700
Positron emission mammography (F <sup>18</sup> -FDG)	7 mSv	1 in 3,500
Pentretotide ( <sup>111</sup> In)	12 mSv	1 in 2,000
Tumor ( <sup>18</sup> F-FDG)	14.1 mSv	1 in 1,700
Gallium 67 citrate	15 mSv	1 in 1,600
<b><i>Interventional radiology and cath lab</i></b>		
Head and neck angiography	5 mSv	1 in 5,000
Thoracic angiography of pulmonary artery or aorta	5 mSv	1 in 5,000
Coronary angiography (dx)	7 mSv	1 in 3,500
Abdominal angiography or aortography	12 mSv	1 in 2,000
Coronary percutaneous transluminal angioplasty, stent placement, or RF ablation	15 mSv	1 in 1,600
Pelvic vein embolization	60 mSv	1 in 400
Transjugular intrahepatic portosystemic shunt placement	70 mSv	1 in 350

Adapted from data obtained by the Department of Radiology, University of Colorado School of Medicine – Denver.<sup>8</sup>

**Table 3. Estimated effective radiation dose and lifetime risk — by body region or system**

Procedure	Estimated Effective Radiation Dose	Estimated lifetime risk of fatal cancer
<b>Abdominal region and/or pelvis</b>		
X-ray: lower GI tract (small-bowel series)	3 mSv	1 in 8,000
X-ray: upper GI tract (with floro)	6 mSv	1 in 4,000
X-ray: barium enema	8 mSv	1 in 3,000
X-ray: abdomen/hip/pelvis	0.7 mSv	1 in 35,000
Endoscopic retrograde cholangiopancreatography	4 mSv	1 in 6,000
CT: abdomen	8 mSv	1 in 3,000
CT: pelvis	6 mSv	1 in 4,000
CT: virtual colonoscopy	10 mSv	1 in 2,400
CT: 3-phase liver study	15 mSv	1 in 1,600
Nucmed: GI emptying ( <sup>99m</sup> Tc-labeled solids)	0.4 mSv	1 in 60,000
Nucmed: GI Bleeding ( <sup>99m</sup> Tc-labeled RBCs)	7.8 mSv	1 in 3,100
Nucmed: renal ( <sup>99m</sup> Tc-DTPA)	1.8 mSv	1 in 14,000
Nucmed: renal ( <sup>99m</sup> Tc-glucoheptonate)	2 mSv	1 in 12,000
Nucmed: renal ( <sup>99m</sup> Tc-MAG3)	2.6 mSv	1 in 9,400
Nucmed: renal ( <sup>99m</sup> Tc-DMSA)	3.7 mSv	1 in 7,400
Liver-spleen ( <sup>99m</sup> Tc-sulfur colloid)	2.1 mSv	1 in 12,000
Biliary tract ( <sup>99m</sup> Tc-disofenin)	3.1 mSv	1 in 7,900
Interventional radiology: pelvic vein embolization	60 mSv	1 in 400
Interventional radiology: transjugular intrahepatic portosystemic shunt placement	70 mSv	1 in 350
<b>Bone</b>		
X-ray: cervical spine	0.2 mSv	1 in 120,000
X-ray: thoracic or lumbar spine	1.25 mSv	1 in 20,000
X-ray: extremity (hand, foot, etc.)	0.005 mSv	1 in 5 million
X-ray: bone densimetry-DEXA scan (dual x-ray absorptionmetry)	0.001 mSv	1 in 24 million
CT: spine	6 mSv	1 in 4,000
Nucmed: bone ( <sup>99m</sup> Tc-MDP)	6.3 mSv	1 in 4,000
<b>Central nervous system</b>		
CT: head	2 mSv	1 in 12,000
CT: spine	6 mSv	1 in 4,000
Nucmed: brain ( <sup>99m</sup> Tc-ECD-neurolite)	5.7 mSv	1 in 4,000
Nucmed: brain ( <sup>99m</sup> Tc-HMPAO-exametazine)	6.9 mSv	1 in 3,500
Nucmed: brain ( <sup>18</sup> F-FDG)	14.1 mSv	1 in 1,700
<b>Chest</b>		
X-ray: chest (PA + lateral)	0.1 mSv	1 in 240,000
X-ray: chest, low dose (PA only)	0.02 mSv	1 in 1.2 million
Mammography: bilateral	0.48 mSv	Age 70: 1 in 500,000 Age 60: 1 in 250,000 Age 50: 1 in 125,000 Age 40: 1 in 70,000
CT: chest	7 mSv	1 in 3,500
CTPA: chest for pulmonary embolism	15 mSv	1 in 1,600

Adapted from data obtained by the Department of Radiology, University of Colorado School of Medicine – Denver.<sup>8</sup>



Procedure	Estimated Effective Radiation Dose	Estimated lifetime risk of fatal cancer
Nucmed: lung ventilation ( <sup>99m</sup> Tc-DTPA)	0.2 mSv	1 in 120,000
Nucmed: lung ventilation ( <sup>113</sup> Xe)	0.5 mSv	1 in 50,000
Nucmed: lung perfusion ( <sup>99m</sup> Tc-MAA)	2 mSv	1 in 12,000
Nucmed: positron emission mammography (F <sup>18</sup> -FDG)	7 mSv	1 in 3,500
Nucmed: breast-specific gamma imag ( <sup>99m</sup> Tc-sestamibi)	9.4 mSv	1 in 2,600
<b>Endocrine</b>		
Nucmed: thyroid scan (Sodium iodine-123)	1.9 mSv	1 in 13,000
Nucmed: thyroid scan ( <sup>99m</sup> Tc-pertechnetate)	4.8 mSv	1 in 5,000
Nucmed: parathyroid scan ( <sup>99m</sup> Tc-sestamibi)	6.7 mSv	1 in 3,600
<b>Heart, lungs, and cardiovascular</b>		
CT: coronary CT angiography	12 mSv	1 in 2,000
CT: cardiac CT for calcium scoring	3 mSv	1 in 8,000
CTPA: chest for pulmonary embolism	15 mSv	1 in 1,600
Nucmed: cardiac ventriculography ( <sup>99m</sup> Tc-labeled RBC)	7.8 mSv	1 in 3,100
Nucmed: cardiac rest-stress, 1-day ( <sup>99m</sup> Tc-sestamibi)	9.4 mSv	1 in 2,600
Nucmed: cardiac rest-stress, 2-day ( <sup>99m</sup> Tc-sestamibi)	12.8 mSv	1 in 1,900
Nucmed: cardiac rest-stress ( <sup>99m</sup> Tc-tetrofosman)	11.4 mSv	1 in 2,100
Nucmed: cardiac stress-rest (thallium 201 Cl)	40.7 mSv	1 in 600
Nucmed: cardiac ( <sup>18</sup> F-FDG)	14.1 mSv	1 in 1,700
Angiogram: head and neck	5 mSv	1 in 5,000
Angiogram: thoracic, pulmonary artery, or aorta	5 mSv	1 in 5,000
Angiogram: coronary angiography (dx)	7 mSv	1 in 3,500
Angiogram: abdominal or aortography	12 mSv	1 in 2,000
Cath lab: coronary percutaneous transluminal angioplasty, stent placement, or RF ablation	15 mSv	1 in 1,600
Cath lab: pelvic vein embolization	60 mSv	1 in 400
<b>Whole body</b>		
Nucmed: white blood cells ( <sup>111</sup> In)	6.7 mSv	1 in 3,600
Nucmed: white blood cells ( <sup>99m</sup> Tc)	8.1 mSv	1 in 3,000
Pentretotide ( <sup>111</sup> In)	12 mSv	1 in 2,000
Tumor ( <sup>18</sup> F-FDG)	14.1 mSv	1 in 1,700
Gallium 67 citrate	15 mSv	1 in 1,600

Adapted from data obtained by the Department of Radiology, University of Colorado School of Medicine – Denver.<sup>8</sup>

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