SUMMARY

Computed Tomography and Its Carcinogenic Effects in Children and Youth in Québec:
Scope of the Issue and Proposed Strategies

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Developments in diagnostic radiology have made it possible not only to perform increasingly precise scans and but also to reduce their associated radiation doses. Yet the growing use of these scans in medical practice and the advent of new technologies expose the population to an increasingly high collective dose. Computed tomography (CT) has been estimated to account for roughly 50% of diagnostic medical radiation in the general public, with another 25% due to nuclear medicine, and the remaining 25% due to all the other radiological tests (conventional radiography, fluoroscopy, PET, etc.) [Fazel et al., 2009; Mettler et al., 2008a].

This report was prepared at the request of the Direction québécoise du cancer (DQC), which was especially interested in several issues: the cancer-related risks of diagnostic CT in children and young adults; available imaging options; and the means taken to reduce CT-related risks. The DQC asked us to focus on children and youth, given their increased sensitivity to radiation, their longer life expectancy, and the possibility that absorbed doses may be higher in these patients.

The aspects studied concerned the link between cancer and radiation from diagnostic medical procedures. Our examination of the link between radiation and cancer development, and of the quantification of absorbed doses (dosimetry), raised the following questions:

What is the best estimate of the extent of CT use in children and youth in Québec? What information is there on (i) the number of scans per age group; (ii) the effective dose associated with these scans; (iii) the contributions of the different CT scans; and (iv) radiation doses delivered in CT compared with those from other radiation sources?

What is the estimated carcinogenesis, specifically, the number of new cancer cases (incidence) and deaths (mortality) associated with CT in children and youth below the age of 20 years in Québec?

This review summarizes the literature on the link between ionizing radiation and cancer. To clearly highlight the areas of consensus or debate, we performed a literature search in the databases containing primary scientific articles and systematic reviews published from 2000 to 2010, with no restriction as to language of publication. Special attention was paid to studies addressing CT-related radiation in children and youth below the age of 20 years. An estimate of different exposures to natural radiation sources is provided based on information available worldwide, in Canada and in Québec. A similar estimate was produced for artificial radiation sources, primarily from medical procedures.

We used data supplied by the RAMQ for 2009 and a dose-effect relationship model published in the literature to estimate the number of new cancer cases and cancer-related deaths potentially occurring during the lifetime of those exposed to CT radiation. These estimates were compared with others previously produced for Québec, the rest of Canada and the United States.

It was found that less than 4% of the CT scans done in Québec in 2009 were performed in children and youth aged 0 to 19 years, from a total of approximately 888,000 scans. This percentage varied with the anatomical site examined. Data indicate that 35% of CT procedures in adults were abdominal (26% for abdomen and pelvis, 8% for chest and abdomen, 1% for abdomen alone), whereas the head was the most common area of investigation in children and youth below the age of 20 years.

No matter how small, the risk associated with the thousands of scans performed each year suggests that a certain number of cancers are likely to occur. By applying a risk model adjusted for age distribution and for the health status of people undergoing CT scans, Berrington de González et al. [2009] derived an estimate of 14,500 deaths per year in the U.S. (equal to approximately 360 deaths in Québec). An analogous calculation was applied here to derive a more appropriate estimate for Québec in 2009, based on information on CT scan volume per anatomical site and per age-sex distribution.

For estimating carcinogenesis in children, the number of scans and the effective doses associated with
different pediatric CT scans were used under the
basic assumption that pediatric doses are similar to
adult doses. In 2009, 1.7 million children and youth
below the age of 20 years accounted for 22% of the
Québec population. The 32,668 CT scans in these
children and youth accounted for 3.7% of those
performed for all ages, and for 2.5% of the effective
doses associated with these scans.

The link between radiation and cancer is well
established, but the exact quantification of its effects
remains a topic of controversy, especially for doses
less than 100 mSv, which are typical in medical
practice. For our estimates, we used the BEIR model
[NRC, 2006], which assumes a linear relationship
between the doses received and the probability of
developing cancer. The application of these doses to a
patient population may overestimate the carcinogenic
effect produced in people who may sometimes have
limited life expectancies. Berrington de González et
al. [2009] reduced their cancer risk estimate by 11%,
accounting for people who die from cancer within
five years of their scans, and by 9% by eliminating
the scans performed in people who had already
been diagnosed with cancer. By applying the 20%
reduction proposed by Berrington de González, we
obtained an estimate on the order of 300 new cancer
cases (estimate produced with our model: 286 new
cancer cases and 184 deaths), including twenty or
so in children and youth below the age of 20 years
(estimate produced with our model: 24 cancer cases
and 11 deaths in children and youth below the age of
20 years).

By comparison, we estimated that in 2009 there
would have been 44,200 new cancer cases in Québec
and 20,100 cancer deaths, accounting for 35% of the
57,200 deaths from all causes in Québec. Changing
demographics will cause these figures to rise rapidly
over the next two or three decades. The number of
potential CT-induced cancers in Québec therefore
accounts for only a small proportion of the total
number of cancers.

Estimates of the number of cancer cases and the
number of cancer-related deaths are dependent upon
various assumptions, and reasonable variations in
these assumptions may easily generate estimates
roughly twice as high or twice as low. This
quantitative analysis considered only the negative
effects of CT imaging, which may be quantified
by estimation. However, it is much more difficult
to measure the morbidity and mortality that these
32,668 CT scans may have prevented, owing
to earlier or more accurate diagnoses of serious
diseases.

In the case of CT scans, the conventional medical
attitude is to expect positive effects to significantly
outweigh negative effects. This attitude should
perhaps be tempered by recognizing the cancer risk
associated with these scans, while emphasizing
the importance of the diagnostic information they
yield. The challenge of implementing best practices
in CT is to make sure that this is the case for each
clinical indication for which it is used. Two major
strategies may help ensure the preponderance of
positive effects: optimization of CT performance and
justification of the use of CT scans.

Internationally, the risk associated with diagnostic
radiation has been recognized since the advent
of radiology and nuclear medicine. Historically,
risk control, through radiation protection and the
judicious use of these technologies, has kept pace
with developments in the available techniques. The
advent of CT, which delivers much higher radiation
doses than conventional radiography, has led to new
initiatives for aligning practices with this new reality,
especially for pediatric patients. Examples include
the Image Gently movement launched in 2006, the
FDA’s collaborative initiatives with manufacturers
ever in 2010, and Health Canada’s Security Code 35
introduced in 2009. The present analysis provides
an overview of the measures found in the medical
literature that are designed to limit radiation-related
dangers, while preserving the many benefits that
these technologies offer to patients. These measures
include:

• providing professional training and awareness
  about the issues;
• producing information to help physicians make
decisions about the use of CT scans;
• developing dose-rate standards;
• developing guidelines on the indications for the
different imaging techniques; and
• implementing quality-assurance measures in
  clinical and radiology facilities.

In this dynamic environment, these measures must
be developed and supported to allow patients to take
full advantage of the promising benefits of these
technologies and to reduce the risk of inducing
cancers that is inevitably linked to ionizing radiation.