TITLE: Computed Tomography: A Review of the Risk of Cancer Associated with Radiation Exposure

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CONTEXT AND POLICY ISSUES:

Health care professionals order diagnostic imaging for their patients to help make a diagnosis, monitor treatment progress, determine the extent of a disease, or to reassure a patient of the absence of a disease. One diagnostic modality that is both widely and increasingly being used in Canada and elsewhere is computed tomography (CT). Other commonly used diagnostic imaging modalities are magnetic resonance imaging (MRI) and ultrasound (US).

Determining which diagnostic imaging test a patient should undergo requires the referring health care professional to consider factors such as diagnostic accuracy, cost, and patient safety.

For CT examinations, one primary area of interest of patient safety is the risk for radiation-induced cancer. During CT examinations, cells are modified by the radiation which may cause these exposed cells to develop into cancer after a latency period. The risk of cancer can also be passed on to offspring of the patient if the modified cells are in areas like the patient’s ovaries or testes. The cancer that develops can be fatal or nonfatal and can appear after a long latency period (between 10 to 20 years for solid cancers) or a shorter latency period (two to five years for leukemia).

Radiation risk varies for many reasons, including the size of the patient, whether the patient is a child, and the location on the body of the scan. There is no radiation dose threshold deemed to be absolutely safe and the relationship between radiation dose and risk of adverse events are theorized to be linear. Thus, for patients undergoing CT examinations, medical exposure to radiation should be kept as low as reasonably achievable.

Cumulative cancer risk in Canadians from diagnostic x-rays (including CT examinations) was estimated by one group to be 1.1% for people up to age 75, which translates into 784 cases of
cancer each year. The National Research Council estimated the cancer risk was one in 100 people from a radiation dose equivalent to 10 abdominal CT examinations; the International Commission on Radiological Protection estimated this risk to be six out of 1,000 people. These lifetime risks may be worse for children due to the fact that they have longer life expectancy and have increased sensitivity to radiation exposure. Currently, there is no Canadian regulation governing the radiation patients are exposed to from medical tests.

Given the risks associated with radiation exposure, it is an important consideration alongside cost and diagnostic accuracy when determining which diagnostic imaging test to order for a patient. To help health care professionals better understand the risks associated with patient radiation exposure and how to minimize patient radiation exposure from CT examinations, a review of the literature has been undertaken.

RESEARCH QUESTION:

What is the evidence for the risk of cancer associated with radiation exposure from computed tomography?

METHODS:

A limited literature search was conducted on key health technology assessment resources, including OVID’s Medline, the Cochrane Library (Issue 3, 2009), University of York Centre for Reviews and Dissemination (CRD) databases, ECRI, EuroScan, international health technology agencies, and a focused Internet search. The search was limited to English language articles published between 2004 and July 2009. A focused search (focused mesh subject headings and all main concepts appeared in the title field) was performed. Filters were applied to limit the retrieval to health technology assessments, systematic reviews, meta-analyses, randomized controlled trials, controlled clinical trials, and guidelines. Internet links were provided, where available.

HTIS reports are organized so that the higher quality evidence is presented first. Therefore, health technology assessment reports, systematic reviews, and meta-analyses are presented first. These are followed by randomized controlled trials, controlled clinical trials, and evidence-based guidelines.

SUMMARY OF FINDINGS:

One systematic review and three guidelines were identified about radiation risk due to CT. No relevant health technology assessments, randomized controlled trials, or controlled clinical trials were identified. All of the literature identified stressed that radiation exposure should be as low as reasonably achievable and provided options on minimizing radiation exposure.

Systematic reviews and meta-analyses

Semelka, et al. reviewed literature on the radiation risk of fatal and nonfatal cancers with CT utilization (2007). The authors summarized the effective doses of CT examinations and the risk of cancer associated with CT examinations and concluded with three ways to reduce the radiation exposure to patients, such as using MRI as an alternative to CT.

The authors stated that the review was systematic, however, the methodology section was contained to the abstract and details such as the number of reviewers, a priori inclusion criteria,
and the types of studies searched were not reported. The authors reported that one major medical database was searched along with major reports from large agencies and US government sites. It was also unclear whether more than one reviewer abstracted the data.

The authors reported that the effective dose, measured in sieverts (Sv) or mSv, can help assess radiation risk. The effective dose considers the irradiated organs and tissues and each of their radiosensitivities which indicate the amount of radiation an individual will receive during the CT examination. The average effective dose for CT, per session, was reported to be 2.0 mSV for head CT, 10.0 mSV for abdominal CT, 10 mSV to 40 mSV for chest CT, 20 mSV to 40 mSv for pulmonary angiography, and 25 mSv for PET-CT. The authors reported that approximately 30% of patients who have a CT scan have at least three examinations and therefore the overall doses would be higher for these patients. Radiation doses for CT are higher than for conventional radiography; for example, a chest x-ray effective dose is 0.02 mSv, an abdominal x-ray effective dose is 0.53 mSv, and a head x-ray effective dose is 0.077 mSv.

Effective doses can also be converted into risk of mortality; the authors cited 5.0% mortality risk per Sv when averaged over the whole population. The authors stated that pediatric populations are more vulnerable than adults as the doses are higher and young children have a higher radiosensitivity than adults. One estimate the authors reported was that a one-year old receiving a single abdominal CT examination has a 1 in 550 risk for developing cancer. The authors also cited that the Food and Drug Administration (FDA) estimated that an effective dose of 10 mSv (equal to one CT examination of the abdomen) may be associated with an increased chance of developing a fatal cancer for one in 2,000 patients (unclear whether this included adults and children). The risk escalates when assessing the risk at the population level. For example, a patient experiences an excess risk of mortality of 0.05% after undergoing a CT scan of 10 mSv which translates into 50 radiation-induced deaths per 100,000 people. The authors stated that there were approximately 60 million CT examinations per year in the United States.

The authors presented three options to reduce radiation exposure in patients. First, CT should be reserved for the situations where it is clearly superior to other diagnostic imaging modalities such as MRI or US. Four examples where CT was reported to be superior were the evaluation of primary lung disease, chest and abdominal trauma, evaluating tubes and catheters in postoperative or intensive-care patients, and identification of renal calculi. When CT is not clearly superior, alternatives such as MRI or US should be considered. MRI avoids the health risk associated with radiation doses, which is beneficial for patients who require more than one assessment, it is superior for soft-tissue contrast, the gadolinium-based contrast agents used in MRI are considered safer than the iodine-based contrast agents used in CT, and a single MRI examination allows for more types of tissue to be interrogated than during a CT examination. However, there are contraindications (e.g., cannot be used in individuals with pacemakers) to consider when determining whether MRI should be used.

Second, CT should be use only when it is indicated. CT examinations account for the largest source of man-made exposure to the population and accounts for up to 67% of the medical radiation in hospitals and use of CT is increasing. The reasons behind this increase in the United States include overly cautious physicians, fee-for-service, and pressure from the public to use high-end technology.

Third, the lowest possible amount of radiation should be used during a CT while preserving the required diagnostic performance. This can be achieved through adjusting doses for patient’s size as well as reducing multiple examinations where possible. The authors stated that other means of reducing radiation are being investigated, for example, dual source CT has been
marketed with the expectation that it decreases radiation exposure by half, as compared to traditional CT scanners.

**Guidelines and recommendations**

The National Cancer Institute updated their guidelines in 2008 on the value of CT and the importance of minimizing the radiation dose for the pediatric population. The authors stated that four to seven million CT examinations are performed each year on children in the United States, with anticipated annual increases of approximately 10%. The authors did not report any methodology or evidence upon which the guidelines were based. In addition, the guidelines were not supported with any grading or indication of strength of evidence.

The authors stated that the risk for cancer with radiation exposure is of more concern in the pediatric population for three reasons. First, children are more sensitive to radiation. Second, children have a longer life expectancy than adults which results in a longer available latency period for the radiation exposure to express its damage. And third, children receive a higher dose than necessary when adult settings are used.

The authors stated that no amount of radiation can be considered absolutely safe and that CT radiation exposure should be minimized. Three suggestions to minimize radiation were provided:

- Perform CT examinations only when indicated and when the CT examination is superior to MRI or US.
- Adjust the radiation exposure by accounting for size and weight of child, by limiting the region being scanned to the smallest possible region, and by adjusting the CT parameters for different organ systems.
- Adjust the scan resolution to achieve the resolution required for diagnostic accuracy, not the highest resolution image possible, and minimize multiple scans.

A report from Healthcare Human Factors published recommendations to improve CT radiation safety in Ontario (2006). The focus was on 64-slice CT scanners. It was conducted as a result of a recommendation from the Ontario Health Technology Advisory Committee after the finding that there was unknown benefit from newer CT technologies. Several recommendations for CT radiation dose were reported.

The evaluation of CT radiation safety and methods to reduce radiation dose exposure to patients in Ontario resulted in eight recommendations:

- Establish a CT radiation safety steering committee that consists of experts such as radiologists, medical radiation technologists, physicists, dentists, Ministry of Health and Long-Term Care representation, and CT scanner manufacturer representation. This committee would develop CT standards and monitor radiation exposure to patients and staff, test and inspect CT scanners, and be involved in CT protocols and other dose reduction strategies.
- Update the Healing Arts Radiation Protection (HARP) Act to include the operation, use, testing, and inspection of CT scanners.
- Develop best-practice protocols with shared access between health-care institutions. One example reported was to have the protocols housed in a web-based repository.
- Collect and analyze radiation dose information from various CT scanners across Canada.
- Develop diagnostic reference levels for Canada.
• Establish guidelines on patient shielding.
• Develop a training program for interventional radiologists on CT fluoroscopy as none exists in Ontario.
• Establish guidelines on coronary CT angiography protocols to minimize radiation exposure.

The literature review was noted to have included published and peer-reviewed articles along with guidelines, regulations, reports, and articles from various levels of governmental organizations across and outside of Canada. A survey was sent to 19 Ontario healthcare institutions with 64-slice CT scanners, 18 of which responded. The survey provided information on utilization practices. In addition, interviews and site visits were conducted with manufacturers, radiologists, CT technologists, and various representatives (e.g., government agencies, dental CT manufacturers). The number of reviewers selecting articles and performing data extraction was not reported; thus, it was not clear whether the methodology was systematic.

The Canadian Association of Radiologists published a diagnostic imaging guideline report in 2005. The typical effective dose for a CT of the head, chest, and abdomen or pelvis was stated to be 2.0 mSv, 8 mSv, and 10 mSv, respectively. These amounts were stated to be equivalent to the radiation dose of 100, 400, or 500 chest x-rays. However, it was stated that CT remains the optimal diagnostic imaging modality for many clinical problems of the chest and abdomen.

The authors stated that it is important that CT requests are justified and that considering alternatives is always a worthwhile exercise.

As MRI does not use radiation, it was recommended to be the preferred diagnostic test when it provides similar information to CT examinations, there are no contraindications to its use (e.g., patient with a pacemaker or cochlear implant), and it is available.

The Canadian Association of Radiologists guidelines were prepared by an expert advisory committee in collaboration with the Canadian Association of Nuclear Medicine. The guidelines were based on the Royal College of Radiologists document entitled, “Making the Best Use of a Department of Clinical Radiology: Guidance for Doctors, fifth edition.” Additional literature was searched through major medical databases; grey literature was also searched. Additional methodological details were not reported. Thus, it is unclear whether the guidelines were based systematic methodology. The authors did not report the evidence base upon which the guidelines were based was stated; the authors did not grade the guidelines.

**Limitations**

Non-English language, unpublished, and non peer-reviewed articles were not searched for this report. In addition, limits were placed upon the study designs eligible for consideration. These a priori decisions are considerations when interpreting both the literature review and the conclusions of this report.

Very limited research was identified and included. One review that labeled itself as systematic was retrieved but limited detail describing the methodology was reported and therefore the rigour of the report methods were unclear. In addition, the impact of MRI and lowered radiation exposure on risk of cancer was theorized but actual cancer trends were not discussed. None of the three guidelines reported using a systematic methodology or graded their recommendations. With an unknown evidence base, the strength of the recommendations in each of the guidelines is questionable.
Much of the research from the initial literature search appeared to be narrative reviews such as Brenner and Hall\textsuperscript{10} and UptoDate.\textsuperscript{2} Accessing these articles and similar articles may provide some additional insight into radiation risk associated with CT examinations. However, narrative reviews lack the systematic methodology which may lead to a report and conclusions that are vulnerable to bias. Summarizing and critiquing narrative reviews are beyond the scope of the HTIS report.

**CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING:**

All of the research identified stated that radiation risk is a concern at a patient and population level. The literature agreed that risk can be offset in different ways such as ensuring the dose of the CT is as low as possible, using other diagnostic imaging modalities like MRI that do not pose a radiation risk when they can provide comparable accuracy, and ensuring that CT examinations are ordered only when indicated. The three guidelines provide some Canadian,\textsuperscript{3,5} pediatric,\textsuperscript{5} and adult\textsuperscript{3,5} recommendations in regard to radiation risk and CT examinations. However, with the lack of reported systematic methodology or transparent evidence base, the strength of the recommendations is unclear.

Most of the research available on this topic is a weaker level of evidence such as narrative reviews. Thus, it can be difficult to interpret the true risk that radiation poses for individuals and subsequently population level health. Before firm conclusions and more detailed radiation dosing guidelines can be published, additional research is required that focuses on the relationship between CT quality and radiation dose and the relationship between CT radiation and cancer risk for patients of various subpopulations (e.g., small-sized adults, pediatrics).

Based on the current evidence, there is a valid and measurable risk associated with exposing patients to radiation from CT examinations. Measures taken to limit radiation exposure from CT examinations with the intent to minimize the public health issue of radiation-related cancer could be beneficial. The lack of high quality rigorous evidence about radiation risk from CT is an important consideration.

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