# Should We Be Concerned About the Rapid Increase in CT Usage?

**President's Cancer Panel January 27, 2009**

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## INTRODUCTION: WHAT IS CT SCAN?

Computed Tomography (CT) has transformed much of medical imaging by allowing three-dimensional views of the organ or part of the body of interest. The basic principles of axial and helical (also known as spiral) CT scanning are illustrated in Figure 1. In contrast to conventional radiographs, like a chest x-ray or a mammogram, essentially many images are taken, which are then combined by computer to produce a 3-D image.

## WHY ARE WE PARTICULARLY CONCERNED ABOUT CT?

1. CT usage has recently increased rapidly.
2. Compared to most radiological examinations, CT produces a larger x-ray radiation dose.
3. CT x-ray doses are typically large enough that there is direct epidemiological evidence for an increase in cancer risk.
4. Increased CT usage on children.
5. CT usage is likely to undergo a further major increase in the next decade.

### CT Usage Has Increased Rapidly in the Past Decade

Currently, about 70 million CT scans per year are being performed in the USA—so on average 1 in 4 individuals are receiving a CT scan every year. In the US, this translates into about 1/4 of the average radiation exposure, from all sources, that we receive.

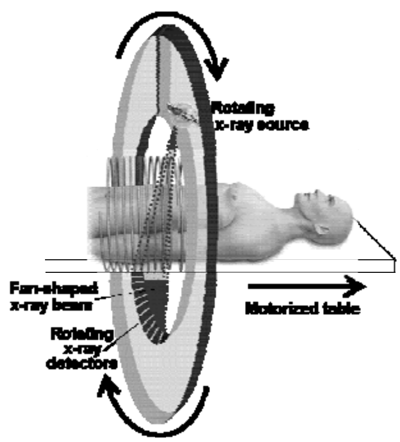
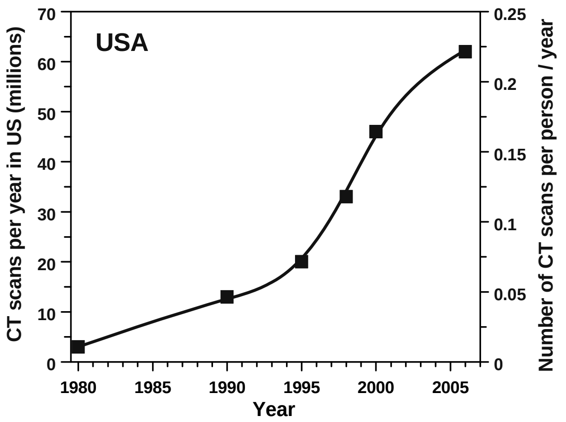
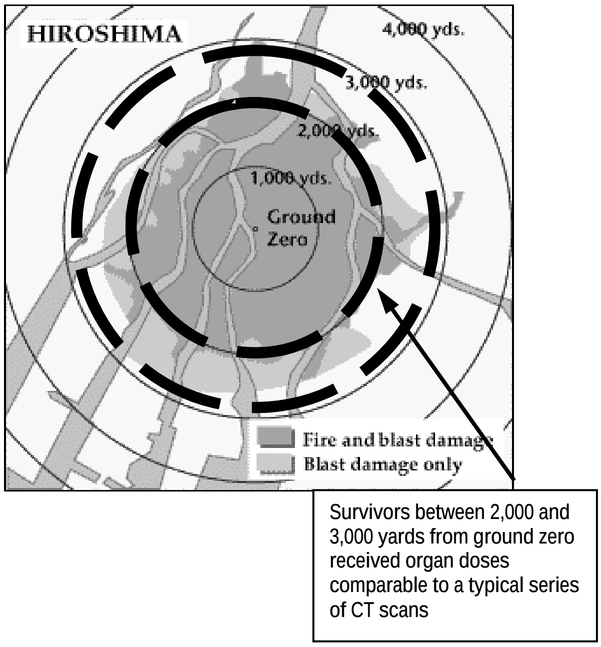



**Fig. 1:** **The Basics of CT.** A motorized table moves the patient through the CT imaging system. At the same time, a source of x-rays rotates within the circular opening, and a set of x-ray detectors rotates in synchrony on the far side of the patient. The x-ray source produces a narrow, fan-shaped beam, with widths ranging from 1 to 20 mm. In axial CT, commonly used for head scans, the table is stationary during a rotation, after which it is moved along for the next slice. In helical CT, which is commonly used for body scans, the table moves continuously as the x-ray source and detectors rotate, producing a spiral or helical scan. The illustration shows a single row of detectors, but current machines typically have multiple rows of detectors operating side by side, so that many slices (currently up to 320) can be imaged simultaneously, reducing the overall scanning time. All data are processed by computer to produce a series of image slices representing a three-dimensional view of the target organ or body region.




## Compared to Most Radiological Examinations, CT Produces a Larger Radiation Dose

Because a CT scan effectively involves taking many individual radiographs, x-ray radiation doses from CT examinations are considerably larger than those from the corresponding conventional x ray radiograph. For example, a typical x-ray dose to the lung from a conventional chest x ray is about one hundred times less than that from the corresponding chest CT.

## CT Doses are Typically Large Enough that there is Epidemiological Evidence for an Increase in Cancer Risk

Because CT is a relatively new modality, and because there is typically a delay of decade(s) between radiation exposure and the appearance of an induced cancer, only now are direct epidemiological studies of the effects of CT scans being initiated.

More generically, our knowledge of the biological effects of ionizing radiation comes from the study of Japanese A-bomb survivors. The reason that the A-bomb survivors are such a useful source of risk estimates is a) they represent a cross section of a normal population (not, for example, individuals already ill), b) they have been studied intensively for more than half a century and c) the radiation doses that each survivor received is moderately well known.

Of course survivors who were very close to the bomb epicenters were exposed to very high doses, but survivors who were roughly two to three thousand yards away from the explosion were exposed to doses similar to the organ doses from a typical series (2 or 3) of CT scans.

Specifically there were about 28,000 survivors exposed in this relevant dose range, and they show a small but statistically significant irradiation-associated increase in cancer risk. Thus there is direct evidence that the radiation doses associated with CT scans are associated with an increase in cancer risk.

## CT usage for Children

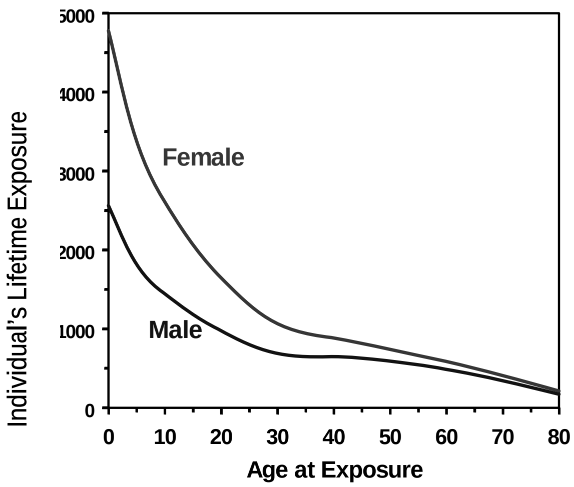
Pediatric CT has become a commonly used modality rather more recently than was the case for adult CT. This is because early CT scanners required exposure times of several tens of seconds, which in turn typically required that children be sedated. Now that exposure times are around 1 second, sedation is no longer needed. Reasonable estimates of the number of pediatric CT scans performed per year in the US were about ½ million in 1989, and currently about 5 million per year.

Pediatric CT is qualitatively different from adult CT for several reasons:

1. CT radiation doses can be much larger for children than adults.
2. Pediatric CT usage is increasing rapidly.
3. Children are much more sensitive to radiation-induced cancer than adults.

With regard to the radiation sensitivity of children, they are more sensitive to radiation than adults for two reasons:

1. There is a long "latency period" between radiation exposure and a possible radiation-induced cancer appearing—often several decades. So an exposed child potentially has more time for a cancer to appear than, say, an individual exposed in old age.
2. Children are inherently more sensitive to radiation-induced exposure, because they have a larger proportion of dividing cells than adults.




As a result of these two effects, children are much more sensitive than adults to a given dose of radiation, as shown in this graph which depicts lifetime cancer risks from a given low dose of radiation, based on results from A-bomb survivors exposed at differing ages.

**CT Usage is Likely to Undergo a Further Major Increase in the Next Decade**

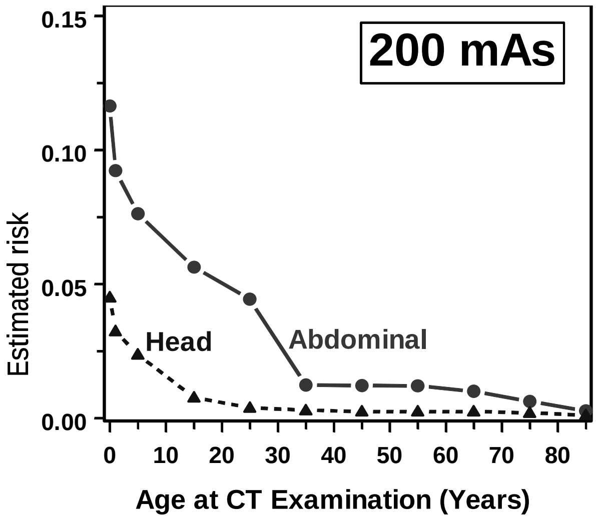
Until recently, CT has been predominantly used for diagnosing disease in individuals who are sick or injured. However, there is increasing interest in its use for diagnosing disease in apparently healthy individuals – often referred to as "screening". The balance between benefit and risk is clearly very different for screening, compared to the conventional used of CT. The four types of CT-based screening of interest are

- lung cancer screening in smokers and ex smokers
- cardiac disease screening
- colon cancer screening – "virtual colonoscopy"
- whole body CT screening

With the exception of whole-body screening, these represent very promising modalities, though the efficacy of both CT-based lung screening and cardiac screening are not yet fully established, and are in fact the subject of much controversy. However, increasing use of these modalities is expected to result in a further increase in CT usage over the next decade.

## WHAT ARE OUR BEST ESTIMATES OF THE RISKS ASSOCIATED WITH THE RADIATION EXPOSURE FROM CT SCANS?

The "generic" risk estimates shown here of the lifetime cancer risks associated with the radiation from single head and abdominal CT scans come from a) an understanding of the radiation doses to




different organs from these CT scans, and b) risk estimates from A-bomb survivors exposed to similar doses to those from CT scans (see above).

Note that these are small risks. As an example, the lifetime cancer risk estimate associated with an abdominal CT scan on a 25 year old is 0.05% which is 1 in 2,000. This is not a large individual risk, and most often the potential benefit of the CT scan will far outweigh this individual risk.

## INDIVIDUAL RISKS VS. PUBLIC HEALTH RISKS

While the individual risk estimates shown above are small, the concern about CT risks is related to the current rapid increase in CT usage—small individual risks applied to an increasingly large population may result to a potential public health issue some years in the future. Based on such risk estimates, and using 1991 through 1996 CT usage data, it has been estimated about 0.4% of all cancers in the US might be attributable to the radiation from CT examinations. Adjusting this estimate for current CT usage (see page 47), we might anticipate that, some decades from now, this estimate will be in the range from 1.5% to 2%.

## WHAT CAN BE DONE TO REDUCE THE PUBLIC HEALTH RISKS ASSOCIATED WITH INCREASED CT USAGE?

There are two ways to reduce the population risk associated with the sharp increase in population dose and risk from CT

1. Reduce the radiation dose per CT scan
2. Minimize unnecessary CT scans

### Reducing the Radiation Dose per CT Scan

There is particular potential for reducing the radiation dose per CT scan for children. Because children are thinner than adults, they need a smaller number of x rays to produce the same quality of image, and so the machine settings can and should be reduced for children. This is not, however, always done.

In recent years a new generation of CT scanners has reached the market, that feature various types of “automated tube current modulation”, in which the machine assesses the shape of the individual being scanned and determines the minimum amount of radiation to produce an acceptable image. Typically these approaches can reduce the radiation dose, and hence the risk, by about one third.

### Minimizing Unnecessary CT scans

It is generally accepted that a significant fraction of CT scans (perhaps 1/3) could practically be replaced by alternate approaches or need not be performed at all. However, targeting this “one third” is a very hard task, in that physicians are subject to significant “non-medical” pressures of various different types, including throughput, legal, economic, and from patients themselves. Probably the only realistic way to overcome these pressures is through widely accepted and used decision rules, i.e. evidence based imaging protocols for most common scenarios.

As an example, it is now unusual for a child to undergo an appendectomy without a prior CT scan to confirm appendicitis. While CT is indeed the gold standard for diagnosing appendicitis, decision rules could reduce the proportion of children receiving a CT before appendectomy by as much as 50%, while maintaining diagnostic efficiency. Some other common potential CT scenarios where widely accepted clinical decision rules would be beneficial are renal colic, abdominal and chest trauma, and pulmonary embolus. In fact the American College of Radiology and other bodies do have many relevant decision rules for a variety of scenarios, but they are not in routine use.

## SUMMARY

- ❖ There has been a rapid increase in the population dose from medical radiation within the last 20 years, particularly due to the increase in CT usage.
- ❖ Currently, about 65 million adult and 5 million pediatric CT exams are being performed in the US each year.
- ❖ CT-related x-ray doses are small, but very much larger than for most conventional radiological examinations.
- ❖ CT-related x-ray doses are large enough that there is statistically-significant epidemiological evidence of a small increase in cancer risk. Risks are larger for children.
- ❖ Estimated individual risks from CT are small, but the increasing population dose from increased CT usage leads to concerns about future public health problems.
- ❖ The various CT-based health screening applications are not yet quite ready for mass use, but will be soon, resulting in an expected further jump in CT usage.
- ❖ There is considerable potential, using ongoing technological developments, to reduce radiation doses per CT scan, and therefore the risks.
- ❖ There are significant numbers of CT scans (perhaps 1/3) which, based on medical considerations alone, either need not be done, or could reasonably be replaced with other imaging modalities.
- ❖ Developing and following clinical decision rules can reduce unnecessary CT usage.
- ❖ Communication between physician and patient about the benefits and also about the potential small risks of CT is a positive development, unlikely to reduce patient compliance.

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