REPORT

OF THE DIAGNOSTIC

IMAGING SAFETY COMMITTEE FOR

COMPUTED TOMOGRAPHY

(CT)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Computed tomography (CT) has revolutionized the investigation of patients who have a wide variety of medical conditions and has led to more efficient patient care. The technology for this imaging modality has advanced rapidly over the past decade and as a result, there has been a significant increase in the use of CT in Ontario and around the world.

Ionizing radiation, as used for CT, can increase an individual's lifetime risk of developing cancer. This risk increases as the dose increases, is greater for children than for adults, and is greater for females than for males. As with all medical procedures, the small potential risk from a CT examination must be weighed against the potential benefits.

As with all medical imaging technology involving ionizing radiation, the principle of ALARA (As Low As Reasonably Achievable) should be applied in CT. In other words, CT examinations should be performed using sufficient dose to achieve acceptable image quality given the clinical context, but without exposing patients to unnecessary amounts of ionizing radiation. It is recognized that this is often a complex balancing act. Much effort needs to be focused now and in the future on *dose management and optimization* so that CT technology continues to be used appropriately in Ontario.

The recommendations in this report are intended to be applicable to any diagnostic CT scanner in Ontario that is used for the purpose of medical imaging of humans, and include a section focusing on the pediatric population. Because of the rapid changes in CT technology, the emphasis in this report is on the newer multidetector CT (MDCT) scanners. In the future, newer imaging technologies that use ionizing radiation will need to be assessed in light of existing regulations, and safety standards will need to be developed for their use.

The Healing Arts and Radiation Protection (HARP) Act, Revised Statutes of Ontario, 1990, and the X-ray Safety Code (Regulation 543) cover the use of x-rays for the irradiation of human beings in the province of Ontario. Under the X-ray Safety Code, a "computed transaxial tomography x-ray machine" is specifically excluded from the definition of a "diagnostic x-ray machine." At the same time, a "computed axial tomography (CT) scanner or machine" is not defined in the HARP Act. Due to the rapid technological developments and increase in CT use, any future revisions to the HARP Act should define what a CT scanner is and should recognize that the radiation doses associated with CT examinations are generally higher than those associated with conventional x-ray examinations.

RECOMMENDATIONS

The Committee recommends that the province of Ontario put in place regulations and/or legislation as follows:

HARP Act

1. The HARP Act should be revised to include a definition of a "computed axial tomography (CT) scanner or machine." Future revisions to the HARP Act should also recognize that the radiation doses associated with CT examinations are generally higher than those associated with conventional x-ray examinations.

Dose Reduction Strategies

This section focuses on strategies and recommendations that can be used to manage and reduce the radiation dose related to CT scanning.

Alternative Imaging Methods

2. The decision to perform a CT examination must be justified based on the clinical setting and is a shared responsibility between the referring clinician and the radiologist. Alternative imaging methods that do not use ionizing radiation — such as ultrasound (US) or magnetic resonance imaging (MRI) — should be considered if appropriate.

Prescribing or Requesting a CT Scan

3. CT examinations should specifically be excluded from Medical Directives. The larger radiation doses generally associated with CT compared to those associated with conventional x-rays pose patient safety concerns in the use of Medical Directives for CT examinations.

4. The HARP Act should be revised to ensure that only individuals who have the appropriate clinical knowledge and training in radiation safety are permitted to prescribe or request CT examinations.

Pregnancy

5. Each CT facility shall have a policy for screening women of childbearing age for pregnancy before performing a CT examination. If the patient is pregnant or possibly pregnant, the benefits of performing the CT must be weighed against any potential risk to the fetus.

Patient Shielding

6. The Radiation Protection Officer (RPO) at each facility shall develop a policy for patient shielding specifically for CT. The policy should be appropriate for the facility's CT equipment and patient population, and comprise protocols for in-beam and out-of-beam shielding accessories. The policy should be reviewed on a regular basis, taking into consideration changes in practice and technological innovations.

7. The Committee recommends that in-beam shielding *not* be used under the following conditions:

a) when real-time dose modulation is used and the presence of the shield will cause the CT scanner to compensate by increasing dose; or

b) where there is proof that in-beam shielding will interfere with the imaging objectives.

Anatomic Coverage

8. The anatomic coverage of a CT examination should be limited to the area of clinical interest.

CT Protocols

9. CT protocols should be designed to obtain the necessary diagnostic information based on the clinical indication of each situation. CT protocols should be reviewed periodically by radiologists and CT technologists to ensure dose optimization.

CT Scanning Parameters

10. CT technologists and radiologists must be knowledgeable about how the manipulation of various scanning parameters may influence dose and image quality in their CT scanners.

Multiphase Image Acquisition

11. The acquisition of more than one set of images from the same anatomic region must be justified based on detailed medical and radiological knowledge.

Repeat CT Examinations

12. When a follow-up or repeat CT examination is requested, the referring clinician and the radiologist must first consider other imaging modalities that do not use ionizing radiation, such as US or MRI. Repeat CT examinations must be justified based on the clinical indication. If a follow-up CT examination is justified, the examination may be modified to reduce the dose, as long as clinical care is not compromised.

CT Manufacturers/Vendors

13. Upon installation of a new CT scanner, a facility's Radiation Protection Officer (RPO) shall provide the X-ray Inspection Service (XRIS) of MOHLTC proof that the technologists and physicians operating that specific make and model of CT scanner have received training on dose reduction strategies appropriate to the planned clinical operation of the scanner. This proof would be in the form of a certificate of training provided by the vendor. In addition, the RPO must keep a permanent record of authorized operators and their training status on installed CT scanners for review by MOHLTC and its enforcement agents for at least six years.

Diagnostic Reference Levels

14. Ontario should establish Diagnostic Reference Levels for the following CT examinations: head CT, chest CT, and abdominal/pelvic CT. A team consisting of members from professional medical bodies should be established to review the methods for establishing DRLs, administer the survey, collect the data, determine the DRLs, and disseminate the information to all stakeholders. Once established, DRLs

should be reviewed periodically. Funding that is appropriate to the scope of the project will be required.

15. Manufacturers of CT scanners (including Positron Emission Tomography/CT units) must display the dose for each CT examination on the control console.

16. The dose for each CT examination must be recorded. This record must be kept and be available for periodic audit.

17. In pediatric cases, the size of the CT phantom used in calculating dose information must be displayed.

Pediatric CT

18. All requests for CT examinations for children must be reviewed by a radiologist prior to booking to ensure that the referral is appropriate and that possible alternative imaging modalities have been considered.

19. Each CT facility must establish local protocols for use in pediatric scanning. The Radiation Protection Officer must demonstrate to MOHLTC that technologists and radiologists operating the CT scanner have received instruction on the appropriate use of pediatric protocols.

20. All CT manufacturers must have suggested protocols specific to children of varying ages available on all models of scanner, for all commonly performed examinations.

21. As an additional safeguard to promote the use of weight-adjusted protocols in children, it is recommended that all manufacturers adapt CT software to promote protocol adjustments based on patient weight.

CT Technologist Training

22. MOHLTC should continue to provide support for a standardized CT curriculum for all undergraduate/college Medical Radiation Technologist (MRT) programs and for access to the same curriculum for MRT graduates in Ontario.

23. The CT curriculum shall include training in radiation safety and dose management.

CT Personnel and the Work Environment

24. In addition to existing legislation and policies, CT facilities shall adopt the following safety guidelines:

a) Doors accessible to the general public that enter into a CT scan room must be locked during scanner operation.

b) CT operators must be within arm's length of the scan abort button during image acquisition.

c) CT operators must be in visual contact with the patient during image acquisition.

CT Scanner Testing and Inspection

25. The testing and inspection of CT scanners should be specifically incorporated into the HARP Act. This may require a major revision to the HARP Act and the X-ray Safety Code. The role and duties of the X-ray Inspection Service may also need to be modified so that XRIS is able to perform and audit the inspection and maintenance of CT scanners, including dental cone beam CT, in Ontario. The appropriate resources to expand this service will be necessary.

Education Materials

Health Care Workers

26. The province should designate an organization to develop and disseminate information for physicians and other health care workers that helps them to better weigh the benefits and risks of CT studies for their patients. The topic of benefits and risks of procedures that use ionizing radiation such as CT should be included in the

training programs of health care providers who are involved in the prescribing or performing of such procedures.

Patients

27. The province should designate an organization to develop and disseminate information concerning the benefits and risks of imaging studies involving ionizing radiation, specifically CT, to patients and the general public.

Monitoring Patient Dose

28. At this time, the Committee does not recommend attempting to establish a permanent, portable record of the cumulative dose that each patient in Ontario receives.

Dental Cone Beam CT

29. The HARP Act should be revised to reflect the newer technology of dental CBCT.

30. MOHLTC should lift the current moratorium on approval of dental CBCT scanners, but approval should be restricted to Oral and Maxillofacial Radiologists and graduate Oral Radiology academic centres.

31. Dental CBCT scanners must be operated under the supervision of an Oral and Maxillofacial Radiologist.

32. All requests for dental CBCT examinations must be reviewed and approved according to protocol by an Oral and Maxillofacial Radiologist prior to performing the examination.

Research

33. Close collaboration among CT manufacturers, imaging scientists, and radiologists is encouraged to further explore and promote methods of dose management for CT.

FULL REPORT

BACKGROUND

The Ontario Health Technology Advisory Committee (OHTAC) recommended that a study of the safety aspects of computed tomography (CT) and magnetic resonance imaging (MRI) be conducted. The Ministry of Health and Long-Term Care (MOHLTC) provided a research grant to the Healthcare Human Factors Group at the University Health Network to investigate and provide safety recommendations on CT and MRI for OHTAC's consideration. Recommendations from the two reports, covering CT and MRI safety, were endorsed by OHTAC **[1,2]**. One of the recommendations was to create a Diagnostic Imaging Safety Committee for CT and MRI. The CT Safety Committee would be responsible for the development of recommendations concerning standards and best practices for CT, including methods of dose reduction to patients and medical imaging staff, as well as the testing and inspection of CT scanners in Ontario.

INTRODUCTION

The use of CT imaging has revolutionized the investigation of patients who have a wide variety of medical conditions, including cancer, trauma, and cardiovascular, neurological, respiratory, gastrointestinal, urological, and musculoskeletal illnesses. CT technology has advanced rapidly in the past decade, creating an even wider application of this imaging modality and enabling more efficient patient care. As a result, there has been a significant

increase in the use of CT for medical imaging in the province of Ontario and around the world **[3,4]**.

Although there will always be some debate in an issue involving risk estimates, it is accepted from the consensus of scientific literature that there is no level of ionizing radiation that can be considered completely safe. Ionizing radiation, as used for diagnostic CT imaging, carries the potential of increasing an individual's lifetime risk of developing cancer. The Biological Effects of Ionizing Radiation (BEIR) VII report estimates that "approximately one individual per thousand would develop cancer from an exposure of 0.01Sv," which is the dose estimate from an abdominal CT scan. To put the risk in perspective, in the United States, the overall lifetime risk of cancer in the general population is 42 out of 100 people. In other words, a person's risk of developing cancer related to the radiation from an abdominal CT scan would increase to 42.1% from 42.0%. It is also recognized that the risk increases as the dose increases, that the risk is greater for children than for adults, and that the risk is slightly greater for girls than for boys **[5]**.

The relative risk from exposure to low levels of radiation should be weighed against the potential clinical benefits of a CT examination by a qualified health care practitioner. The recommendations of this report should not be a substitute for clinical judgment and it is recognized that each patient and clinical scenario is unique.

As with all medical imaging technology involving ionizing radiation, the principle of ALARA (As Low As Reasonably Achievable) should be applied. In other words, CT

imaging studies should be performed using sufficient dose to achieve acceptable image quality given the clinical context, but without exposing patients to unnecessary amounts of ionizing radiation. It is recognized that this is often a complex balancing act and that a great deal of effort needs to be focused now and in the future on *dose management and optimization*, so that CT technology continues to be used appropriately in Ontario.

The recommendations contained in this report are intended to be applicable to any diagnostic CT scanner in Ontario that is used for the purpose of medical imaging of humans for routine clinical practice. The recommendations apply to all patients and include a section focusing on the pediatric population. Because of the rapid changes in CT technology, the emphasis in this report is on the newer multidetector CT (MDCT) scanners.

Generally, a CT scanner is considered an x-ray device that uses a rotating fan-beam and detector system to acquire data that can be reconstructed into a three-dimensional (3D) image. The 2006 Annual Report of the Office of the Auditor General of Ontario considered safety issues relevant to fan-beam devices **[3]**. There is a wider class of specialty device that is able to acquire images that can be reconstructed into 3D images, but these devices are not considered CT scanners for billing purposes under the Ontario Health Insurance Plan (OHIP). However, they meet the functional definition of CT in the eyes of MOHLTC. Primarily, these devices are described as cone-beam imagers, volume imagers, or cone-beam CT. Presently, any x-ray device that has the ability to take precisely positioned angled views and that is fitted with a digital receptor is potentially

able to produce 3D images with the addition of appropriate reconstruction software. Therefore, x-ray devices being produced now and in the future that meet these specifications may potentially be considered CT scanners. In the future, specific recommendations for the use of cone-beam devices and other imaging devices that use ionizing radiation will be needed.

It is the responsibility of the Radiation Protection Officer (RPO) of a CT facility to assess new technology in light of existing regulations and to develop safety standards for its use. Facilities owning and operating cone-beam technology should have policies in place that address issues of dose monitoring, dose reduction, and quality control, consistent with the Healing Arts Radiation Protection (HARP) Act. Patient dose monitoring is a particularly important issue because cone-beam devices do not estimate dose in the same manner that fan-beam CT scanners estimate and display dose.

The HARP Act, Revised Statutes of Ontario, 1990, and the X-ray Safety Code (Regulation 543) cover the use of x-rays for the irradiation of human beings in the province of Ontario. Under the X-ray Safety Code, a “computed transaxial tomography x-ray machine” is specifically excluded from the definition of a “diagnostic x-ray machine.” At the same time, a “computed axial tomography (CT) scanner or machine” is not defined in the HARP Act. Due to the rapid technological developments and increase in CT use, any future revisions to the HARP Act should define what a CT scanner is and should recognize that the radiation doses associated with CT examinations are generally higher than those associated with conventional x-ray examinations.

At the national level, a Safety Code for Radiation Protection in Radiology for Large Facilities is currently being prepared by Health Canada. It is anticipated that this Safety Code will contain recommended safety procedures for the installation, use, and control of x-ray equipment, including CT scanners, in large radiological facilities. There are a number of other national and international bodies also currently working on guidelines for managing patient dose with MDCT scanners, including the International Commission on Radiological Protection (ICRP) **[6]**. These reports and guidelines will need to be taken into consideration as they become available.

RECOMMENDATIONS

For the purposes of this report, it is intended that recommendations made to "Ontario" or to "the province of Ontario" be understood as being made to Ontario's Ministry of Health and Long-Term Care (MOHLTC) or any other provincial body responsible for governing CT facilities.

The Committee recommends that the province of Ontario put in place regulations and/or legislation as follows:

HARP ACT

1. The HARP Act should be revised to include a definition of a "computed axial tomography (CT) scanner or machine." Future revisions to the HARP Act should also recognize that the radiation doses associated with CT examinations are generally higher than those associated with conventional x-ray examinations.

DOSE REDUCTION STRATEGIES

This section focuses on strategies that can be used to manage and reduce the radiation dose related to CT scanning. The discussion includes specific recommendations to pursue the goal of dose reduction.

Alternative Imaging Methods

Radiation protection includes *justification* for medical imaging studies that use ionizing radiation **[6]**. When a CT scan is requested, the referring clinician and the radiologist should consider the clinical question and determine whether an alternative imaging method that does not use ionizing radiation — such as ultrasound or MRI — might be more appropriate. This is particularly important for the pediatric population. The clinical setting, patient age and gender, local expertise, and available resources will influence the

determination. There are national published guidelines that may help referring clinicians and radiologists to determine the appropriateness of imaging studies for a variety of clinical scenarios. These publications include:

- Diagnostic Imaging Referral Guidelines (Canadian Association of Radiologists) **[7]**
- American College of Radiology Appropriateness Criteria, 2000 (American College of Radiology) **[8]**
- Royal College of Radiologists, 2003 – Making the Best Use of a Department of Clinical Radiology: Guidelines for Doctors (Royal College of Radiologists, United Kingdom) **[9]**
- European Guidelines for Multislice Computed Tomography, 2004 – CT Quality Criteria (European Commission) **[10]**

2. The decision to perform a CT examination must be justified based on the clinical setting and is a shared responsibility between the referring clinician and the radiologist. Alternative imaging methods that do not use ionizing radiation — such as ultrasound or magnetic resonance imaging (MRI) — should be considered if appropriate.

Prescribing or Requesting a CT Scan

The draft of the Safety Code being prepared by Health Canada outlines the responsibility of the referring physician with regards to prescribing or requesting x-ray procedures and states: “The main responsibility of the referring physician is to ensure that the use of x-rays is justified.” In Ontario, the HARP Act indicates who can prescribe or request the operation of an x-ray machine for the irradiation of a human being. At some institutions, a member of the College of Nurses of Ontario who holds an extended certificate of registration may request an x-ray examination. Currently, where a local Medical Directive is in place, some nurses or other authorized health care professionals may be requesting x-ray examinations, including CT scans.

3. CT examinations should specifically be excluded from Medical Directives. The larger radiation doses generally associated with CT compared to those associated with conventional x-rays pose patient safety concerns in the use of Medical Directives for CT examinations.

4. The HARP Act should be revised to ensure that only individuals who have the appropriate clinical knowledge and training in radiation safety are permitted to prescribe or request CT examinations.

Pregnancy

Ionizing radiation is recognized to be potentially harmful to the developing fetus and is dose-dependent **[5]**.

5. Each CT facility shall have a policy for screening women of childbearing age for pregnancy before performing a CT examination. If the patient is pregnant or possibly pregnant, the benefits of performing the CT must be weighed against any potential risk to the fetus.

Patient Shielding

Patient shielding devices are designed to reduce the amount of radiation absorbed by a particular body part. Shielding devices can be used to cover anatomic structures outside the area of irradiation that may receive scatter radiation (out-of-beam) or within the area of irradiation (in-beam). With state-of-the-art MDCT scanners, the x-ray beam is narrowly collimated. As a result, the majority of the radiation exposure that organs receive outside of the primary beam comes from internal scatter. The exception to this principle is when contiguous anatomy is significantly higher or lower than the area being scanned. Therefore, with MDCT scanners, the use of “out-of-beam” shielding is often of little or no practical benefit with regards to patient dose reduction. The Health Physics Society, an American scientific and professional organization whose members specialize

in radiation safety, currently is of the opinion that the practice of out-of-beam shielding is of limited or no benefit but its use may provide psychological reassurance to the patient **[11]**.

In-beam shields, however, are believed to provide a benefit in terms of dose reduction. Studies have shown that in-beam shielding can significantly reduce the dose to the breasts, thyroid gland, and eyes **[12, 13]**. However, in-beam shielding devices may interfere with image quality **[14]**. In addition, one of the features of MDCT scanners is automatic tube current modulation (also known as automatic exposure control or AEC), which aims to optimize the dose according to patient size and desired image quality. The technology for dose optimization with MDCT scanners, including AEC, is rapidly evolving and there is variation among vendors in the methods used for automatic tube current modulation **[15]**. Currently, there is a paucity of literature on the subject of in-beam shielding for state-of-the-art MDCT scanners, including a discussion of the interaction between such shields and AEC, and the resulting impact on dose and image quality.

Some in-beam shielding devices, such as eye shields, are intended for single use, while others, such as breast shields, are designed for multiple uses. When considering the use of patient shielding devices, the cost and disposability of these devices, the impact on workflow, and any infection control issues should be taken into consideration.

All facilities with CT scanners should consider maintaining an inventory of the following protective accessories:

- In-beam protection:
  - eye shields;
  - breast shields (in sizes appropriate to the patient population — small, medium, large);
  - thyroid shields;
  - gonadal shields;
- Out-of-beam protection:
  - wrap-around skirts or lead sheets that meet provincial standards.

6. The Radiation Protection Officer (RPO) at each facility shall develop a policy for patient shielding specifically for CT. The policy should be appropriate for the facility's CT equipment and patient population, and include protocols for in-beam and out-of-beam shielding accessories. The policy should be reviewed on a regular basis, taking into consideration changes in practice and technological innovations. The analysis leading to the facility's shielding policy should be documented and explained to front-line staff so that they may answer patients' questions. The policy should cite each available shielding option and why it is, or is not, appropriate for the stated use. If in-beam shielding is observed to increase repeat examinations, the facility's shielding policy should be re-evaluated.

7. The Committee recommends that in-beam shielding *not* be used under the following conditions:

a) when real-time dose modulation is used and the presence of the shield will cause the CT scanner to compensate by increasing dose; or

b) where there is proof that in-beam shielding will interfere with the imaging objectives.

Anatomic Coverage

The unnecessary irradiation of organs outside the area of clinical interest can be minimized by limiting scanning to the anatomic area in question. For example, in most patients with renal colic, it would be appropriate to limit anatomic coverage from the top of the kidneys to the bladder base. On the other hand, for a patient with a suspected or proven intra-abdominal malignancy, for example, larger anatomic coverage, extending from the top of the diaphragm to the bottom of the bony pelvis, would be more appropriate.

8. The anatomic coverage of a CT examination should be limited to the area of clinical interest.

CT Protocols

CT protocols should be designed to obtain the necessary diagnostic information based on the clinical indication of each situation. In keeping with the ALARA principle, the dose should be *optimized* according to the clinical indication. For example, “low dose” protocols have been successfully used in scenarios with inherent high contrast such as evaluating urinary tract stones or screening for lung or colon cancer (CT colonography) **[16-18]**. Other clinical indications may require a higher dose with “low noise” to ensure optimum image quality. These situations occur when there is inherent low contrast between tumors and background structures. For example, when performing a pre-operative CT for liver tumors or when evaluating a possible pancreatic tumor, the benefits of optimum image quality clearly justify any risks from irradiation. Finally, the majority of other protocols will fall into a “standard dose” category. Thus, CT protocols can be generally grouped into three categories: low dose, standard dose, and low noise. Weight- and age-adjusted protocols should be developed and used for pediatric patients (see Pediatric CT) and small adults.

9. CT protocols should be designed to obtain the necessary diagnostic information based on the clinical indication of each situation. CT protocols should be reviewed periodically by radiologists and CT technologists to ensure dose optimization.

CT Scanning Parameters

CT technologists and radiologists should be knowledgeable about how the manipulation of various scanning parameters may influence dose and image quality. With the rapid changes in CT technology, technologists, radiologists, and medical physicists need to work closely with CT vendors because there will be parameters unique to each make and model of CT scanner that will influence dose and image quality. Parameters that can influence dose and image quality include, but are not limited to: tube current (milliamperes or mA), tube rotation time, tube potential (peak kilovoltage or kVp), collimation, table speed, pitch, scanner geometry, x-ray filters, and reconstruction kernel or algorithm **[19]**. A common and effective method of reducing dose while maintaining diagnostic image quality with MDCT scanners is the use of automatic tube current modulation, also known as automatic exposure control (AEC). Each make and model of CT scanner may construct and apply AEC differently. Therefore, it is imperative that technologists and radiologists understand how this feature influences dose and image quality in their specific equipment. In newer MDCT scanners that can be adjusted to reduce dose, the ability to select a user-defined noise level that will influence image quality is an important parameter that is closely related to the AEC feature **[15]**.

10. CT technologists and radiologists must be knowledgeable about how the manipulation of various scanning parameters may influence dose and image quality in their CT scanner.

Multiphase Image Acquisition

The acquisition of more than one set of images from the same anatomic region should be justified based on detailed medical and radiological knowledge. For example, multiple phases are often needed to detect and characterize liver nodules in patients with cirrhosis **[20]**. As another example, when performing CT urography for evaluating the urinary tract, some published protocols have used up to four acquisitions through the kidneys **[21]**, while others have used only two **[22]**. This reduction in phases of image acquisition has been accomplished by altering the sequence of intravenous (IV) contrast injection and image acquisition, thereby reducing the total potential dose to the patient without significantly diminishing the goals of the examination.

11. The acquisition of more than one set of images from the same anatomic region should be justified based on detailed medical and radiological knowledge.

Repeat CT Studies

12. When a follow-up or repeat CT examination is requested, the referring clinician and the radiologist must first consider other imaging modalities that do not use ionizing radiation, such as ultrasound or MRI. Repeat CT examinations must be justified based

on the clinical indication. If a follow-up CT examination is justified, the examination may be modified to reduce the dose, as long as clinical care is not compromised.

CT Manufacturers/Vendors

In Ontario and elsewhere, when a new CT scanner is installed, CT technologists are trained in the operation of that specific CT scanner by the vendor. Like most sophisticated machinery that incorporates powerful computers and state-of-the-art engineering, CT scanners have manufacturer-specific features. In recent years, manufacturers of MDCT scanners have focused more attention on dose optimization and have introduced new features to reduce dose while maintaining diagnostic image quality. CT technologists and radiologists need to work closely with the vendor when a new make or model of CT scanner is installed in order to properly understand the features that determine dose and image quality in the new CT scanner.

Although MOHLTC approves the installation of CT scanners, the vendor typically conducts training and equipment maintenance.

13. Upon installation of a new CT scanner, a facility's Radiation Protection Officer (RPO) shall provide the X-ray Inspection Service (XRIS) of MOHLTC proof that the technologists and physicians operating that specific make and model of CT scanner have received training on dose reduction strategies appropriate to the planned clinical

operation of that scanner. This proof would be in the form of a certificate of training provided by the vendor. In addition, the RPO must keep a permanent record of authorized operators and their training status on installed CT scanners for review by MOHLTC and its enforcement agents for at least six years, in keeping with Section 8(7) of Regulation 543 of the HARP Act.

Diagnostic Reference Levels

There is tremendous variation in CT protocols and in the engineering of CT machines. Thus, the dose related to a given CT protocol can vary greatly among CT scanners and health care facilities. A number of factors will influence the protocols used at each facility, including, but not limited to: the make and model of CT scanner, the range of clinical indications and their complexity, local expertise, efficient patient throughput, and the spectrum of patients (including their age, gender, and body habitus).

The implementation of Diagnostic Reference Levels (DRLs) is one tool for radiation dose management **[23, 24]**. DRLs are determined by means of a survey of current practice to establish typical dose levels in a given geographic region. They are used to provide guidance for dose management rather than to set limits. A survey of patients of a standardized size is conducted, often with further measurements performed using phantoms designed for the procedure. Common CT studies such as for the head, chest, and abdomen/pelvis are chosen and a survey is conducted of the doses associated with

these studies, at multiple hospitals. A threshold, such as the 80th percentile of recorded radiation doses, or more than twice the standard error of the mean, is then selected as the Diagnostic Reference Level. Institutions are then able to compare their standard doses to the DRL for each of the standard studies. If doses routinely exceed the suggested DRL, an investigation can be conducted to determine if the doses are justified or if the CT protocols can be further optimized. Thus, the purpose of DRLs is to reduce the overall radiation burden to the population over time. Diagnostic Reference Levels have been established in the United Kingdom, the European Union, and the province of British Colombia **[25]**. In the United States, the American Association of Physicians in Medicine recommends reference values for CT **[26]** and the American College of Radiology currently incorporates reference values into their accreditation program for CT **[27]**. The Phase II Report of the MRI and CT Expert Panel submitted to MOHLTC in December 2006 recommended that all existing CT facilities obtain American College of Radiology (ACR) accreditation within a three-year timeframe and that all future CT facilities obtain ACR accreditation within two years of CT installation.

Diagnostic Reference Levels can be expressed in various units, including CTDIvol (CT dose index volume) and DLP (dose length product). The CTDIvol and DLP values can then be converted to estimate the effective dose. The International Commission on Radiation Protection (ICRP) draft emphasizes that “effective dose is intended for use as a protection quantity on the basis of reference values and therefore should not be used for epidemiological evaluations, nor should it be used for any specific investigations of

human exposure. ...The use of effective dose for assessing the exposure of patients has severe limitations”**[28]**.

The ICRP states that it is *inappropriate* to use DRLs for regulatory or commercial purposes. Moreover, the values should be selected by professional medical bodies and be reviewed periodically **[28]**.

14. Ontario should establish Diagnostic Reference Levels for the following CT examinations: head CT, chest CT, and abdominal/pelvic CT. A team consisting of members from professional medical bodies should be established to review the methods for establishing DRLs, administer the survey, collect the data, determine the DRLs, and disseminate the information to all stakeholders. Once established, DRLs should be reviewed periodically. Funding that is appropriate to the scope of the project will be required.

15. Manufacturers of CT scanners (including Positron Emission Tomography/CT units) must display the dose, which follows a currently accepted standard, for each CT examination on the control console.

16. The dose for each CT examination must be recorded. This record must be kept and be available for periodic audit for a minimum period of time, such as six years, in accordance with the HARP Act.

17. In pediatric cases, the size of the CT phantom used in calculating dose information must be displayed.

PEDIATRIC CT

The use of CT in children is increasing throughout the world, probably even more rapidly than in adults, with an estimated 2.7 million pediatric CT examinations per year in the U.S., with 30% of these patients undergoing at least three scans **[29]**. This increase in practice is seen in pediatric hospitals as well as in general community hospitals. Children undergoing repeated CT scans in the follow-up of chronic illnesses are of particular concern with regards to cumulative dose.

Multidetector CT technology enables much faster scanning than previous single slice technology, with a significant reduction in the need for sedation or anesthesia in children. This has made the CT scanning of children more accessible and user-friendly compared to a decade ago. The ever-increasing capabilities and diagnostic quality of CT have also broadened its applications in pediatric care. For example, CT angiography, high-resolution chest CT, trauma care, and oncology (cancer) follow-up scans are all significantly easier to perform and are of higher diagnostic quality now than in the past.

However, the concerns related to the use of ionizing radiation are of particular importance in children because their sensitivity to its effects is greater than that of adults.

There is an exponential increase in lifetime cancer risk with decreasing age **[30, 31]**. This means that a child is more likely to develop a malignancy later in life than an adult exposed to the same amount of radiation, and the younger the child, the greater the risk he/she would have. Multiple factors contribute to this increased sensitivity in children, including the patients' size, their organ development, and their greater life expectancy, over which any resultant malignancies can manifest. As a result, children are between two and ten times more vulnerable than adults to the effects of ionizing radiation.

Many imaging needs in children can be achieved using modalities that do not use ionizing radiation, namely, ultrasound and MRI. The applications of ultrasound in children are often wider than in adults due to smaller patient size and thinner body habitus. MRI also has a significant role, although there is an ongoing need for greater availability and expertise. Pediatric patients frequently require sedation or anesthesia for MRI examinations due to the longer time required for image acquisition. This carries its own risks, and requires resources for the administration of sedation or anesthesia and for patient monitoring.

In 2001, several scientific articles highlighted the risks associated with the levels of ionizing radiation involved in pediatric CT and the importance of reducing radiation dose when scanning children **[32-34]**. There is now increased awareness internationally among radiologists of the need to adjust CT settings for pediatric patients rather than using standard adult protocols, which results in unnecessarily high radiation doses to children.

However, there remains considerable variation among institutions in the technical parameters used in pediatric scanning. This has been demonstrated in many countries, including the U.K., the E. U., and the U.S. **[10,24,33]**, and was also recently highlighted in the 2006 Annual Report of the Office of the Auditor General of Ontario **[3]**. This variability in technical parameters and patient dose is not confined to pediatric patients but is of particular concern in children, given their increased vulnerability to ionizing radiation.

CT manufacturers are making progress in developing specific pediatric protocols with dose-saving features, and new approaches continue to evolve. Such development, along with ongoing, collaborative research with clinical users, should be actively encouraged.

The variability in performance characteristics among CT manufacturers and scanner types means that one particular set of pediatric protocols will not optimize the performance characteristics of all scanners. Scanner performance and dose implications are affected by multiple factors, including type and number of detectors, scanner geometry, and filtration. It is therefore necessary for CT users to work in conjunction with their vendor to establish appropriately optimized pediatric protocols for their scanner.

General guidelines on the principles of achieving dose reductions in pediatric CT are available from sources in Canada, the U.S., and Europe **[34-39]**. These include using weight-adjusted tube current (mAs); reducing kVp, pitch, and slice width selection; using

AEC (automatic exposure control) technology; avoiding pre-contrast scans and multiphase imaging when possible; limiting region of anatomic coverage; and establishing further dose-reducing protocols for specific clinical indications or follow-up examinations. Examples of institution-specific pediatric protocols are also available **[34-40]**.

Pediatric CT dosimetry is a developing area of scientific research. The variability in the size of pediatric patients — from premature babies to teenagers — increases the complexity of establishing dose measures and risk estimates. Commonly displayed dose measures such as CTDIvol and DLP are often based on phantoms intended for adult patients. Further work on the validity of dose measures, on the most appropriate phantoms and dose measures for use in pediatric CT, and on a uniform method of dose display among manufacturers, is needed.

Diagnostic Reference Levels for two pediatric studies (CT head and thorax) have been suggested recently in the U.K **[24]**. These are not yet in widespread use, partly due to the complexities given above. This is, however, an area of ongoing international development, and institutions in Ontario and across Canada should be encouraged to contribute to these advances.

18. All requests for CT examinations for children must be reviewed by a radiologist prior to booking to ensure that the referral is appropriate and that possible alternative imaging modalities have been considered. It is the joint responsibility of the referring

physician and the radiologist to ensure that the optimal imaging management occurs for each patient, taking into account both benefits and risks.

19. Each CT facility must establish local protocols for use in pediatric scanning. These protocols may be suggested by the manufacturer or be developed based on local expertise. The establishment of further dose-reducing protocols for specific clinical indications should be encouraged. The RPO must demonstrate to MOHLTC that technologists and radiologists operating the CT scanner have received instruction on the appropriate use of pediatric protocols.

20. All CT manufacturers must have suggested protocols specific to children of varying ages available on all models of scanner, for all commonly performed examinations.

21. As an additional safeguard to promote the use of weight-adjusted protocols in children, it is recommended that all manufacturers adapt CT software to promote protocol adjustments based on patient weight.

CT TECHNOLOGIST TRAINING

Medical Radiation Technologists (MRTs) working in CT in Ontario are primarily Radiological (x-ray) Technologists with enhanced CT knowledge, skill, and judgment. MRTs, including those who perform CT, are governed by national standards developed

by the national professional association, the Canadian Association of Medical Radiation Technologists (CAMRT). These standards are identified in the competency profile provided by CAMRT. In some provinces, including Ontario, MRTs are also regulated by provincial standards. The College of Medical Radiation Technologists of Ontario (CMRTO) is the regulatory body for MRTs in Ontario. In order to practice medical radiation technology in Ontario, an MRT must possess a CMRTO certificate of registration.

There are four specialties within CMRTO: Radiography, Nuclear Medicine, Radiation Therapy, and Magnetic Resonance Imaging. CT is not a specialty within the College. MRTs in any specialty registered with CMRTO can perform CT, assuming they have the knowledge, skill, and judgment to perform CT.

The educational requirements for MRTs are covered by the registration regulations. For a CT technologist, basic CT knowledge is acquired in their initial undergraduate/college program in one of the specialties. Most CT training is presently acquired “on the job,” during employment as an MRT. Employers/hospitals usually set minimum requirements for knowledge, skill, and judgment, but there are no standards. CAMRT offers a specialty certificate in computed tomography imaging (CTIC). The specialty certificate demonstrates that a higher level of CT knowledge has been achieved. CAMRT has recently revised all MRT competency profiles to reflect current and future MRT practice, including the practice of CT by MRTs in all specialties. These new profiles will be effective for the 2011 certification examinations. The level of CT expertise within each

discipline's competency profile differs depending on the CT practice within that specialty. For example, the Radiological Technology profile includes in-depth CT competencies related to diagnostic CT, whereas the Nuclear Medicine profile includes competencies related to the performance of PET/CT (positron emission tomography/CT), and the Radiation Therapy profile includes CT competencies related to radiation therapy planning. With the advent of hybrid imaging such as PET/CT, all specialties will be performing CT to some degree and level.

In October 2004, MOHLTC established an MRI and CT Expert Panel. A Phase I Report, submitted in April 2005, provided recommendations on the education of CT technologists. This report included a recommendation (Recommendation 10) for Ontario MRT programs to expand their curricula to include CT competencies and to provide training to current technologists to upgrade their skills. The report is posted on the MOHLTC website:
http://www.health.gov.on.ca/renouvellement/wait_timesf/wt_reportsf/mri_ct.pdf.
In response to this recommendation, MOHLTC has provided funding to The Michener Institute in Toronto to develop a CT curriculum. The curriculum will provide a standard level of education for CT technologists across Ontario by offering CT courses as part of full-time undergraduate imaging programs and by providing graduate MRTs access to the same CT educational opportunities. Course development has begun, with input from a variety of stakeholders.

The following are key elements of the curriculum development:

a) the curriculum receives funding and support from MOHLTC for its development;

b) the curriculum establishes a standard level of education for CT technologists in Ontario;

c) the curriculum recognizes the increased complexity of knowledge and skill required of CT technologists;

d) the curriculum's CT theory component includes optimization of image quality and dose management;

e) the curriculum includes management of quality control for CT equipment;

f) the curriculum recognizes the recent significant advances in CT technology;

g) the curriculum includes a hands-on laboratory component (most CT courses presently available focus on theory only); and

h) the curriculum is offered in distance format to ensure accessibility for all MRTs in Ontario.

The first course of the CT program will begin in May 2007. The curriculum will be available for inclusion in undergraduate MRT programs in Ontario.

The MRI and CT Expert Panel Phase II Report, submitted in December 2006, recommended that MRT programs continue to incorporate full CT competency into their curriculum.

22. MOHLTC should continue to provide support for a standardized CT curriculum for all undergraduate/college MRT programs and for access to the same curriculum for MRT graduates in Ontario.

23. The CT curriculum shall include training in radiation safety and dose management.

CT PERSONNEL AND THE WORK ENVIRONMENT

The safety of personnel in the CT environment is governed by provincial legislation. Federal guidelines and internal policy and procedures may be used as complementary measures and best practice standards. The current status of safety for CT personnel is attached in Appendix A, “Worker Radiation Protection in CT Applications.”

24. In addition to existing legislation and policies, CT facilities shall adopt the following safety guidelines:

a) Doors accessible to the general public that enter into a CT scan room must be locked during scanner operation. This will diminish the potential for unnecessary exposure to personnel working in the CT environment or to the general public. Locked doors also prevent interruption of a scan in progress.

b) CT operators must be within arm's length of the scan abort button during image acquisition.

c) CT operators must be in visual contact with the patient during image acquisition.

CT SCANNER TESTING AND INSPECTION

The X-ray Inspection Service (XRIS) is a unit within MOHLTC and is the enforcement body for the HARP Act. XRIS works at arm's length from the HARP Commission. Currently, CT scanners are not inspected by XRIS and are excluded from the HARP Act in this regard.

25. The testing and inspection of CT scanners should be specifically incorporated into the HARP Act. This may require a major revision to the HARP Act and the X-ray Safety Code. The role and duties of X-ray Inspection Service may also need to be modified so that XRIS is able to perform and audit the inspection and maintenance of CT scanners, including dental cone beam CT, in Ontario. The appropriate resources to expand this service will be necessary.

EDUCATION MATERIALS

Health Care Workers

Recent studies have shown that there is a lack of awareness among patients and physicians regarding the magnitude of radiation doses involved in CT and its associated risks **[41, 42]**. An increased awareness of the risks and benefits of procedures using ionizing radiation would help health care workers make appropriate decisions for their patients and would reduce the risk of unnecessary patient exposure to radiation. The draft of the Safety Code currently being prepared by Health Canada states that the referring physician, who is the individual authorized to prescribe or request x-ray procedures, should "be aware of the risks associated with x-ray procedures."

26. The province should designate an organization to develop and disseminate information to physicians and other health care workers that helps them to better weigh the benefits and risks of CT studies for their patients. The topic of benefits and risks of procedures that use ionizing radiation such as CT should be included in the training programs of health care providers who are involved in the prescribing or performing of such procedures.

Patients

Health care is a shared responsibility between health care providers and patients. In order to participate in the decision-making process, patients should be aware of the basic benefits and risks of a CT scan and, indeed, of any test for diagnostic or therapeutic purposes. Any material provided for patients should be presented in a way that does not provoke anxiety in patients, but rather provides an appropriate perspective for making decisions.

27. The province should designate an organization to develop and disseminate information concerning the benefits and risks of imaging studies involving ionizing radiation, specifically CT, to patients and the general public.

Using a website to provide the above information would be an effective way to disseminate educational materials to patients and health care workers. The educational material for patients would be accessible to the general public, whereas the educational material for health care workers would be available through professional organizations such as the College of Physicians and Surgeons of Ontario (CPSO) and CMRTO. The content of these educational materials would require input from several groups, including, but not necessarily limited to: Ontario Association of Radiologists (OAR), CPSO, and CMRTO. Such a website would require funding for its development and maintenance.

MONITORING PATIENT DOSE

Increased awareness among patients and health care workers that any amount of ionizing radiation is potentially harmful is, in and of itself, likely to help promote the safe and appropriate use of CT scanners and other devices that use ionizing radiation. It is recognized that there is a cumulative risk from multiple examinations or procedures that use ionizing radiation. If it were possible to collect the data and monitor the cumulative dose from all radiation emitting devices that patients were exposed to, patients may be more likely to avoid investigations and procedures that use ionizing radiation. One potential method of monitoring patient dose is the concept of a “dose card” that could document cumulative dose.

The concept of a “dose card” for each patient was reviewed by the Committee. A “dose card” would be part of a patient’s permanent medical record. Each time an investigation or procedure using ionizing radiation was performed, the dose would be recorded. The advantage of such a system would be that a patient’s cumulative dose could be monitored. However, there are a number of important issues and limitations to such a proposal. Currently, dose information is captured in different units by different radiation emitting devices. The dose information from a CT examination can be expressed in various units, the two most common being CTDIvol (CT dose index volume) and DLP (dose length product). Typically, both these measurements are displayed on the CT console for each CT examination. It must be noted, however, that these measurements are

an *indirect estimate* of dose. More work on the validity of DLP estimates, especially in children, is needed.

Exact measurements of dose in a given patient for a given CT study would be difficult to determine and could involve time-consuming and complex measurements and calculations. In addition, new methods and standards to quantify dose for MDCT may be introduced in the future. The current lack of measurement standardization across the range of radiation emitting devices and the fact that doses are typically indirectly estimated are major obstacles to implementing a system for monitoring patient dose. Other issues include: who would be responsible for monitoring dose information; who would be responsible for calculating the risks for patients before they undergo an investigation or procedure using ionizing radiation; and how useful would this information be if patients forget to bring their dose card to an examination/procedure. Furthermore, setting an absolute dose limit would not be appropriate because the benefits and risks of each procedure must be assessed on an individual basis in the context of the patient's overall care.

28. At this time, given the above limitations, the Committee does not recommend attempting to establish a permanent, portable record of the cumulative dose that each patient in Ontario receives. Once a comprehensive, electronic record-keeping system is in place for the citizens of Ontario, it would allow for at least a record to be kept of the type and frequency of x-ray examinations. This information may influence a physician's decision when considering a request for imaging tests.

DENTAL CONE-BEAM CT (CBCT)

Currently, panoramic radiology is used for many conventional diagnostic dental examinations and is associated with a significantly lower radiation dose compared to dental cone-beam (CBCT) scanners, which use cone-beam CT technology **[43]**. Dental CBCT scanners are specifically designed for advanced dental applications and are used primarily for dental implant and orthognathic surgical planning. Other applications include 3D localization of impacted teeth and diagnosis of pathology related to the maxilla and mandible. Compared to CT scanners used for “body” imaging, dental CBCT scanners are relatively simple and use significantly lower radiation doses to produce high-resolution images. Image acquisition is almost completely automated, with a limited number of parameters that can be adjusted.

However, if dental CBCT scanners become readily available for use by general dentistry practices, it is possible that this technology will replace panoramic radiology for conventional diagnostic dental examinations. This raises concerns about a potential increase in patient and population exposure to radiation. Also of concern is the current lack of training for general dentists in the interpretation of images generated by dental CBCT scanners. Within the dental profession, the specialty of Oral and Maxillofacial Radiology has training in both the application and the interpretation of images produced by dental CBCT scanners.

The HARP Act currently states who is qualified to operate an x-ray machine [Section 5 (1) (2)] and who can prescribe the operation of an x-ray machine (Section 6). The HARP Act does not specifically state who can operate a dental CBCT scanner or who can prescribe the operation of a dental CBCT scanner.

Currently, MOHLTC does not approve requests for installation and operation of additional dental CBCT scanners in Ontario.

29. The HARP Act should be revised to reflect the newer technology of dental CBCT.

30. MOHLTC should lift the current moratorium on approval of dental CBCT scanners, but approval should be restricted to Oral and Maxillofacial Radiologists and graduate Oral Radiology academic centres.

31. Dental CBCT scanners must be operated under the supervision of an Oral and Maxillofacial Radiologist.

32. All requests for dental CBCT examinations must be reviewed and approved according to protocol by an Oral and Maxillofacial Radiologist prior to performing the examination.

RESEARCH

Because CT technology is advancing rapidly, the current research base for clinical guidance is limited. Close collaboration among CT manufacturers, imaging scientists, and radiologists should be encouraged to further explore and promote methods of dose management for CT. Therefore, the appropriate resources will be required to keep pace with these changes.

33. Close collaboration among CT manufacturers, imaging scientists, and radiologists is encouraged to further explore and promote methods of dose management for CT.

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APPENDIX A

Worker Radiation Protection in CT Applications

Installation Approval

The MOHLTC's current policy is that any x-ray machine used to irradiate a human being — including CT scanners — for any purpose, including research and analysis, is covered by the HARP Act and must be approved and designated according to the HARP Act prior to installation and operation. Proposed installations are reviewed by the X-ray Inspection Service of the MOHLTC and must comply with Regulation 543: X-ray Safety Code under the HARP Act, as well as with Appendix 2 of Safety Code 20A (federal legislation).

For facilities under Ministry of Labour jurisdiction (e.g., veterinary, forensic, training exclusively with phantoms, research), CT installations are further required to have locks or interlocks on all entry doors.

The following radiation protection requirements are subject to Regulation 861/90, respecting X-ray Safety and Regulation 67/93 for Health Care and Residential Facilities, made under the Ministry of Labour's Occupational Health and Safety Act.

Radiation Safety Training

As required under the Occupational Health and Safety Act, Section 25 (2) (a) and (d) state:

25 (2) Without limiting the strict duty imposed by subsection (1), an employer shall:

(a) provide information, instruction and supervision to a worker to protect the health or safety of the worker;

(d) acquaint a worker or a person in authority over a worker with any hazard in the work and in the handling, storage, use, disposal and transport of any article, device, equipment or biological, chemical or physical agent;

(x-rays are defined as a physical agent)

Further, under the Health Care and Residential Facilities Regulation (Regulation 67/93),

Section 9 (4) states:

The employer, in consultation with and in consideration of the recommendation of the joint health and safety committee or health and safety representative, if any, shall develop, establish and provide training and educational programs in health and safety measures and procedures for workers that are relevant to the workers' work. O. Reg. 67/93, s. 9.

General Duty to Establish Measures and Procedures

In consultation with the joint health and safety committee or representative, an employer shall develop, establish, and put into effect measures and procedures for the health and safety of workers.

Under the Health Care and Residential Facilities Regulation (Regulation 67/93), Section 9 (1) states:

The employer shall reduce the measures and procedures for the health and safety of workers established under section 8 to writing and such measures and procedures may deal with, but are not limited to, the following:

7. The hazards of biological, chemical and physical agents present in the workplace, including the hazards of dispensing or administering such agents.
8. Measures to protect workers from exposure to a biological, chemical or physical agent that is or may be a hazard to the reproductive capacity of a worker, the pregnancy of a worker or the nursing of a child of a worker.
9. The proper use, maintenance and operation of equipment.
10. The reporting of unsafe or defective devices, equipment or work surfaces.
11. The purchasing of equipment that is properly designed and constructed.
12. The use, wearing and care of personal protective equipment and its limitations.

Personal Radio-Protective Equipment

The Ministry of Labour Radiation Protection Service has a written policy on personal radio-protective equipment. For workers remaining in the room during a CT examination, wrap-around aprons, along with thyroid collars having 0.5 mm lead equivalency at the highest used kVp, are required to be worn.

Under the Health Care and Residential Facilities Regulation (Regulation 67/93), Section 10 states:

(1) A worker who is required by his or her employer or by this Regulation to wear or use any protective clothing, equipment or device shall be instructed and trained in its care, use and limitations before wearing or using it for the first time and at regular intervals thereafter and the worker shall participate in such instruction and training.
(2) Personal protective equipment that is to be provided, worn or used shall:
(a) be properly used and maintained;
(b) be a proper fit;
(c) be inspected for damage or deterioration; and
(d) be stored in a convenient, clean and sanitary location when not in use.
O. Reg. 67/93, s. 10.

Dosimetry

Under the X-ray Safety Regulation 861/90, Section 12 states:

12. (1) An employer shall provide to each x-ray worker a suitable personal dosimeter that will provide an accurate measure of the dose equivalent received by the x-ray worker.
(2) An x-ray worker shall use the personal dosimeter as instructed by the employer.
(3) An employer shall ensure that the personal dosimeter provided to an x-ray worker is read accurately to give a measure of the dose equivalent received by the worker and shall furnish to the worker the record of the worker's radiation exposure.
(4) An employer shall verify that the dose equivalent mentioned in subsection (3) is reasonable and appropriate in the circumstances, and shall notify an inspector of any dose equivalent that does not appear reasonable and appropriate.
(5) An employer shall retain an x-ray worker's personal dosimeter records for a period of at least three years. R.R.O. 1990, Reg. 861, s. 12.

The word "suitable" is defined by the Ministry of Labour as a personal dosimeter that provides a measure of dose received by the exposed part of the body. All x-ray workers working with fluoroscopic or other unshielded open-beam x-ray sources (including CT systems, if remaining in the room) shall be provided with an additional head/collar badge (worn on the exterior of the thyroid collar) and/or an extremity badge (worn as a ring on a hand), where deemed appropriate.

Dosimetry is required for all persons who meet the definition of an x-ray worker, including external workers who may service or test the CT machine.

Reporting of a high exposure or possible overexposure

Under the X-ray Safety Regulation 861/90, Section 13 and 14 state:

13. Where a worker has received a dose equivalent in excess of the annual limits set out in Column 4 of the Schedule in a period of three months, the employer shall forthwith investigate the cause of the exposure and shall provide a report in writing of the findings of the investigation and of the corrective action taken to the Director and to the joint health and safety committee or health and safety representative, if any. R.R.O. 1990, Reg. 861, s. 13.

14. Where an accident, failure of any equipment or other incident occurs that may have resulted in a worker receiving a dose equivalent in excess of the annual limits set out in Column 3 of the Schedule, the employer shall notify immediately by telephone, telegram or other direct means the Director and the joint health and safety committee or health and safety representative, if any, of the accident or failure and the employer shall, within forty-eight hours after the accident or failure, send to the Director a written report of the circumstances of the accident or failure. R.R.O. 1990, Reg. 861, s. 14.

Warning Signs

Under the Health Care and Residential Facilities Regulation (Regulation 67/93), Section 16 states:

A warning sign shall be posted on any door, corridor or stairway,
(a) that is not a means of egress but that is located or arranged so that it could be mistaken for one; or
(b) that leads to a hazardous, restricted or unsafe area. O. Reg. 67/93, s. 16.

Under the X-ray Safety Regulation 861/90, Section 11 (1) and (3) state:

The following measures and procedures shall be carried out in a workplace where an x-ray source is used:

1. X-ray warning signs or warning devices shall be posted or installed in conspicuous locations.

3. Where the air kerma in an area may exceed 100 micrograys in any one hour, access to the area shall be controlled by,

    i. locks or interlocks if the x-ray source is one to which subsection 6 (1) applies or is described in subsection 6 (2); and

    ii. barriers and x-ray warning signs if the x-ray source is portable or mobile and is being so used.