Medical Imaging in Canada 2005

Canadian Institute for Health Information
Institut canadien d'information sur la santé

Requests for permission should be addressed to:

Canadian Institute for Health Information
495 Richmond Road
Suite 600
Ottawa, Ontario
K2A 4H6

Telephone: (613) 241-7860
Fax: (613) 241-8120
www.cihi.ca

ISBN 1-55392-754-0 (PDF)

Cette publication est aussi disponible en français sous le titre :
L'imagerie médicale au Canada 2005
ISBN 1-55392-755-9 (PDF)

Acknowledgments

The Canadian Institute for Health Information wishes to acknowledge and thank the many individuals and organizations that contributed to the development of this report.

CIHI is responsible for the National Survey of Selected Medical Imaging Equipment and the information in this report. The dedicated work of the Health Expenditures staff—Melissa Aggerwal, Ruolz Ariste, Geoff Ballinger, Ian Button, Gilles Fortin, Louise Ogilvie and Greg Zinck—is essential to the compilation, analysis and dissemination of information in this report.

CIHI would like to thank members of ProMed Associates Ltd., and in particular Ron Wood and Brian Lentle, for their review of the first chapter. We would also like to thank members of the former Advisory Committee on Information and Emerging Technologies, which consisted of representatives from federal, provincial and territorial governments, who provided support in obtaining and validating aspects of the data contained in the report.

Production of this report involves many people and many aspects of the CIHI organization including individuals from Publications, Translation, Communications, Health Human Resources, Distribution Services and Web.

This report could not have been produced without the generous support and assistance of many other individuals and organizations, including the many hospitals and other facilities that completed the survey on medical imaging technology in Canada.

Highlights

Medical Imaging in Practice—Evolution of Technology and Emerging Applications

This chapter provides information about recent developments in the evolution of diagnostic imaging equipment.

- PET/CT, a new hybrid technology that provides both a functional and a structural image, is being introduced in Canada. It may soon replace the diagnostic images obtained from traditional nuclear medicine devices.
- The 2005 National Survey of Selected Medical Imaging Equipment tracks six types of "high-level" imaging equipment (MRI, CT, nuclear medicine cameras, cardiac catheterization laboratories, angiography suites and PET scanners), at least one of which are found in only a third of Canadian facilities.
- About 60% of hospitals represented in the survey are sending digital medical images either to a Picture Archiving Communications System (or PACS) for departmental viewing or to strategic areas of the facility. However, this represents only about 20% of all hospital sites across Canada.

Imaging Technologies—Supply and Costs

This chapter provides an overview of the supply and distribution of imaging equipment and certain factors that affect the availability of imaging technologies in Canada and internationally.

- The numbers of CT and MRI scanners have grown significantly since they were introduced (in 1973 and 1982, respectively). From 1990 to 2005, the number of CT scanners has grown by 163 (82%), whereas MRIs have increased by 157 (826%). Since 1997, more MRI scanners than CT scanners have been installed.
- As of January 1, 2005, there was just one MRI scanner for every 2.1 CTs in Canada. Newfoundland and Labrador had the lowest ratio of MRIs to CTs (1:10.0), while Alberta had the highest ratio, with one MRI scanner for every 1.2 CTs.
- The growth in the number of MRI scanners in Canada was similar to that in France and Germany from 1990 to 2001. The number of CT scanners in Italy grew at a more rapid rate than in Canada, Germany and France.
- The number of MRIs in free-standing (or non-hospital) imaging facilities has grown every year since 1998. The number of CT scanners in free-standing imaging facilities grew until 2004 and then remained unchanged in 2005. As of January 2005, about 3% of CTs and 15% of MRIs were in free-standing imaging facilities.

- Although more CT and MRI scanners were installed in 2005, the proportion of CTs and MRIs installed within the last 5 years has decreased compared to the proportion of CTs and MRIs were installed between 6 and 10 years ago. This decrease is a result of ageing machines moving from the 0-to-5 age cohort in 2004 to the 6-to-10 age cohort in 2005, increasing the share of the 6-to-10 age cohort.
- In 2004, there were 1,967 diagnostic radiologists in Canada—an increase of 3.0% over the previous year.

Utilization of Medical Imaging Services

This chapter provides an analysis of statistics on the utilization of medical imaging equipment (number of exams and number of hours in operation) in Canada and selected countries.

- Among the provinces and territories, jurisdictions with lower numbers of scanners per million population in 2004–2005 generally had longer hours of operation per week than jurisdictions with higher numbers of scanners per million population.
- While the U.S. had more MRI and CT scanners per million population, available scanners were used more intensively in Canada. The numbers of MRI and CT exams per scanner in 2004–2005 were, respectively, 37% and 46% higher in Canada than in the U.S. Canada also had about a third more exams per MRI scanner than England.
- In 2004–2005, MRI exams per 1,000 population ranged from 8.5 in Newfoundland and Labrador to 36.6 in Alberta, a more than fourfold difference. The average for Canada was 25.4 MRI exams per 1,000 population, compared to 83.2 for the U.S. and 19.0 for England.
- CT exams per 1,000 population in 2004–2005 did not vary as much as MRI exams among the provinces, ranging from 78.2 in British Columbia to 134.8 in New Brunswick. The Canadian average was 87.4. This compares to 172.5 in the U.S. and 43.0 in England.

Medical Imaging in Canada, 2005

Table of Contents

Acknowledgments i

Highlights ii

About This Report 1

  What's New in This Report 2

Chapter 1—Imaging in Practice—Evolution of Technology and Emerging Applications 5

  The Right Tool for the Right Job 6

  Medical Imaging in the Diagnosis of Breast Cancer 8

  Medical Imaging in the Diagnosis of Coronary Artery Disease 13

  Computed Tomography (CT) 18

  Magnetic Resonance Imaging (MRI) 25

  Positron Emission Tomography (PET) and PET/CT 31

  Picture Archiving and Communications Systems (PACS) 34

  References 39

Chapter 2—Imaging Technologies—Supply and Costs 49

  How Many are There? 49

  The Supply of Imaging Technologies in Canada 52

  The International Context 54

  Where Imaging Technologies are Located 59

  Ageing and Renewal of Medical Imaging Technologies 60

  The Cost of Imaging 61

  References 67

Chapter 3—Utilization of Imaging Services 69

  Number of MRI and CT Exams by Jurisdiction 69

  Are Medical Imaging Machines Operated Intensively? 72

  Possible Factors Limiting Access to MRI and CT Exams 79

  References 86

Appendix A—Fast Facts A–1

Appendix B—Methodological Notes B–1

Medical Imaging in Canada, 2005

List of Figures

Figure 1. Percentage Distribution of Diagnostic Imaging Examinations in Hospitals, Nova Scotia, Ontario and British Columbia, 2003–2004 6

Figure 2. Number of Computed Tomography (CT) Scanners, by Age Cohort, by Technology, Canada, as of January 1, 2005 19

Figure 3. Number of Spiral Computed Tomography (CT) Scanners, by Slice, Canada, as of January 1, 2005 20

Figure 4. Number of Computed Tomography (CT) Scans, by Body Site in Emergency Departments, Ontario, 2003–2004 22

Figure 5. Number of Magnetic Resonance Imaging (MRI) Scanners, by Age Cohort, by Technology, Canada, as of January 1, 2005 26

Figure 6. Number of Magnetic Resonance Imaging (MRI) Scanners and Field Strength, by Age Cohort, Closed Bore, Canada, as of January 1, 2005 27

Figure 7. Number of Magnetic Resonance Imaging (MRI) Scanners and Field Strength, by Age Cohort, Open Bore, Canada, as of January 1, 2005 28

Figure 8. Number of Outpatient Magnetic Resonance Imaging (MRI) Scans, by Body Site, Ontario, 1993–1994 to 2003–2004 29

Figure 9. Distribution of Outpatient Magnetic Resonance Imaging (MRI) Scans, by Type, Ontario, 1993–1994 and 2003–2004 29

Figure 10. Growth in Rate of Utilization of Radiological Examinations of the Spine, Ontario, 1992 to 2001 30

Figure 11. Number of Positron Emission Tomography (PET) Scanners, by Technology, by Age Cohort, Canada, as of January 1, 2005 32

Figure 12. Purpose of Positron Emission Tomography (PET) Scanners, Canada, as of January 1, 2005 32

Figure 13. Percentage of Medical Imaging Equipment With Electronic Storage Capacity, by Age Cohort, Canada, as of January 1, 2005 37

Figure 14. Percentage of Medical Imaging Equipment Where Picture Archiving and Communications Systems (PACS) Are Available, by Type of Technology, as of January 1, 2004 and 2005 38

Figure 15. Numbers of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Scanners, Canada, 1983 to 2005 51

Figure 16. Number of Selected Medical Imaging Equipment per Million Population, Canada, as of January 1, 2003 to 2005 52

Figure 17. Number of Computed Tomography (CT) Scanners per Million Population in Selected OECD Countries With a Population of One Million or More and the Year for Which Rates Were Reported 55

List of Figures (cont'd)

Figure 18. Number of Magnetic Resonance Imaging (MRI) Scanners per Million Population in Selected OECD Countries With a Population of One Million or More and the Year for Which Rates Were Reported 56

Figure 19. Number of Computed Tomography (CT) Scanners per Million Population in Selected G8 Countries for Which Time Series Were Available, 1990 to 2005 57

Figure 20. Number of Magnetic Resonance Imaging (MRI) Scanners per Million Population in Selected G8 Countries for Which Time Series Were Available, 1990 to 2005 58

Figure 21. Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Scanners in Free-Standing Imaging Facilities, Canada, 1998 to 2005 59

Figure 22. Distribution of Selected Medical Imaging Equipment, by Age Cohort Since Installation, by Survey Year, Canada... 60

Figure 23. Distribution of Diagnostic Imaging Operating Expenses in Canadian Hospitals, 2003–2004 61

Figure 24. Total Hospital Operating Expenses for Selected Types of Medical Imaging Equipment, Ontario, 1999–2000 and 2003–2004 63

Figure 25. Distribution of Hospital Operating Expenses for Selected Types of Medical Imaging Equipment, Ontario, 2003–2004...................................... 64

Figure 26. Total Capital Expenditures on Construction, Machinery and Equipment of Hospitals, Clinics, First-Aid Stations and Residential Care Facilities, by Public and Private Sector Payers, Canada, 1990 to 2005 65

Figure 27. Number of Magnetic Resonance Imaging (MRI) Exams per 1,000 Population, by Jurisdiction and Canada, 2003–2004 and 2004–2005 71

Figure 28. Number of Computed Tomography (CT) Exams per 1,000 Population, by Jurisdiction and Canada, 2003–2004 and 2004–2005 71

Figure 29. Average Number of Magnetic Resonance Imaging (MRI) Exams per Machine per Year, by Jurisdiction and Canada, 2003–2004 and 2004–2005............ 73

Figure 30. Average Number of Computed Tomography (CT) Exams per Machine per Year, by Jurisdiction and Canada, 2003–2004 and 2004–2005.................. 74

Figure 31. Average Number of Hours of Operation per Week, Selected Medical Imaging Technologies, Canada, 2003–2004 and 2004–2005 75

Figure 32. Average Number of Hours of Operation per Week, Magnetic Resonance Imaging (MRI) Scanners, by Jurisdiction and Canada, 2003–2004 and 2004–2005 76

List of Figures (cont'd)

Figure 33. Average Number of Hours of Operation per Week, Computed Tomography (CT) Scanners, by Jurisdiction and Canada, 2003–2004 and 2004–2005 76

Figure 34. Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Exams per FTE Technologist, New Brunswick and Ontario, 2003–2004...... 77

Figure 35. Number of Selected Medical Imaging Professionals, Canada, 2004............... 82

Figure 36. Percentage of Medical Radiation Technologists (MRT)s Working Full-Time/Part-Time, Canada, 2001 to 2004... 84

Figure 37. Total Number of Diagnostic Radiology Physicians Who Moved/Returned From Abroad, Canada, 1991 to 2004.. 85

List of Text Tables

Table 1. Which Test? 17

Table 2. Number of Machines (#) and Number of Machines per Million Population (Rate) of Selected Imaging Technologies, by Jurisdiction, as of January 1, 2005... 53

Table 3. Ratios of Magnetic Resonance Imaging (MRI) to Computed Tomography (CT) in Hospitals and Free-Standing Imaging Facilities, by Jurisdiction, as of January 1, 2005... 54

Table 4. Percentage Distribution of Operating Revenue by Source for Selected Types of Medical Imaging Equipment and Total Number of Machines Installed in Hospitals and Free-Standing Imaging Facilities, Canada, as of January 1, 2005... 63

Table 5. Federal Government Funding Commitments for Medical Equipment in the 2001, 2003 and 2004 Health Accords 66

Table 6. Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Exams, by Jurisdiction and Canada, 2003–2004 and 2004–2005 70

Table 7. Average Number of Hours of Operation per Week, Selected Medical Imaging Technologies, by Jurisdiction, 2003–2004 and 2004–2005 75

Table 8. Average Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Exams per 1,000 Population, per Scanner, per FTE Technologist, and Average Number of Hours of Operation of Scanners per Week in the U.S., England and Canada, 2004–2005 or Latest Year... 78

Table 9. Rules for the Evaluation of Medical Equipment.. 80

About This Report

In the past century, we have witnessed dramatic technological changes in the field of medicine. The same is true for medical imaging. For example, X-rays were just starting to be used for medical purposes in the late 1890s. Today, radiologists can read X-rays and other diagnostic images produced thousands of kilometres away in a matter of minutes. Surgeries that once required several days of hospitalization are now being performed on an outpatient basis. And more sophisticated forms of medical imaging, such as the ability to generate images of almost any structure within the body, are becoming essential to the provision of general and specialized medical care and treatment.

Nevertheless, little is known about the actual use of these technologies in Canada. This report aims to address this gap. It is meant to serve as a consolidated reference of what we know about medical imaging across Canada, helping to inform decisions as we move forward. We look in particular at the numbers of different kinds of machines in Canada and how they are used, as well as the skilled health professionals who operate the equipment and interpret results. In general, we tend to focus on a selection of more recent imaging technologies where the information base is strongest. Many of the issues that we highlight, however, may apply across the spectrum of imaging technologies.

The report is divided into three chapters:

Chapter 1: Imaging in Practice—Evolution of Technology and Emerging Applications. Included in this chapter is information about the way that these technologies are evolving, as well as emerging applications for their use and an overview of the available information on imaging technologies in Canada today.

Chapter 2: Imaging Technologies—Supply and Cost provides an overview of the available information on the supply of imaging equipment and where in the country machines are located. It also provides information on factors affecting how much imaging technology we have, including the cost of purchasing imaging equipment.

Chapter 3: Utilization of Imaging Services*.* Having more machines available does not necessarily mean that more people will receive imaging services. The machines could be underused for a variety of reasons, such as funding limitations or human resources constraints. The focus of this chapter is to present some statistics on utilization of medical imaging equipment (number of exams and number of hours in operation) on an annual basis and to assess the level of intensity in the operation of medical imaging equipment.

Where possible, the report includes national and international comparisons. It also includes a Fast Facts section in Appendix A. Fast Facts provides an expanded range of comparative data on medical imaging technologies across the country.

WHAT'S NEW IN THIS REPORT

Medical Imaging in Canada, 2005 draws on new data and analysis from CIHI, as well as research produced at provincial/territorial, national and international levels to explore what we know and don't know about medical imaging in Canada. Examples of the kinds of new information contained in this report are listed below:

- The number, age and distribution of selected medical imaging technologies located in hospitals and free-standing imaging facilities across Canada as of January 1, 2005, and how these characteristics have changed over time;
- How selected imaging technologies are being used in various settings;
- The proportion of hospital spending on medical imaging services in selected provinces; and
- A methodological notes section that provides information on methods and data quality.

For More Information

Highlights and the full text of *Medical Imaging in Canada, 2005* are available free of charge in both official languages on the CIHI Web site, at www.cihi.ca. To order additional print copies of the report (a nominal charge applies to cover printing, shipping and handling costs), please contact:

Canadian Institute for Health Information Order Desk
495 Richmond Road, Suite 600
Ottawa, Ontario K2A 4H6
Tel.: (613) 241-7860
Fax: (613) 241-8120

There's More on the Web!

This report is only part of what you can find at our Web site (www.cihi.ca). On the day that *Medical Imaging in Canada, 2005* is released and in the weeks and months following, we will be adding more information to what is already available electronically. For example, it will be possible to:

- Download free copies of the report in English or French;
- Download report highlights and an index of the report's contents;
- Download data from the 2003, 2004 and 2005 National Survey of Selected Medical Imaging Equipment; and
- Look at CIHI's annual reports, such as *National Health Expenditure Trends*, and the regular series of reports on aspects of health care in Canada, health human resources, health services and population health.

We welcome comments and suggestions about this report and about how to make future reports more useful and informative. Please email them to cmdb@cihi.ca.

Chapter 1

Imaging in Practice— Evolution of Technology and Emerging Applications

In today's modern society, technology has become an indispensable part of our daily lives. It comes as no surprise that the use of technology in the practice of medicine is increasing and improving at a very rapid rate. Imaging technologies became part of the arsenal of tools used to find and fight disease in the last century. Today, clinicians use dozens of types of imaging, often as early diagnostic steps that may precede or preclude other health care services. Some technology, such as that used in X-ray machines, has been used for more than a century. Other technology, including that used in magnetic resonance imaging (MRI), computed tomography (CT) and positron emission tomography (PET) scanners, is a more recent part of an increasingly sophisticated range of imaging technology.

According to the World Health Organization (WHO), the assumption is that diagnostic imaging is needed in some 20% to 30% of medical cases worldwide, as clinical considerations alone are not sufficient to make a correct diagnosis. Of those cases that require diagnostic imaging, some 80% to 90% of diagnostic problems can generally be solved using "basic" X-ray and/or ultrasound examinations.[1]

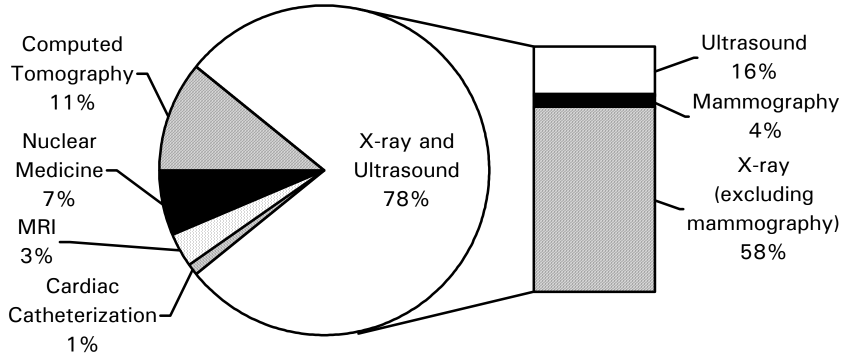
If data from Nova Scotia, Ontario and British Columbia provide any indication, then the Canadian experience seems to follow along the same lines. Basic X-ray and ultrasound examinations together accounted for nearly 80% of all medical imaging examinations (excluding angiography) in the hospitals of the three provinces in 2003–2004 (Figure 1). X-ray examinations, including mammography, represented 63% of examinations, while the share of ultrasound was 16%. CT, nuclear medicine, MRI and cardiac catheterization accounted for respectively 11%, 7%, 3% and 1% of all medical imaging examinations.

Percentage distribution of problems that require diagnostic imaging as estimated by the WHO (all problems that require diagnostic imaging = 100%):

Chest problems	40%
Accidents and injuries	20%
Pregnancy-related problems	15%
Abdominal problems	10%
Musculoskeletal problems	10%
Other	5%

Source: World Health Organization, Department of Essential Health Technologies. *Essential Diagnostic Imaging*, [online], cited September 26, 2005, from <www.who.int/eht/en/diagnosticimaging.pdf>.

Figure 1. Percentage Distribution of Diagnostic Imaging Examinations in Hospitals, Nova Scotia, Ontario and British Columbia, 2003–2004



Source: Canadian MIS Database, Canadian Institute for Health Information.

Note:
Excludes angiography studies.

THE RIGHT TOOL FOR THE RIGHT JOB

Medical imaging may be done for many reasons: screening patients at risk for a disease, reducing uncertainty about a diagnosis to reassure patients and caregivers, assisting with decisions about care choices, assessing treatments and prognoses and/or guiding surgery or other interventions.[2, 3]

Deciding which is the best tool (or tools) to use in each of these contexts for different patients is challenging, particularly given the ongoing evolution of imaging technologies, research evidence and practice patterns. Often, a particular type of imaging is of obvious, undisputed value for some groups of patients or types of research. Other cases are less clear. Examples of factors that may influence decisions include:

- **Technical efficacy**, which is measured by how well an imaging technique represents the physical structure of the body site in question;
- **Diagnostic accuracy**, which shows to what degree test information is likely to contribute to the determination of a correct diagnosis;
- **Comparative efficiency**, which tells us how much better (or worse) the diagnostic information produced is than that generated by other approaches;
- **Therapeutic impact**, which measures to what extent diagnostic information is likely to affect care decisions; and
- **Health outcomes**, which are the net expected effects on morbidity and mortality outcomes as a result of both diagnosis and treatment.[4]

In addition, non-clinical and other factors may be considered when deciding between alternative technologies—these include access to technology, cost-effectiveness and safety issues.

More recent technology, such as CT and MRI, is increasingly used to investigate non-specific symptoms. Possible factors for the increase in utilization include growing patient demand and increased access to scanners, clinicians' concerns about missing a treatable illness and concerns about litigation if an important abnormality is not diagnosed. Guidelines are needed to help clinicians and patients determine when a CT or MRI scan or any other diagnostic imaging procedure is indicated. Progress is being made in Canada in this regard, as the Canadian Association of Radiologists is developing evidence-based guidelines for all diagnostic imaging procedures.[8]

Safety of Medical Imaging

Medical imaging tests, like other health care interventions, are rarely risk-free. For instance, X-rays carry risks associated with radiation exposure. Technologies that do not use ionizing radiation may pose other risks. Examples include potential mechanical, thermal and biological effects.[5] For many patients, the potential benefits of the information obtained from tests clearly outweigh foreseeable risks, including the consequences that may arise from false-positive or false-negative findings.[6] For others, careful consideration of potential benefits, costs and risks is required. In some cases, the best option is to rely on approaches used for centuries, such as careful observation or feeling a joint to check for a break. This balance may vary from test to test, place to place, patient to patient and over time.[7]

Although millions of Canadians use imaging services each year, still relatively little is known about how these technologies are used and how they affect patient care and outcomes. Pockets of information do, however, exist. Last year's report, *Medical Imaging in Canada, 2004*, briefly discussed two well-established modalities in the diagnosis of breast cancer and coronary artery disease—namely mammography and coronary angiography. This chapter goes a step further in examining the use of various imaging technologies (both traditional and emerging) in the diagnosis of the two major diseases. Breast cancer is the most commonly diagnosed form of cancer among Canadian women. Coronary artery disease accounts for more than half of all cardiovascular deaths in Canada. The chapter then focuses on the evolution since their early clinical applications of three types of imaging—CT, MRI and PET (including PET/CT)—as well as the characteristics of the machines installed in Canada and emerging applications due to recent technological advances. Finally, the picture archive and communications system (PACS) is discussed in the Canadian context. PACS is an information technology tool that allows diagnostic images to be stored in a central location (PACS server) and transmitted to any workstation linked to the server.

MEDICAL IMAGING IN THE DIAGNOSIS OF BREAST CANCER

Mammography: Looking for Breast Cancer

Mammography uses low-dose and low-energy X-rays to produce an image of internal breast tissue. The image of the breast is produced as a result of some of the X-rays being absorbed while others pass through the breast to expose either a film (conventional mammography) or a digital image receptor (digital mammography). Film-screen mammography systems are by far the most widely available. Digital mammography systems have recently been introduced.

The National Cancer Institute of Canada estimates that there will be about 21,600 new cases of breast cancer and about 5,300 cancer deaths among Canadian women in 2005. This makes breast cancer the most commonly diagnosed form of cancer among women, although lung cancer is the leading cause of cancer deaths among women.[9] Mammography is the prevalent imaging technique for breast cancer screening of asymptomatic women (that is, women who have no breast complaints such as a breast mass, pain or nipple discharge). Conventional mammography is an X-ray of the breast that uses a low-dose X-ray system specially designed for breast imaging and high-contrast, high-resolution film to ensure that the radiologist can see as much as possible from a patient's mammogram.[10] Most medical experts agree that successful treatment of breast cancer is linked to early diagnosis.[11] Early detection of breast cancer increases the chance for longer cancer-free survival, while resulting in less surgery, less chemotherapy and less stress for the patient and her family. According to the American Cancer Society, when breast cancer is detected in the localized stage when it has not spread to the lymph nodes, the five-year survival rate is 97%. If the cancer has spread to underarm (axillary) lymph nodes, the rate drops to 79%. If the cancer has spread (metastasized) to distant organs such as the lungs, bone marrow, liver or brain, the five-year survival rate is 23%.[12]

Of 688 breast screening machines in Canada, 540 are accredited by a voluntary accreditation program administered by the Canadian Association of Radiologists (CAR). According to a *Globe and Mail* investigation, 148 hospitals and clinics across Canada are operating breast screening machines that have either failed accreditation (50), have never been tested (48) or are no longer being tested (50), based on CAR records. The *Globe and Mail* reported that both the Breast Cancer Society of Canada and the Canadian Cancer Society advocate a mandatory quality test of all mammography machines in Canada so women are not subjected to outdated equipment, untrained staff or, potentially, having their breast cancers missed.

Source: L. Priest, *The Globe and Mail*, "Machines That Detect Cancer Need Check-up, Groups Say," May 2, 2005.

In 2002, a working group convened by the WHO's International Agency for Research on Cancer evaluated the available evidence on breast cancer screening. The group, consisting of 24 experts from 11 countries, concluded that there is sufficient evidence for the efficacy of mammography screening of women between 50 and 69 years. The reduction of mortality from breast cancer among women 50 to 69 years of age who chose to participate in screening programs was estimated by the working group to be about 35%. For women aged 40 to 49 years, the working group found only limited evidence for a reduction in mortality from breast cancer.[13] A 2005 review of articles on randomized controlled trials assessing effectiveness of breast cancer screening in the United States, Sweden, Canada and the United Kingdom concluded that screening mammography reduces breast cancer mortality by about 20% to 35% in women aged 50 to 69 years at 14 years of follow-up.[14] The evidence for the reduction in mortality is also supported by another study published in 2005 that examined the results of the Copenhagen mammography service screening program, over the 10-year period from 1991 to 2001. The study group included women aged 50 to 69 invited for screening at two-year intervals. The Danish study found that overall breast cancer mortality was reduced by 25%, compared with what the researchers would have expected in the absence of screening. For women who chose to participate in the Copenhagen screening program, breast cancer mortality was reduced by 37%.[15]

The Canadian Cancer Society recommends a screening mammogram every two years for women aged 50 to 69.[16] In the 2003 Canadian Community Health Survey (CCHS), 71% of Canadian women aged 50 to 69 reported having a mammogram in the last two years; 49% of all women in this age group said that their mammogram was specifically for routine screening.[17] All major medical organizations in the U.S., including the American Cancer Society, recommend that screening begin at age 40, although the benefit from screening women in their 40s may be somewhat less than that of older women. Women in their 40s have a lower incidence of disease, denser breast tissue (which can lower the sensitivity of mammography), and, on average, faster-growing cancers.[11, 14, 18] In August 2005, the Agence d'évaluation des technologies et des modes d'intervention en santé (AÉTMIS) in Quebec published a report that examined the appropriateness of extending screening to women less than 50 years old. The report concluded that trial data published to date did not provide scientific justification to recommend screening for women younger than 50. However, this conclusion did not exclude the possibility that screening of individual women, based on a personalized risk assessment, could be of benefit. The Quebec report stated that these conclusions should be reviewed when the results of the randomized trial of mammography screening for women in their early 40s conducted by the United Kingdom Coordinating Committee on Cancer Research become available.[19]

Initial mammographic images themselves are not always enough to identify or rule out cancer. After 5% to 15% of screening mammograms, more testing is required, such as additional mammograms or ultrasound. Usually, most of these tests turn out to be normal. If there is an abnormal finding, a follow-up or biopsy may have to be performed. Typically, most of the biopsies confirm that no cancer is present. In the U.S., it has been estimated that a woman who has yearly mammograms between age 40 and 49 has about a 30% chance of having a false-positive mammogram at some point in that decade. The estimate for false-positive mammograms is about 25% for women aged 50 or older.[11] Conventional mammography also misses from 10% to 30% of breast cancers (false-negative mammograms).[20, 21]

While X-ray mammography may result in both false-positive and false-negative tests, it is still the first-line method of choice for screening asymptomatic women. It is the only dependable technique for detecting microcalcification and has high sensitivity in detecting cancer in women with fatty breasts. However, it is not reliable in the assessment of dense breast tissue.[12, 14, 22]

Adjunctive imaging technologies to supplement mammography are being used or explored in view of reducing the biopsy rate after false-positive mammograms and detecting the cancers missed by false-negative mammograms. Some new or experimental breast imaging methods are being tested as alternatives to mammography, particularly in detecting tumours in women with dense breast tissue and women with an inherited susceptibility to breast cancer.

Adjunctive and Alternative Imaging Technologies to Mammography

Breast Ultrasound

Breast ultrasound is the most common adjunctive test to mammography. Ultrasound is usually used to target a specific area of concern found by the mammography. Ultrasound helps distinguish between cysts and solid masses and between benign and cancerous tumours. However, small calcium deposits, which are one of the earliest signs of cancer, are not visible by ultrasound. The benefit of ultrasound is greatest for women with high breast density, and some studies have suggested that ultrasound be added for screening women with dense breasts.[12] A New Zealand study investigated the use of ultrasound as a first-line diagnostic tool, on an equal basis with mammography. The study concluded that the use of ultrasound and mammography in combination is significantly better than either modality used alone, resulting in 9% more breast cancers being detected.[23] In the U.S., a clinical trial is currently underway to determine what role, if any, ultrasound has in detecting breast cancer in high-risk women. Participants will undergo an ultrasound screening and mammogram annually for three years.[24]

Magnetic Resonance Imaging (MRI)

Recent studies conducted in Canada, the U.S. and Europe reported that MRI appears to be more sensitive than mammography, ultrasound or both in detecting tumours in women with an inherited susceptibility to breast cancer. Results from these studies suggest that MRI-based cancer detection may become the cornerstone of breast cancer surveillance for women at high risk for developing breast cancer.[25, 26, 27] Other studies also found MRI to be more sensitive than mammography for the detection of cancer in fibroglandular or dense breasts.[28, 29] However, specificity of MRI tends to be lower than that of mammography, resulting in higher false-positive rates. False-positive results have been associated with anxiety and additional costs. MRI has not been studied in the general population as a screening tool, and the results from MRI screening of high-risk women may not apply to women at average risk. Factors that may prohibit the routine use of MRI for screening general populations, at least in the near future, are its high cost, its relatively low specificity, its incapacity to detect microcalcifications and the lack of standard techniques and interpretation norms for breast MRI examinations.[12, 14]

A clinical trial is being conducted by 22 centres in the U.S., Canada and Germany to determine the performance of MRI in detecting breast cancer in high-risk women. Some 1,000 women diagnosed with cancer in one breast received an MRI exam of the other breast determined to be cancer-free by mammography and physical exam. Results are expected in late 2005.

Source: Radiological Society of North America, *Radiology Info—News From the RSNA Media Briefing—New Breast-Imaging Technology Could Save More Women's Lives*, [online], last updated June 2005, From <www.radiologyinfo.org/content/news/target.cfm?ID=196>.

Digital Mammography

The current standard, film-screen mammography has certain inherent limitations in terms of image quality. Mammography is one of the last radiographic procedures to go digital.[30] Digital mammography was developed as a convenient alternative that is expected to improve the quality of breast imaging and reduce the radiation dose required.

Digital mammography involves the digital capture of images through two different technologies:[31]

- Computed radiography mammography (CR-M) is an indirect system: X-ray information is captured on a detector plate, from which a digital image is created.
- Digital radiography mammography (DR-M), also called "full-field digital mammography," is a direct system: X-ray information is directly converted into a digital image.

In 1991, an expert panel from the U.S. National Cancer Institute concluded that full-field digital mammography was the technology that held the greatest promise to improve breast cancer detection. In 2000, General Electric became the first manufacturer with a full-field digital mammography device approved by the Food and Drug Administration (FDA). Digital imaging has not yet been widely implemented in the U.S. or other countries. As of May 1, 2005, only 6.4% of accredited mammography units in the U.S. were digital.[32, 33] Full-field digital mammography allows electronic transmission, storage and retrieval of images. The digital format also allows easier use of computer-aided detection (CAD) software that can mark calcifications, masses or other potential lesions on the mammogram, and therefore may increase the number of cancers detected. With digital mammography, multiple images can be combined, manipulated, added and subtracted. New techniques being investigated include contrast-medium digital mammography and dual-energy subtraction mammography. In contrast-medium digital mammography, images are obtained pre and post contrast. This allows the subtraction of unenhanced images from enhanced images. In a breast with cancer, the uptake of contrast medium will be different from that of a normal breast. The second technique, dual-energy subtraction mammography, involves the injection of a contrast agent to highlight new blood vessel development that accompanies malignant growth. Two images are taken at different energy levels and subtracted from one another to disclose the tumour.[20, 21, 34, 35, 36]

Digital mammography is a new technology that has not been extensively studied. In October 2002, the Canadian Coordinating Office for Health Technology Assessment (CCOHTA) concluded, after a literature review, that full-field digital mammography and conventional film-screen mammography had a comparable ability to detect cancer. According to CCOHTA, conventional film-screen mammography was still the technology of choice because of its lower cost. CCOHTA further stated that potential clinical benefits of full-field digital mammography (improved diagnostic accuracy, shorter examination time, lower radiation dose) had not yet been demonstrated in a clinical setting.[31] Subsequent studies have found reasonable evidence that digital mammography is comparable with screen-field mammography in terms of sensitivity and specificity.[14, 21, 33] The results of a major clinical trial study, the American College of Radiology Imaging Network Digital Mammography Imaging Screening Trial, involving the participation of more than 40,000 women at 33 sites in the U.S. and Canada, were published recently (September 16, 2005). The clinical trial, which began in July 2001, was designed to measure any potential benefit of digital mammography in screening. The trial study concluded that the overall diagnostic accuracy of digital and film mammography as a means of screening for breast cancer is similar, but digital mammography is more accurate in women under the age of 50 years, women with dense breasts, premenopausal and perimenopausal women. While these findings are encouraging, the higher cost of digital mammography may still represent a major impediment to its adoption.[37]

Computer-Aided Detection

The rate of false negative interpretations from conventional mammography is relatively high (between 10% and 30%).[20, 21] It is for this reason that computer-aided detection (CAD) has been increasingly used as an aid to screening mammography. CAD is most commonly performed with film-screen mammograms. It has been introduced into clinical practice over the past decade and has been reported to improve the sensitivity of film-screen mammograms by up to 20%. The film-screen mammogram image is converted by a digitizer into a digital signal that is analysed by a computer and displayed on a video screen. CAD uses software to search the image and provides prompts, usually in the form of marks and symbols on the screen, to alert the radiologist to features that might otherwise have been overlooked. The cost of the software and hardware (for example, digitizers and multiviewers) required for CAD with film-screen mammography is said to have been a major obstacle to its widespread use in medical practice. Full-field digital mammography allows easier use of CAD and might be more cost-effective, because images are already in digital format.[14, 21, 33, 38, 39]

Nuclear Medicine

Scintimammography and PET are two nuclear medicine imaging techniques that can be used in the diagnosis of breast cancer.

- Scintimammography uses a gamma-ray emitting radiopharmaceutical (radionuclide)—a tracer with a half life of several hours that is excreted through the liver and biliary system and a camera for imaging the lesion. After the radionuclide is injected into the patient, as the isotope decays, it emits gamma rays, and the isotope distribution in the breast cancer cells can be detected by a gamma camera. According to a literature review prepared by the Medical Advisory Secretariat of the Ontario Ministry of Health and Long-Term Care in 2003, the limited data available suggested that scintimammography had high sensitivity and performed slightly better than ultrasound in certain malignant tumours larger than 1 centimetre. The Medical Advisory Secretariat concluded that there may be a role for scintimammography as an adjunctive technique in the evaluation of breast anomalies.[22]

- Positron emission tomography (PET) uses a radioactive substance that, when injected into the patient, gives a small amount of radiation that is detected by a PET scanner to form an image. The most commonly used substance is fluorodeoxyglucose, which is metabolized in the body like sugar. It goes where the tissue metabolism is the most active, especially highlighting cancerous tissue. PET is used to detect metastatic disease (cancer spread), but its use for primary breast cancer detection is limited, as it does not reliably detect tumours smaller than 1 centimetre. However, combined PET/mammography units, currently under development, show promise for detection of small tumours.[12, 40]

MEDICAL IMAGING IN THE DIAGNOSIS OF CORONARY ARTERY DISEASE

In the 2003 Health Services Access Survey (HSAS) by Statistics Canada, about 1% of respondents aged 15 and older reported that they had had a non-emergency angiography within the last 12 months. These respondents tended to be middle aged and older Canadians (aged 45 and over); 54% were men. Most (83%) said that their procedure was done in a hospital or public clinic.[41]

Most angiographies are done to detect coronary artery disease. According to the Canadian Heart and Stroke Foundation, cardiovascular disease accounts for the deaths of more Canadians than any other disease, and 54% of all cardiovascular deaths in 2002 were due to coronary artery disease.[42] Coronary artery disease occurs when the arteries that carry the blood to the heart become narrowed or blocked and can no longer give enough blood to meet the heart's demand.

Coronary angiography (or diagnostic cardiac catheterization) is considered the gold standard for the diagnosis of coronary artery disease. It is an invasive procedure that involves insertion of a contrast agent in the bloodstream through a catheter. Coronary angiography provides images of blood vessels or chambers of the heart. It can be an important tool in detecting obstructions in coronary arteries and is often performed to determine the necessity of further interventions, such as angioplasty or bypass surgery. The Canadian MIS Database reported that the diagnostic imaging personnel of hospitals in Nova Scotia, Ontario and B.C. performed 156,643 cardiac catheterization examinations in 2003–2004.

Angiography is used to find and treat abnormalities in the blood vessels. Using fluoroscopy images to guide placement, a fine hollow catheter may be inserted into small blood vessels deep in the body. A contrast agent is injected into the bloodstream through the catheter to outline the blood vessel by X-ray and reveal blockages or abnormalities in the blood supply to organs. The catheter may also be used to treat the blockage (angioplasty).

Risks associated with catheterization include the following:[43]

- Bleeding, infection and pain;
- Damage to the blood vessels by the catheter;
- Breakage of the catheter;
- Formation of blood clots on the catheter that could block blood vessels somewhere in the body; and
- Damage to kidneys caused by the contrast material.

Angiography is one of the many tests used to diagnose heart disease. As with other diseases, tests may be used alone or in combination. The choice of which test(s) to use—and when—may depend on factors such as the patient's risk factors, health history and current symptoms and situation; the availability of different tests and skilled professionals to conduct them and to interpret the results; and options for proceeding after test results are known.[44] The routine use of coronary angiography without prior non-invasive testing is not recommended, due to its high cost and associated risks. Diagnostic tests other than coronary angiography that are commonly done for coronary artery disease include those listed on the following pages.[43, 45]

Electrocardiogram (ECG)

A printed record of the heart's electrical activity over a short period (about 10 minutes) when the patient is at rest. It is a non-invasive procedure, as nothing is injected or put into the body. Small metal electrodes are attached to the arms, legs and chest.

Exercise Stress Tests

In an exercise ECG, the electrical activity of the heart as well as blood pressure is monitored while the patient exercises, usually by walking on a treadmill.

Nuclear Imaging (Such as Thallium or Single-Photo Emission Computed Tomography)

Nuclear imaging provides information about the flow of blood into the heart. A radioactive tracer is injected into a vein of the arm and a special camera then measures the amount of radioactivity that is carried by the bloodstream into the heart. Areas with poor blood supply will not pick up the tracer and will appear as dark areas on the scan.

Echocardiography

In conventional (transthoracic) echocardiography, high-frequency sound waves are emitted toward the heart by a transducer held against the chest. The returning sound waves (echoes) provide information about the blood flow through the heart. In a form of echocardiography called transesophageal echocardiography (TEE), a tube with a transducer is inserted into the esophagus. Because the esophagus is close to the heart, TEE gives very clear pictures of the heart.

Other less commonly used modalities for the investigation of coronary artery disease include intravascular ultrasound, cardiac PET, CT (including electron-beam CT) and MRI. Many of these modalities are still being assessed and are generally not covered by provincial or territorial medical care insurance plans.

Intravascular Ultrasound

This modality involves the insertion of a tiny ultrasound device via a catheter to visualize the interior of arteries. Intravascular ultrasound can provide additional information to that available through angiography. However, some studies found the available evidence with regard to reliable implications for clinical practice and cost-effectiveness of this modality to be too weak or insufficient.[46]

Positron Emission Tomography (PET)

PET is a type of nuclear medicine that measures chemical process in the body. A Quebec study found PET to have clinical utility in studying myocardial viability.[47] On the other hand, a study from Ontario found that there was no convincing evidence of the clinical utility of PET for cardiac indications.[48] The American Heart Association states that PET is highly accurate for detecting, localizing and describing coronary artery disease that impairs blood flow to the myocardium (heart muscle).[49] See also the section on PET and PET/CT.

Coronary CT Angiography

CT technology used for cardiovascular imaging employs either a rotating electron beam (electron beam CT) or a rotating X-ray source with a circular stationary detector array (spiral or helical CT—see the section on CT). Electron beam computed tomography (EBCT), which first appeared in the U.S. in 1984, is the only CT device specifically designed from inception for cardiac imaging.[50] While the technology is not used in Canada [51] CCOHTA states that EBCT has been considered the modality of choice for evaluation of coronary calcification (a marker for coronary artery disease). However, CCOHTA also reports that a 1999 systematic review for the UK National Health Service found no evidence to support the use of EBCT in an asymptomatic population for predicting subsequent coronary events.[52]

Spiral CT with multiple rows of detector arrays (multi-detector CT—see the section on CT) has been proposed as a replacement for coronary angiography to detect coronary artery disease. The Medical Advisory Secretariat of the Ontario Ministry of Health and Long-Term Care performed a systematic literature review from 2003 to January 2005 to determine the effectiveness of multi-detector CT (16-slice and 64-slice) compared to coronary angiography to detect coronary artery disease. Based on the review, the Secretariat concluded that there is insufficient evidence to suggest that 16-slice or 64-slice CT angiography is equal to or better than coronary angiography to diagnose coronary artery disease in people with symptoms or to detect disease progression in patients who had previous cardiac interventions. An analysis of the evidence suggested that in investigating the suspicion of coronary artery disease by multi-detector CT a substantial number of cases would be missed and therefore the patients would not be appropriately treated. The Secretariat stated that, until more definite evidence is published, CT angiography is unlikely to replace coronary angiography and will probably be used adjunctively with other cardiac diagnostic tests.[43] The Ontario Expert Panel on MRI and CT recommended in its Phase I report of April 2005 that, as a minimum standard, all CT centres in Ontario be capable of doing CT angiography.[53]

Cardiovascular Magnetic Resonance

Cardiovascular magnetic resonance represents the specialized application of magnetic resonance to the cardiovascular system employing specialized receiver coils, pulse sequences and a gating method. Magnetic resonance imagers need to be equipped with a localized multichannel radiofrequency surface coil and electrocardiography gating. The American College of Radiology recommends that imagers for cardiovascular magnetic resonance have a field strength of 1.0 Tesla or higher.[54] The Ontario Expert Panel on MRI and CT stated that the minimum standard for MRI scanners in hospitals should be a 1.5 Tesla magnet with the capacity of doing MRI angiography.[53] While coronary angiography is the preferred test for defining the site and severity of coronary artery lesions, the routine use of this invasive modality is not recommended without prior non-invasive testing. In 2003, the Medical Advisory Secretariat of the Ontario Ministry of Health and Long-Term Care concluded, based on a systematic literature review, that there is insufficient evidence on whether functional cardiac medical resonance imaging can better select which patients should proceed to invasive coronary angiography for the definitive diagnostic of coronary artery disease, compared with an alternate non-invasive medical technology.[55] In 2005, CCOHTA reported on five reviews that examined the use of CT and MRI in the investigation of coronary artery disease. These modalities were found to be promising but not yet superior to coronary angiography. [51]

CT, MRI and PET are experiencing rapid technical advances and may have an increasing role in cardiovascular imaging. For example, the Chairman of the Board of Chancellors of the American College of Radiology envisions that the standard of care for a patient with chest pain throughout the U.S. will soon be CT angiography or MRI.[56] Yet, the appropriateness rating of CT and MRI for a patient with acute chest pain and suspected myorcardial ischemia still falls in the bottom portion of the appropriateness scale developed by the American College of Radiology's Expert Panel on Cardiovascular Imaging (see Table 1). In its 2005 review and update of appropriateness criteria for a patient with acute chest pain of suspected myocardial ischemic origin, the Panel mentions that continuing developments in the assessment or coronary blood flow and myocardial perfusion using magnetic resonance and PET may prove helpful in the future. The Panel also states that the presence of coronary atherosclerosis and stenosis can be documented with the newer rapid CT technologies, such as electron beam CT or helical or multi-detector CT, but their use in the evaluation of acute coronary syndrome patients has not been established.[57]

Table 1. Which Test?

Appropriateness ratings (1 = least appropriate; 9 = most appropriate) and related comments for radiological exam procedures that may be used for a patient with acute chest pain and suspected myocardial ischemia, assigned by the American College of Radiology's Expert Panel on Cardiovascular Imaging (2005 update).

Radiological Exam Procedure	Appropriateness Rating	Comments
Chest film (X-ray)	9	Plain films are needed to exclude other causes for chest pain.
Coronary angiography	8	Necessary to define extent of stenosis. Usually done late in the work-up.
Transthoracic echocardiography (TTE)	7	Indicated as a screening test to evaluate cardiac function. Inexpensive and portable.
Left ventricular (LV) angiography	7	Indicated to define ventricular function as part of the ischemia evaluation.
Radionuclide myocardial perfusion scan	6	May be indicated to evaluate extent of ischemia. Usually done after initial screening tests suggest ischemia.
Radionuclide ventriculogram	6	May be indicated to evaluate cardiac function.
Infarct avid imaging	5	May be indicated in questionable cases to confirm infarction.
Transesophageal echocardiography (TEE)	4	May be indicated to evaluate cardiac function or to rule out aortic dissection.
Electron beam CT/multihead ultrafast CT with contrast	4	Probably not indicated except for quantitating ventricular function. Noncontrast images may be useful in screening for coronary calcification.
Magnetic resonance angiography (MRA)	4	
Conventional computed tomography (CT) with contrast	3	Little indication except for documenting other sources of chest pain.
Magnetic resonance imaging (MRI)	3	Little indication except for screening for possible aortic dissection. May have some applicability in evaluating cardiac function.
MR perfusion studies	2	Research studies show promise in evaluating infarction. Not used clinically to any extent.
Positron emission tomography (PET)	2	See comments on MR perfusion studies.

Source: American College of Radiology, *Acute Chest Pain—Suspected Myocardial Ischemia* (2005), [online], from <www.acr.org/s_acr/bin.asp?TrackID=&SID=1&DID=11740&CID=1208&VID=2&DOC=File.PDF>.

COMPUTED TOMOGRAPHY (CT)

Computed tomography (or CT), also known as "computer assisted tomography" (or CAT), is used to create three-dimensional images of the structures within the body. CT scans use X-ray images processed by a computer to create virtual slices of the part of the body being examined.
A computer then processes the data to create images that show a cross-section of body tissues and organs.

Physicians use CT scans for diagnosing a wide and changing range of conditions, such as head injury, chest trauma and musculoskeletal fractures. According to the 2003 Health Services Access Survey data, about 962,000 Canadians aged 15 and older (3.7% of all Canadians aged 15+) reported that they had had a non-emergency CT scan in the past 12 months. The leading reason for these tests, accounting for 19% of scans, was neurological or brain disorders, followed by fractures or problems of joints (16%). About 48% did not specify a reason for their CT scans. Most respondents (96%) stated that their CT scan was done in a hospital or public clinic.[41]

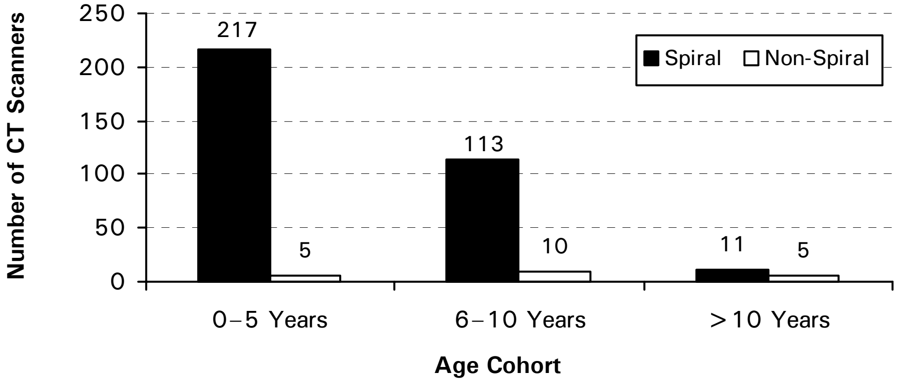
Evolution of Technology: From Single-Slice Conventional Scanning to Spiral Multi-Slice Scanning

The first medical CT scanner in Canada was installed at the Montreal Neurological Institute in 1973.[58] Since then, CT scanners installed in Canada increased by about a hundred units every decade. In 1983, 98 hospitals reported performing CT examinations (some hospitals might have had more than one scanner).[59] In 1993, there were 216 CT scanners[60] and by 2003, this number had reached 325.[61] In 2005, there were 361 CT scanners installed.[62]

Two major components of a CT scanner are a gantry (a frame housing an X-ray tube and a detector array, with a large opening into which the patient is inserted lying on a table) and a computer processor. The gantry takes consecutive images or rotates around the patient, gathering data that are converted to images by the computer processor. All original or early scanners (until 1987) used conventional or non-spiral scanning: the patient was moved forward, when the gantry had come to a complete stop after a rotation, by an increment equal to the slice thickness. Non-spiral scanning is relatively slow and resulting images are prone to artefacts caused by movement.[52, 63] Relatively few scanners currently installed in Canada still use this original technology.

Only 20 CT scanners, representing 6% of all scanners installed as of January 1, 2005, were non-spiral scanners. Half of the non-spiral scanners (10) were between 6 and 10 years old. Five were five years old or younger and five were older than ten years (Figure 2).

Figure 2. Number of Computed Tomography (CT) Scanners, by Age Cohort, by Technology, Canada, as of January 1, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

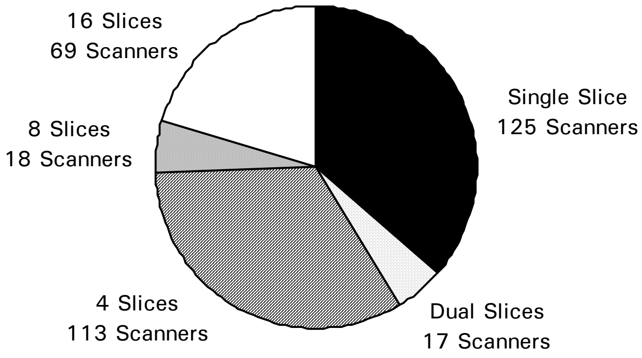
Slip-ring technology, introduced in 1988, allows continuous rotation of the gantry and, as the patient is moved, a spiral or helical scan is obtained, hence the name "spiral" or "helical" CT. It permits data to be acquired rapidly, reduces artefacts due to movement and increases resolution.[52, 63]

As of January 1, 2005, 94% of CT scanners were spiral CTs, almost two-thirds of them installed in the preceding five years.

A further technological advance, multi-detector CTs (MDCTs), which are a new generation of spiral CTs with multiple detectors, have a greater imaging speed and detection capacity than single-slice spiral CTs. An MDCT allows multiple image slices to be simultaneously acquired during a single rotation of the X-ray tube. MDCTs with the capacity to simultaneously acquire an increasing number of slices have been introduced over the years. In 1998, the introduction of four-slice CT scanners resulted in improvements in imaging of the chest and abdomen, among other indications. In 2001, with the availability of 16-slice acquisition, the use of CT expanded to include vascular investigations.[8] More recently, CTs with a capacity of 32 simultaneous slices and even 64 slices have been introduced.

As of January 1, 2005, there were 217 MDCTs installed in Canada, of which about half (113) were four-slice CTs. At the higher end of the technology, 69 scanners had the capacity to simultaneously acquire 16 slices (Figure 3).

Figure 3. Number of Spiral Computed Tomography (CT) Scanners, by Slice, Canada, as of January 1, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Some of the cited clinical advantages of MDCT scanners over conventional CT scanners for general scanning purposes are as follow:[43]

- MDCT has faster and better spatial resolution, covers more volume and uses contrast media more efficiently.
- MDCT may be used for pediatrics, geriatrics, bariatrics and cardiology.
- MDCT may replace other more invasive or cumbersome procedures.
- MDCT has faster scanning times (some users are scanning about 60 patients per day, compared to 25 with a conventional scanner).
- MDCT images can be sent straight to the software, but efficient image management is necessary.

A cited disadvantage of MDCT scanners is a higher radiation dose than conventional CT or other imaging tools. Ionizing radiation doses from CT examination are among the highest of those for any diagnostic imaging modality. The effective dose from diagnostic medical exposure is measured in millisieverts (mSv). Conventional CT scanners deliver effective doses of 2.3 mSv, 8 mSv and 10 mSv respectively for a typical head, chest and abdomen or pelvis examination. This is a radiation dose respectively equivalent to 115, 400 and 500 chest X-rays. For perspective, the amount of radiation that one gets from background, or natural, sources is 2 or 3 mSv per year.[43, 64, 65] With the increased use of CT, there has been an increase in average effective dose of hospital patients. For example, at the Vancouver General Hospital, the average annual patient effective dose has almost doubled between 1991 and 2002.[66] MDCT may even produce higher radiation doses than a conventional CT because of higher X-ray tube currents that are necessary for multiple slices. However, over the past few years, CT manufacturers have added the capability to vary the X-ray tube current according to the size of the patient and the X-ray attenuation[i] of the body part being scanned. The tube current may be automatically reduced at some angular tube position, at which the X-ray attenuation of a patient is smaller (for example, posterior-anterior scan angle versus lateral) and at locations at which the anatomy is less attenuating (for example, chest versus abdomen). With dose reduction and X-ray optimization techniques, CT scans can be performed with a radiation dose that is as low as reasonably achievable without compromise to the resulting images.[43, 50, 67]

MDCT scanners also cost more than conventional scanners. Additional hardware and software costs may be incurred to make use of the full capabilities of MDCT, and there may be additional annual service (maintenance) costs.[43] In 2003, acquisition costs for a new spiral CT ranged from $375,000 to $1.6 million (U.S. dollars), the cost for MDCTs being at the high end (more than $1.2 million U.S. dollars).[52, 63]

Performing CTs in the Context of Emergency Care in Ontario

Radiology plays an important role in support of the emergency department. Used appropriately, imaging can, for example, aid in identifying patients who may benefit from immediate intervention, monitoring or early discharge.

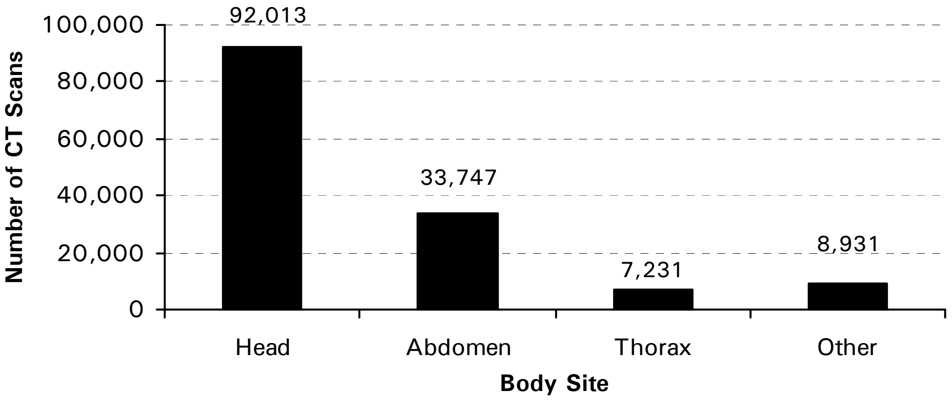
Depending on a patient's condition and circumstances, different types of imaging (or no imaging) may be used. Some types of tests are relatively common—1.5 million X-rays were performed for patients in emergency departments across Ontario in 2003–2004. Others are used less often. For example, as reported in Figure 4, about 142,000 CT scans were performed in the same period. Almost two-thirds of these tests (92,013) were head scans; another 24% (33,747) were of the abdomen. The number of men receiving CT scans was higher than the number of women for all age groups, except those 75 years and over. Patients 70 years of age or older underwent 30% of scans, although they accounted for only 14% of all emergency visits.

Source: National Ambulatory Care Reporting System, Canadian Institute for Health Information.

---

[i] X-ray attenuation is the loss of energy of the X-ray beam as it passes through the body part to transmit measurements to the detector array.

Figure 4. Number of Computed Tomography (CT) Scans, by Body Site in Emergency Departments, Ontario, 2003–2004



Source: National Ambulatory Care Reporting System, Canadian Institute of Health Information.

Note:
"Other" includes CT scans not otherwise specified.

CT scanning is an increasingly used modality for the diagnosis of injuries and diseases. It is most notably used for clinical investigations of the abdomen/pelvis and the brain. The introduction of multi-slice CTs with very short scan time has opened the door to new applications, such as coronary angiography and screening tests (for example, calcium scoring for coronary disease, low-dose CT of the chest to detect malignancy in high-risk groups and CT colonography for colorectal cancer screening).[53, 63] However, these emerging applications are still being assessed. The following section examines the use of CT in screening for colorectal cancer.

Emerging Application: CT Colonography (Virtual Colonoscopy)

Colorectal cancer is the fourth most commonly diagnosed cancer and the second leading cause of cancer-related death in Canada (the first cause of cancer-related death among non-smokers). In 2005, there will be an estimated 19,600 new cases of colorectal cancer and 8,400 deaths from colorectal cancer in Canada. The average lifetime risk of a diagnosis of colorectal cancer in Canada is about 7% for men and 6% for women, with most cases occurring after 50 years of age.[68]

About 5% of colon cancers are associated with genetically defined colon cancer family syndromes, and 20% to 30% have a potentially definable inherited cause.[69] However, most colorectal cancers develop in people with no genetic predisposition. Colorectal cancer generally arises from the mutation of precursor adenomatous polyps, benign growths in the inner wall of the colon and rectum. The average time required for a precancerous polyp to progress to a carcinoma is estimated at 10 to 20 years. Colorectal cancer lends itself well to population screening, being prevalent, treatable and preventable by well-established techniques.[69, 70, 71]

Colonoscopy is considered to be the gold standard for the diagnosis of colorectal cancer. It is a procedure that lets a doctor look at the lining of the entire colon by means of a colonoscope, a flexible, lighted tube inserted through the rectum.[72]

Both the Canadian Association of Gastroenterology and the American College of Gastroenterology recommend that asymptomatic individuals aged 50 years and over undergo colonoscopy every 10 years.[69, 73] However, discomfort and the risk of complications are reasons frequently mentioned by individuals for not undergoing the procedure.[74]

CT and MRI colonographies, also called virtual colonoscopy, are non-invasive emerging technologies that are potential alternatives to colonoscopy in the diagnosis of colorectal cancer; however, thus far CT has been studied and used more extensively than MRI.

In October 2003, after an Ontario hospital was interested in establishing a service of CT colonography (CTC), the Ontario Ministry of Health and Long-Term Care completed a literature review to assess the effectiveness and safety (radiation exposure) of CTC as a screening method for the detection of colon cancer and precancerous polyps with the reference standard of conventional colonoscopy.[71]

Ontario Ministry of Health's conclusions:

- With the limited sensitivity and specificity of CTC relative to colonoscopy, together with the lack of therapeutic intervention, this method of screening may result in inconvenience, cost and complications.
- Based on the current evidence, CTC cannot be proposed for population-based colorectal cancer screening.
- Patients with colonic symptoms or a personal or family history of polyps will benefit more in several ways if they undergo colonoscopy, including excision of premalignant polyps.
- Considering the possibility of assessing the entire colon, extracolonic structures and tumour staging, CTC can be the examination of choice for preoperative evaluation of patients with colorectal carcinomas.
- CTC can be considered for diagnostic purposes in patients in whom performing colonoscopy is clinically contraindicated or for those patients who had incomplete colonoscopy because of stenosis or obstruction of the colon.
- Exposure to ionizing radiation is a potential disadvantage of CTC.
- Radiation dose associated with CTC is higher with the use of multi-slice scanner and increases with dual positioning.
- Radiation exposure is higher for females than for males.
- MRI-based colonography that excludes the risk of ionizing radiation could become more attractive than CTC in the future.

The American College of Radiology Imaging Network (ACRIN) has announced that it will be coordinating a study to compare the effectiveness of state-of-the-art CT colonography to colonoscopy. The ACRIN National CT Colonography Trial is projected to enroll more than 2,300 patients at 15 sites in the U.S.

Source: American College of Radiology, <www.acrin.org/ 6664_brochure.html>.

More recently, in November 2004, CCOHTA completed a pre-assessment of the literature on CTC.[75]

CCOHTA reported on the findings of a meta-analysis of CTC on colorectal polyps published in the *American Journal of Roentgenology* in December 2003.[76] Specificity and sensitivity of CTC were found to be high for polyps 10 millimetres or larger. CCOHTA also reported on the findings of cost studies and patient preferences studies. CTC was found to be less cost-effective than colonoscopy. Although less cost-effective and less accurate in the detection of small polyps (<10 millimetres) than colonoscopy, one advantage of CTC might be a lower level of inconvenience for patients. In most studies reviewed by CCOHTA and published over the period 2001 to 2003, patients' acceptance and preference were greater for CTC than for colonoscopy.

Another study conducted in the Netherlands and published in the November 2004 issue of *Radiology* prospectively evaluated short- and mid-term preference of CTC relative to colonoscopy in patients with increased risk for colorectal cancer because of a personal or family history of colorectal pylops or cancer. In the study, patients underwent CTC prior to scheduled colonoscopy. Patient experience and preference were assessed both immediately after the examinations and five weeks after the examinations. Fewer patients experienced severe or extreme pain during CTC (3%) than during colonoscopy (34%). Directly after both examinations, 71% of patients preferred CTC, but this preference decreased to 61% five weeks later. Implementation of CTC in colorectal cancer prevention programs may result in better attendance rates than those attained with colonoscopy, because the patients' discomfort is considerably less.[74]

For both CTC and colonoscopy, bowel preparation was cited by patients as a severe burden for the examinations. Early feasibility studies indicate that a bowel preparation consisting of a low-fibre diet and ingestion of contrast agents is sufficient for CTC. More limited bowel preparation would further increase patients' preference for CTC.[74] However, because of the disadvantages noted in the literature review by the Ontario Ministry of Health and Long-Term Care, CTC will most likely not be covered by provincial and territorial health insurance plans in Canada, even with increased patient preference.

MAGNETIC RESONANCE IMAGING (MRI)

MRI was first applied clinically in 1978 when two prototype clinical medical resonance imagers were installed in the UK.[77] In Canada, the first three MRI scanners were installed in late 1982 and early 1983, at St. Joseph's Hospital, London, University of British Columbia Hospital, Vancouver, and Princess Margaret Hospital, Toronto. At that time, MRI was primarily used for research. In 1985, St. Joseph's hospital became the first Canadian hospital to utilise MRI primarily for clinical services.[58, 78, 79]

According to the Health Services Access Survey conducted by Statistics Canada in 2003, it is estimated that approximately 892,000 Canadians aged 15 and over (3.4% of Canadians age 15+) had a non-emergency MRI scan in the past 12 months. About 35% were scans of joints and/or fractures, followed by tests for neurological or brain disorders (14%).[ii] As with CT scans, most patients (90%) underwent their MRI tests in hospitals or public clinics.[41]

Magnetic resonance imaging (MRI) uses three components to create detailed images of the inside of the body—hydrogen atoms in the tissues, a strong external magnet and intermittent radio waves. In a strong magnetic field, atoms tend to line up like iron filings around a bar magnet. A pulse of radiofrequency radiation (like that used in a microwave oven) disturbs that alignment. When the atoms return to their former state, they emit the energy from the radiation that reveals their molecular environment and spatial location. For example, the nucleus of a hydrogen atom in a molecule of fat will emit a different signal than a hydrogen atom in the protein of muscle.

MRI can provide detailed images of all tissues except bone (where the protons are tightly bound and less susceptible to magnetic influence). Images are created using algorithms similar to those used in CT. MRI techniques can be enhanced by injected agents such as gadolinium chelates, much as radiography is enhanced by contrast materials.

Evolution of the Technology

MRI uses radiofrequency waves and a strong magnetic field to provide a picture of internal organs and tissues. The technology is used in the diagnosis of a broad range of pathologic conditions in all parts of the body, including cancer, heart and vascular disease, stroke and joint and musculoskeletal disorders.[80]

All MRI systems consist of certain basic components, regardless of their size, type or level of sophistication.[79]

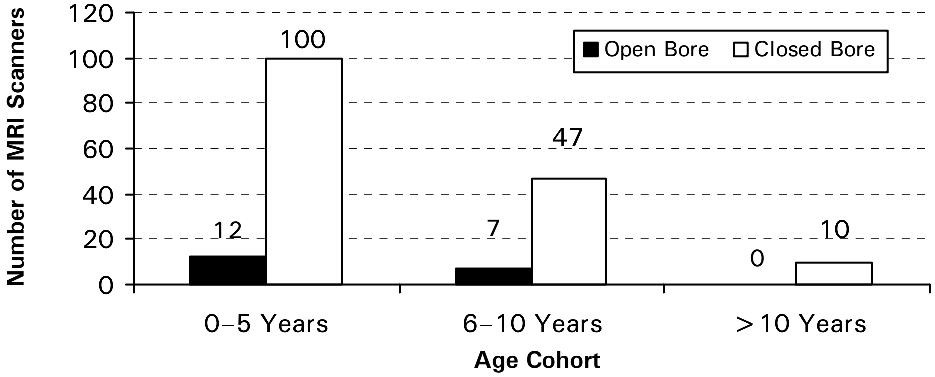
1. Magnet—generally surrounds the subject; generates a homogeneous magnetic field.
2. Radiofrequency coils and receiver—including the source of radiofrequency signals used to excite the nuclei of atoms (transmitter) and the unit to detect the energy emitted from the nuclei upon relaxation when returning to their previous state (receiver).
3. Computer and display system—convert the radiofrequency signals produced by the nuclei into an image.

[ii] The reason for the MRI was unspecified in 35% of all cases.

The conventional MRI unit has a closed cylindrical magnet in which the patient must lie totally still for several seconds at a time, and consequently may feel "closed-in" or truly claustrophobic. The "open-bore" systems are wider and shorter and do not fully enclose the patient. Some newer units are open on all sides.[80]

As of January 1, 2005, there were 176 MRI scanners installed in Canada, 19 of which were open-bore. Most scanners were installed within the last five years. Among the 159 closed-bore scanners, 64% were 5 years old or less, while 30% were from 6 to 10 years old, and the remaining 6% were older than 10 years. A slightly lower proportion of the 19 open-bore scanners were 5 years old or less (63%), while 37% were between 6 and 10 years old.

Figure 5. Number of Magnetic Resonance Imaging (MRI) Scanners, by Age Cohort, by Technology, Canada, as of January 1, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

The magnetic field strength of the magnet is measured in units of Tesla. The magnetic field strength of a Tesla is about twenty thousand times the Earth's magnetic field.[50] In the 1990s, MRI magnets available for clinical applications had a maximum field strength of 2 Tesla. Higher field strengths were generally used for research purposes.[79] In 2001, 3-Tesla MRIs were introduced for clinical applications in the U.S.[81] Higher field strengths, such as 1.5 Tesla or higher, generally mean better images and faster acquisition time, with the capability of doing spectroscopy and new applications such as functional imaging, angiography, spectroscopy and molecular imaging.[53, 81] Members of the MRI and CT Expert Panel of Ontario's Wait Time Strategy stated that the minimum standard for MRI scanners in Ontario hospitals should be a 1.5 Tesla magnet, with the capacity of doing MRI angiography and perfusion studies.[53]

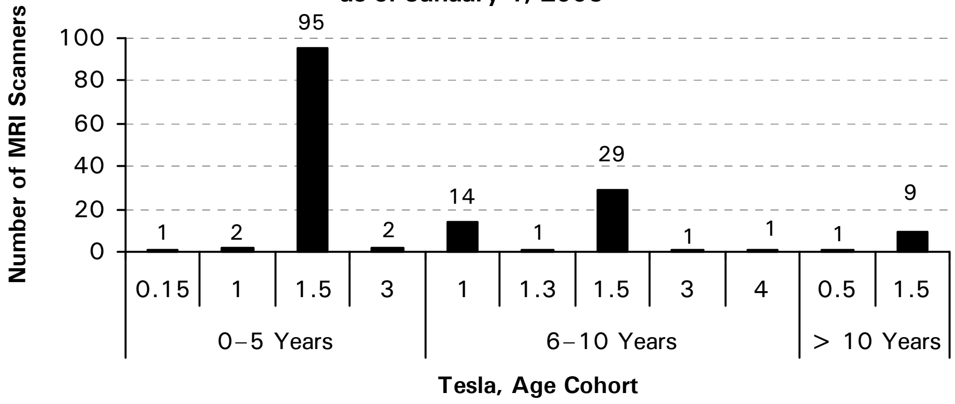
The field strength is not the only factor in determining performance. For conventional applications, current technology has narrowed the gap between lower and higher field systems with new pulse sequences and improved coils for increased signal-to-noise ratio (higher SNR means nicer-looking images) and spatial resolution (allows differentiation between adjacent structures of the body) for routine imaging, and more sophisticated gradient designs to improve field strength per metre for faster echo times, smaller fields of view and thinner slices. Low- and mid-field systems have gained diagnostic recognition while competing with high-field systems for image quality. Stand-up units and dedicated extremity systems for spine and joint studies have gained recognition in the U.S. orthopedic community.[82]

In the early 1980s, only MRI scanners with 0.5 Tesla and below were available for clinical application. In the mid- to late-1980s, the international trend was towards the acquisition of the higher-field strength systems (1.5 Tesla). However, there was a reversal of the trend in the early 1990s, when an increasing proportion of scanners with lower-field strength were installed in many countries, with the exception of Canada.[79]

As of January 1, 2005, 145 of the 175 MRI scanners installed[iii] in Canada, for which a field strength was provided in the survey data, had a field strength of 1.5 Tesla or higher (83%). By comparison, only 61% of all MRI scanners in the U.S. in 2004 had such high field strength. However, in the U.S., more than half of the scanners are installed in non-hospitals, and these tend to have lower-field strength. In American hospitals, 80% of all scanners had a field strength of 1.5 Tesla or higher,[83] similar to the proportion in Canadian hospitals (86%). In Canada, 18 of the 28 scanners installed in clinics had a magnetic field strength of 1.5 Tesla (64%), while 6 scanners had 1 Tesla magnets (21%).

Of the 156 closed-bore MRI scanners installed in Canada, 137 have a field strength of 1.5 Tesla or higher (88%). By contrast, only 8 of the 19 open-bore scanners have a field strength of 1.5 Tesla or higher (42%).

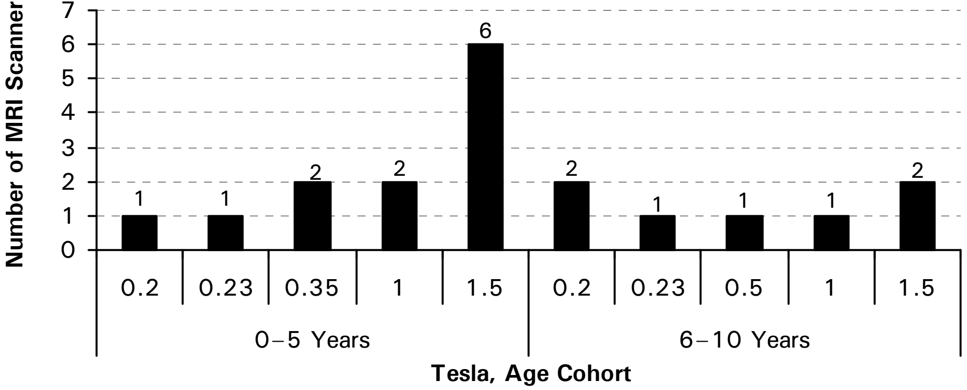
Figure 6. Number of Magnetic Resonance Imaging (MRI) Scanners and Field Strength, by Age Cohort, Closed Bore, Canada, as of January 1, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

[iii] A facility with one closed-bore MRI scanner did not identify MRI field strength. This reduces the total number of MRI machines by one for this analysis.

Figure 7. Number of Magnetic Resonance Imaging (MRI) Scanners and Field Strength, by Age Cohort, Open Bore, Canada, as of January 1, 2005



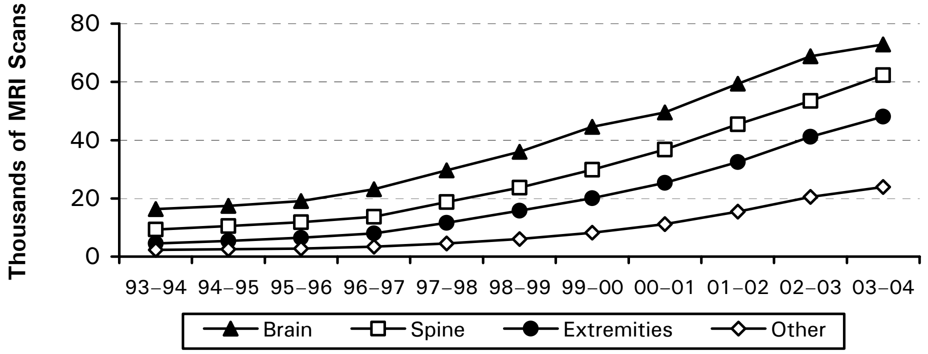
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Magnetic resonance spectroscopy (MRS) is an option on high-field-strength MRI systems available from several manufacturers. MRS measures chemical entities at the cellular level. It provides data on tissue biochemistry. For example, in the management of prostate cancer, MRS has been used to measure cellular metabolites, including citrate, creatine and choline. Citrate has been suggested as a marker for discriminating between areas with prostate cancer and surrounding disease-free tissue. CCOHTA has found the accuracy of MRS and MRI used in combination for the diagnosis of prostate cancer to be better than that of MRI alone, though the improvement seems to be modest.[84]

Clinical indications for cardiovascular magnetic resonance in ischemic heart disease include regional and global function, perfusion, viability and coronary angiography.[50] In 2003, the Medical Advisory Secretariat (MAS) of the Ontario Ministry of Health and Long-Term Care conducted a literature review of functional cardiac MRI in the assessment of viability and perfusion. The MAS concluded that there is some evidence that the accuracy of functional cardiac MRI compares favourably with alternate imaging techniques (such as SPECT, PET and echocardiography) for the assessment of myocardial viability and perfusion.

As in other parts of the world, available provincial administrative data suggest that scan rates have increased in recent years, and applications of the technology have changed.[85, 86] For example, researchers from Ontario's Institute for Clinical Evaluative Sciences (ICES) showed that the number of outpatient MRI scans in the province increased between 1993–1994 and 2003–2004, as indicated in Figure 8.

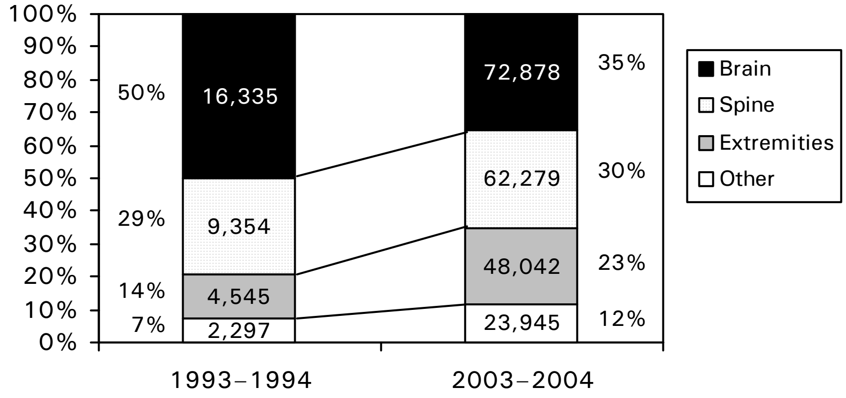
Figure 8. Number of Outpatient Magnetic Resonance Imaging (MRI) Scans, by Body Site, Ontario, 1993–1994 to 2003–2004



Source: *Access to Health Services in Ontario: ICES Atlas* (Toronto: Institute for Clinical Evaluation Sciences, 2005).

Note:
"Other" includes MRI scans for abdomen, pelvis, thorax and neck.

Figure 9. Distribution of Outpatient Magnetic Resonance Imaging (MRI) Scans, by Type, Ontario, 1993–1994 and 2003–2004



Source: *Access to Health Services in Ontario: ICES Atlas* (Toronto: Institute for Clinical Evaluation Sciences, 2005).

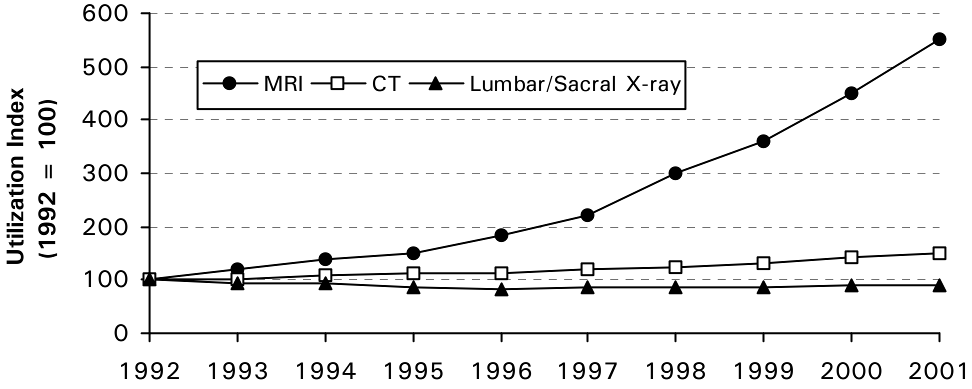
Although scanning of the brain remains the most frequent type of MRI, its share of total MRI scans diminished from 50% to 35% over the decade. Scans of the spine and the extremities represented respectively 30% and 23% of all outpatient MRI scans in Ontario in 2003–2004, while 12% of the scans were on other areas such as abdomen, pelvis, thorax and neck (Figure 9).[8]

Note:
"Other" includes MRI scans for abdomen, pelvis, thorax and neck.

While the share of scanning of the brain has declined in Ontario, the proportion still remains higher than in the U.S. In 2003, scanning of the brain was the second most frequent type of MRI procedure in the U.S. (24%), after procedures on the spine (27%).[83]

MRIs of the spine are the second most common type of outpatient MRI scan in Ontario. The utilization of MRIs of the spine increased more markedly than the utilization of CT scans of the spine over the period 1992 to 2001 in Ontario (Figure 10). The rate of utilization of outpatient MRI scans of the spine per 100,000 people aged 20 and up increased by 450%, while the rate of utilization of CT scans of the spine increased by 51%. Meanwhile, the rate of utilization of plain X-ray of the lumbar spine diminished by 11%.

Figure 10. Growth in Rate of Utilization of Radiological Examinations of the Spine, Ontario, 1992 to 2001



Source: *Investigation of Acute Lower Back Pain in Ontario: Are Guidelines Being Followed?* (Toronto, Institute for Clinical Evaluation Sciences, 2004).

Note:
Data are age-sex adjusted.

POSITRON EMISSION TOMOGRAPHY (PET) AND PET/CT

Positron emission tomography (PET) scanners create images by detecting subatomic particles emitted from a tracer radioactive substance injected into a patient. When the radionuclide decays, it emits positrons (positively charged electrons also called "beta plus" (ß+) particles, which, when they collide with an electron, generate energy in the form of two gamma rays emitted at 180 degrees to each other. The detection of these gamma rays permits the creation of an image of the distribution of the radionuclide, slice by slice, within certain organs of the body. The sectional images that are created can be used to evaluate some functions in the body.

Positron emission tomography (PET), a type of nuclear medicine examination now most commonly used to detect cancerous tumours, some brain disorders and diseases of the heart and other organs by creating images that measure biochemical processes in the body, was introduced in the early 1970s.[87] A decade later, PET still remained a low-resolution, low-sensitivity, single-slice design. An important advance occurred in the late 1980s with the introduction of 3-D PET for brain imaging. Successful implementation of 3-D methodology for whole-body imaging followed in the mid-1990s.[88] Despite technical improvements and an increasing interest in its clinical uses, PET has evolved slowly as a clinical tool relative to other imaging modalities, such as CT or MRI. The fact that PET was initially developed for research purposes and that it is an expensive technology requiring access to a nearby cyclotron to produce short-lived radioactive molecules (positron emitting tracers) were important barriers limiting PET's acceptance and use in clinical medicine.[89] However, an increasing number of PET scanners were installed in industrialized countries in the late 1990s, particularly the U.S., Germany and Japan.[88] By the year 2000, the U.S. had more than 300 PET centres, while Germany had more than 60. Japan had about 40 PET scanners. Small and medium-sized European countries generally had only a few PET scanners, with the exception of Belgium, which had nine. Larger European countries, such as the UK, Russia, France and Italy, each had fewer than a dozen scanners. Canada had eight PET scanners.[47] A recent development involves combining functional and anatomical imaging from PET and CT in the same display. The prototype PET/CT was installed at the University of Pittsburgh PET Facility in 1998 for clinical evaluation. The first commercial PET/CT scanner was installed in 2001.[88]

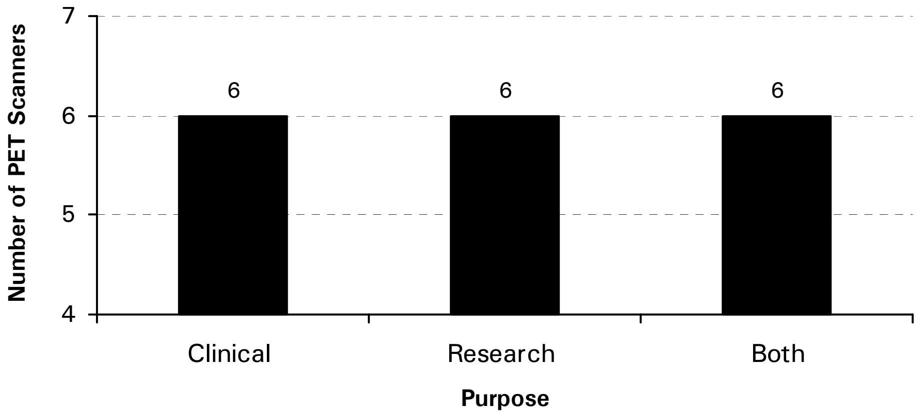
PET scanning is extensively used in the U.S. In 2003, 1,500 hospital and non-hospital sites in the U.S. offered PET imaging. Nearly 900 of these sites provided the services in a mobile van, typically for one to two days a week. In 2004 only, there were 296 PET scanners sold in the U.S. (235 scanners sold in the rest of the world). Some 700,000 PET procedures were performed in the U.S. in 2003 (an increase of about 50% over 2002). Oncology studies comprise 93% of PET studies, with cardiology and neurology applications comprising the remaining 7%. PET/CT scanners have become the preferred technology for PET imaging. In 2003, PET/CT comprised 79% of total PET billings in the U.S. While PET/CT scanners represented about 50% of all PET scanners installed in 2003, at least 90% of the PET units planned for purchase in the U.S. over the next three years will be PET/CT scanners.[90, 91]

As of January 1, 2005, 18 PET scanners, including 6 PET/CT scanners, were installed in Canada: 15 can accommodate full-body scanning while the other 3 are small aperture that can accommodate only the head. Of the whole-body scanners, 13 were installed in the last five years. Among all scanners installed, six were reported to be used exclusively in clinical practice and six exclusively in research. Six scanners were used in both clinical practice and research. Only the four most populated provinces had PET scanners: Ontario (eight), Quebec (five), Alberta (three) and B.C. (two).

Figure 11. Number of Positron Emission Tomography (PET) Scanners, by Technology, by Age Cohort, Canada, as of January 1, 2005

Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure 12. Purpose of Positron Emission Tomography (PET) Scanners, Canada, as of January 1, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Widespread clinical implementation and access to PET for routine clinical care in Canada has been delayed by the high capital and operating costs of the equipment[92] and a perceived need to more fully assess its appropriateness for specific clinical applications. A 2001 report by the Agence d'évaluation des technologies et des modes d'intervention de la santé (AÉTMIS) in Quebec found PET to be useful in several areas of oncology, neurology and cardiology and recommended its gradual deployment for specific applications.[47] The Ontario Institute for Clinical Evaluation Sciences (ICES) also published a report on PET assessment in 2001 and suggested that some 24,000 patients with oncologic and seizure disorders might benefit from PET. However, the Ontario study found no evidence of the clinical utility of PET in cardiology and in the diagnosis or symptomatic management of dementia.[48] ICES has since then posted on its Web site regular updates confirming PET's usefulness in oncology. In 2003, the Norwegian Centre for Health Technology Assessment published a report on the clinical use of PET that updated the findings of a report produced four years earlier on behalf of the International Network of Agencies for Health Technology Assessment.[89] The 2003 report summarized the conclusions of recent health technology assessment (HTA) reports and systematic reviews of relevance. The Norwegian Centre reported that PET was found to be more accurate than other diagnostic procedures for several indications in oncology, mainly in diagnosing non–small cell lung cancer and solitary pulmonary nodules, in staging of Hodgkin's disease, in identifying metastasis from malignant melanoma and colorectal cancer and in finding tumours in the head and neck.[93] Following the report, the Norwegian ministry of health allocated money to establish a PET facility at the National Cancer Hospital. [94] In May 2004, the Ontario Health Technology Advisory Committee endorsed a recommendation from the Provincial PET Steering Committee that any patient in Ontario with a non-biopsiable single pulmonary nodule should be offered a PET scan. Single pulmonary nodules are circumscribed lesions seen on lung imaging and for which there is uncertainty as to whether these are malignant. In some cases these legions cannot be easily biopsied for anatomical reasons or if patients have comorbid conditions that make the biopsy risky.[95]

The new hybrid technology of PET/CT might gain faster acceptance in Canada than PET on its own. A recent document prepared for the Canadian Association of Radiologists identified PET/CT as a driver shaping the future of medical imaging in Canada. It is stated that because PET/CT allows one test to provide both functional and structural images, it may soon replace the diagnostic images obtained from traditional nuclear medicine, which places a radiation source inside the body to produce a functional image.[96] As of January 1, 2005, six PET/CT scanners had been installed in three provinces: Quebec (two scanners), Ontario (three scanners[iv]) and Alberta (one scanner). [62] News releases indicate that additional PET/CT scanners were installed in Ontario, Alberta and B.C. in 2005. A PET/CT scanner was in place and ready for use at the Ottawa Hospital in March 2005. This machine and PET/CT scanners installed one or two years earlier at the Princess Margaret Hospital and the Sunnybrook Regional Cancer Centre in Toronto are available only to people participating in clinical trials to be completed in 2006. If the results of the clinical trials are favourable, Ontario cancer patients will get access to the technology.[97] In June 2005, a PET/CT scanner was installed at the Foothills Medical Centre in Calgary.[98]

[iv] Does not include the PET/CT scanner installed at the Sunnybrook Regional Cancer Centre in 2003. The machine was classified as a CT scanner in the National Survey of Selected Medical Imaging Equipment based on its predominant modality.

In July 2005, the British Columbia Cancer Agency officially opened its PET/CT scanner facility in Vancouver Centre.[99] Other provinces announced their intention to acquire PET/CT scanners. In March 2004, Manitoba announced that a PET/CT will be installed at the planned Institute for Advanced Medicine in Winnipeg.[100] In June 2005, New Brunswick announced its intention to install two PET/CT scanners by September 2006, respectively, at the Dr.-Georges-L.-Dumont Regional Hospital in Moncton and at the Saint John General Hospital.[101] In November 2005, the Quebec ministère de la Santé et des Services sociaux (ministry of health and social services) announced that it is considering installing PET/CT scanners in regional hospitals (Chicoutimi, Gatineau, Rimouski and Trois-Rivières) by 2007.[102]

PICTURE ARCHIVING AND COMMUNICATIONS SYSTEMS (PACS)

With the advent of digital imaging technologies comes the potential to acquire, review, distribute and archive image information electronically. In the late 1970s and early 1980s, the concept of picture archiving and communications systems (PACS) was born.[103] PACS allows images to be stored in a central location (PACS server) and transmitted to any workstation linked to the storage server.

A PACS has many components and involves several related technologies. The general components of a PACS include:

1. Acquisition devices that acquire digital images that are stored by the PACS. There are many modalities that produce images in digital format: for instance, CT, MRI, nuclear medicine cameras and ultrasonography. Most recently, radiography and mammography have made the transition to digital; however, for analog equipment, a digital acquisition device or modality, such as a computed radiography (CR) or digital radiography (DR), is necessary for converting analog images to digital.
2. Image servers (or PACS servers) track all image information, including the locations, attributes and images themselves.
3. Display stations or workstations throughout health facilities allow health professionals to view images.
4. Storage and archive systems provide permanent or long-term storage of radiology images.
5. A communications infrastructure (IT network) provides an electronic medium, allowing the exchange of information.

Other technologies, such as a hospital information system (HIS) or a radiology information system (RIS), are needed for a PACS to be most useful for a radiologist to interpret images. An HIS and RIS contain non-image patient information that is vital to the radiologist when determining the results of the diagnostic exam. However, communication between these systems is not always compatible. PACS uses the standard, called "Digital Imaging and Communications in Medicine" (DICOM), for the transmission and storage of digital images; HISs and RISs use the common standard of Health Level-7 (HL7) for interpreting patient information. International organizations, such as Integrating the Healthcare Enterprise (IHE), are working with health care professionals and industry vendors to promote the coordination of DICOM and HL7 standards to enhance interoperability among health systems.[104, 105, 106, 107]

Integration of non-image data with the digital image data is critical to the efficient function of PACS. Non-image information that identifies the patient (medical record number), the examination (examination identification number), the type of examination (modality and body site imaged), the reason for the study (requisition), etc., is also transmitted to the workstation, along with the digital images. Non-image data belong to the domain of a radiology information system (RIS). An RIS is used to perform functions necessary for the efficient operation of a radiology practice, such as patient registration, ordering of examinations, scheduling and billing. It is also used for the entry, storage and distribution of the radiologist's diagnostic report.[107, 108] In a hospital, the RIS and HIS work together to monitor patient activity throughout the facility.

In addition to an RIS/HIS, other technologies related to PACS can include voice systems, teleradiology and the electronic health record (EHR). Voice systems have two different applications: (i) dictation systems, which allow health professionals to verbally record and store diagnostic reports; and (ii) recognition systems, which translate a radiologist's spoken words into text. Teleradiology is the electronic transmission of radiological images from one location to another for the purpose of interpretation and/or consultation. While preserving and protecting patient privacy, the EHR will enable providers to have timely access to complete and current information on their patients, including medical files, physician appointments, hospital visits, prescriptions, laboratory tests and diagnostic images.[107]

The implementation of a PACS in a single health facility can offer several efficiency gains. However, with the goal of providing better patient care, the implementation of PACS across health regions, a province or territory—or even an integrated system across Canada—creates opportunities for many other applications, such as teleradiology and the EHR, as well as for improving access and reducing wait times for patients.

Benefits of a PACS

A health care facility with a PACS fully integrated with an RIS/HIS can experience several benefits, such as improvement of quality of care, process efficiencies and savings in operating costs. The most obvious benefits are the ability to simultaneously view examinations at different workstations, a reduction in the number of lost films, a reduction in storage space for film and reduced handling of film jackets (folders).

Shorter diagnostic turnaround time reflects efficiency gains from installing a PACS. One facility's experience from switching to digital viewing reduced diagnostic turnaround times (from when the patient had the exam to when a diagnosis is provided) for an abdomen and pelvic CT exam by as much as 85% (3.73 days to 0.56).[109] Another facility experienced similar improvements, from 18 hours to 6 hours or less, allowing patient examinations by CT, MRI, ultrasound and nuclear medicine cameras to increase by 10%.[110] Improvements such as these are clearly beneficial when one considers that patients report average waiting times of 31 and 47 days for non-emergency CT and MRI procedures, respectively, across Canada.[111]

These gains, however, do not simply occur because a PACS is installed. A full transition from film-based imaging to digital, including a change in process, needs to be adopted to gain the most from a PACS. A study conducted in a Baltimore facility reported that prior to implementation of its PACS, it used 59 steps and 11 hospital staff members in processing a single inpatient chest radiograph. After the PACS installation and a reassessment of overall workflow (including the sharing of files electronically to reduce paperwork), the same facility now uses 50 fewer steps and 7 less staff for the same exam.[112] The Baltimore experience showed that these improvements were not simply from installing its PACS; reassessment of workflow and procedures was necessary to complement the PACS and realize the productivity gains.

Telehealth, or, more specifically, teleradiology, are complements to PACS technology—but they do not necessarily have a PACS component or the ability to transmit images from one location to another. Currently across Canada there are many teleradiology systems in place without the ability to share digital images; however, there are several advantages to adding the capacity. Many patients in smaller or remote communities do not have direct access to a specialist or radiologist. The ability to have a diagnostic exam in one facility transmitted to another facility for a specialist or radiologist to view or interpret is beneficial to the patient and the health system. It can save on the cost of shipping film, of sending a specialist to a remote site or even having patients travel to visit specialists in another community.

Canada Health Infoway (or Infoway), whose mission is to accelerate the development of interoperable electronic health information systems across Canada, has a vision for an electronic health record (EHR) in Canada. It includes PACS and the ability to share diagnostic images linked to patients' medical history, saving time and money and ultimately improving the efficiency of the Canadian health care system.

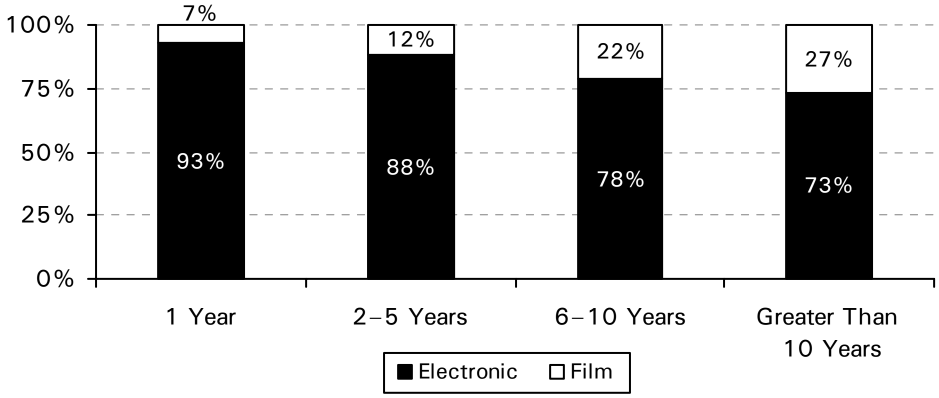
Going Filmless

Implementing a PACS into a health facility requires much preparation and planning, as there are many issues health care managers and facilities need to consider. For instance, the type of PACS hardware and software, IT support, integration with existing medical equipment, departmental viewing options, the cost and staff training. Nevertheless, with EHR seen as the way of the future in Canada and many other parts of the world, many facilities, health regions and provinces and territories are investing in PACS technology.

Switching to filmless operation can sometimes be a difficult sell within a hospital. It requires the support of physicians and clinicians, and staff and clinicians must be trained to use the system. Filmless operations across Canada will require funding from many sources. The vision of the Canadian Association of Radiologists (CAR) for PACS in Canada is to have systems fully implemented for diagnostic imaging in 80% to 90% of Canada's health care facilities and clinics by 2008.[107] In 2004, Prince Edward Island achieved this goal by installing a province-wide PACS/RIS integrated system, at an approximate cost of $5.6 million (or $41 per person).[113] Using P.E.I.'s experience as a baseline, the CAR vision (a fully implemented system across Canada) could cost more than $1 billion.

More and more equipment being installed in Canada can store images in electronic format, and is therefore capable of supporting a PACS. Equipment installed prior to the early 1990s is less likely to have the capability of recording images in an electronic format. However, equipment upgrades and new software can enable older equipment to connect to a PACS. The 2005 National Medical Imaging Equipment Survey, which does not include X-ray machines or ultrasound, indicated that 27% of equipment installed prior to 1995 still used film. By contrast, only 7% of equipment installed in 2004 uses film to record images (Figure 13).

Figure 13. Percentage of Medical Imaging Equipment With Electronic Storage Capacity, by Age Cohort, Canada, as of January 1, 2005



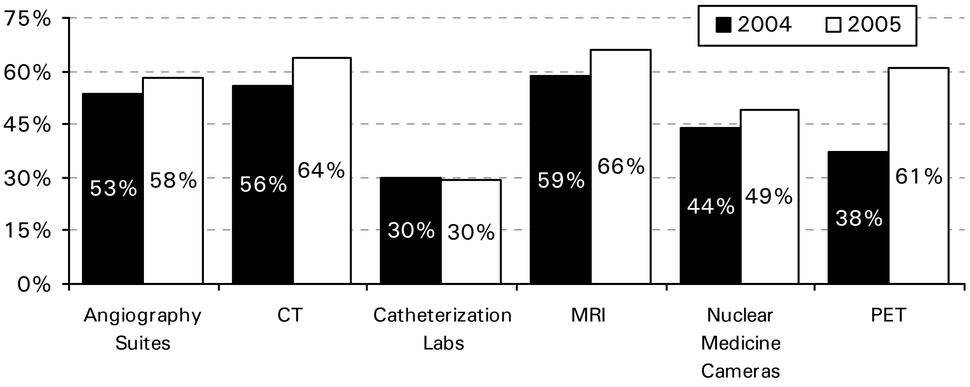
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Since its inception, Canada Health Infoway has invested more than $321 million in 105 projects across Canada relating to telehealth, diagnostic imaging, EHR, infostructure, lab information systems, etc.[114] Two regions in Canada—Thames Valley in Ontario and Fraser Health in B.C.—partnered with Canada Health Infoway in 2003 as part of a $135 million nine-project round of funding to implement filmless diagnostic imaging systems across their respective regions. Implementing these projects across 9 and 12 health care facilities, respectively, required almost two years of planning and preparation. The first hospital in the Thames Valley region went filmless in the fall of 2004, with the last one scheduled for December 2005.[115, 116] The Fraser Health Region's 12 hospitals experienced a similar timeline, with all 12 scheduled for filmless and integrated operation in the spring of 2005.

The single largest Infoway-funded imaging and EHR project to date is an investment of $189 million, which will enable doctors and health professionals to electronically share X-rays, CT and MRI exams across Alberta through the Alberta Electronic Health Record.[117]

Comparing equipment installed in Canada by January 1 of 2004 and 2005 shows a trend towards PACS capabilities, most noticeable in PET scanners, with 61% of PET scanners routing to a PACS in 2005, up from 38% just one year earlier (Figure 14). More than half of the imaging equipment captured in the 2005 survey had images routed to a PACS, up 6% from the previous year (48% to 54%). Further analysis tells us that of the hospitals and free-standing imaging facilities across Canada that have these selected imaging machines, approximately 60% in 2005 are routing images to a PACS. This can include either viewing capabilities in the radiology department and/or viewing capabilities in strategic areas of the health facility. However, 60% is still far from full implementation of PACS and teleradiology access throughout Canada. The percentage is based on facilities that have any of the six types of selected imaging equipment, which account for only about a third of all hospitals and free-standing imaging facilities across Canada, suggesting only a 20% PACS penetration rate across Canada.

Figure 14. Percentage of Medical Imaging Equipment Where Picture Archiving Communications Systems (PACS) Are Available, by Type of Technology, as of January 1, 2004 and 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Facilities implementing PACS are often faced with a daunting task. Some facilities approach it by installing mini-PACS (departmental only) in small strategic areas, while others go with the “big bang” approach and implement facility wide. Regardless of the approach, planning for and installing PACS in health care facilities is a major capital project.[118] Whatever the approach, a successful PACS installation requires planning, phased implementation and an examination of existing workflow practices to maximize the benefits and to ensure successful integration with the least amount of disruption.

REFERENCES

1. World Health Organization, Department of Essential Health Technologies, *Essential Diagnostic Imaging,* [online], from <www.who.int/eht/en/diagnosticImaging.pdf>.
2. K. Iron, R. Przybysz and A. Laupacis, *Access to MRI in Ontario: Addressing the Information Gap* (Toronto: Institute for Clinical Evaluative Sciences, 2003).
3. I. G. Stiell et al., "The Canadian CT Head Rule for Patients With Minor Head Injury," *The Lancet* 357 (May 2001): pp. 1391–1396.
4. D. G. Fryback and J. R. Thornbury, "The Efficacy of Diagnostic Imaging," *Medical Decision Making* 11, 2 (April–June 1991): pp. 88–94.
5. Health Canada, *Guidelines for the Safe Use of Diagnostic Ultrasound* (Ottawa: Health Canada, 2001), [online], cited September 26, 2005, from <www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/radiation/01hecs-secs255/01hecs-secs255_e.pdf>.
6. J. L. Wagner, *Case Study #2: The Feasibility of Economic Evaluation of Diagnostic Procedures: The Case of CT Scanning* (Washington: Office of Technology Assessment, Congress of the United States, April 1981), [online], cited September 26, 2005, from <www.wws.princeton.edu/cgi-bin/byteserv.prl/~ota/disk3/1981/8132/813203.PDF>.
7. G.I. Stiell et al., "Implementation of the Ottawa Ankle Rules," *Journal of the American Medical Association* 271, 11 (March 1994): pp. 827–832.
8. A. Laupacis, M. A. Keller and R. Przybysz, "Chapter 6—CT and MRI Scanning" in *Access to Health Services in Ontario: ICES Atlas* (Toronto: Institute for Clinical Evaluative Sciences, 2005), [online], cited September 26, 2005, from <www.ices.on.ca/file/Access_atlas_Chp6_v5.pdf>.
9. National Cancer Institute of Canada, *Canadian Cancer Statistics 2005* (Toronto, National Cancer Institute of Canada, 2005), [online], cited September 26, 2005, from <www.ncic.cancer.ca/vgn/images/portal/cit_86751114/60/42/393678947ncic_2005stats_en.pdf>.
10. Ontario Association of Radiologists (OAR), *What Is Radiology—Mammography*, [online], last modified 2004, cited September 26, 2005, from <www.oar.info/whatis/mammography.html>.
11. American College of Radiology and The Radiological Society of North America, *Radiology Info—Mammography*, [online], last modified September 2005, cited September 26, 2005, from <www.radiologyinfo.org/content/ mammogram.htm>.
12. American Cancer Society, *Mammograms and Other Breast Imaging Procedures*, [online], last modified September 2003, cited September 26, 2005, from <www.cancer.org/docroot/CRI/content/CRI_2_6X_Mammography_and_other_Breast_Imaging_Procedures_5.asp?sitearea=&level=>.

13. WHO, International Agency for Research on Cancer, Press Release No. 139, *Mammography Screening Can Reduce Deaths From Breast Cancer* (March 19, 2002).
14. J. G. Elmore et al., "Screening for Breast Cancer," *Journal of the American Medical Association* 293, 10 (March 2005): pp. 1245–1256.
15. A. H. Olsen et al., "Breast Cancer Mortality in Copenhagen After Introduction of Mammography Screening: Cohort Study," *British Medical Journal* 330, 220; originally published online 13 Jan 2005.
16. Canadian Cancer Society, *Mammography,* [online], last modified August 2005, cited September 26, 2005, from <www.cancer.ca/ccs/internet/standard/0,2939,3278_10175_275331_langId-en,00.html>.
17. Statistics Canada, "Mammogram Obtained Within the Previous Two Years, by Age Group, Women Age 60 to 69, Canada, Provinces," from the Canadian Community Health Survey, [online], 2003.
18. American Cancer Society, *Detailed Guide: Breast Cancer—Can Breast Cancer Be Found Early?,* [online], last modified June 2005, cited September 26, 2005, from <www.cancer.org/docroot/CRI/content/CRI_2_4_3X_Can_breast_cancer_be_found_early_5.asp?sitearea=>.
19. W. Deck and R. Kakuma, *Mammographie de dépistage: une réévaluation* (Montréal: Agence d'évaluation des technologies et des modes d'intervention en santé [AÉTMIS], 2005).
20. American College of Radiology and The Radiological Society of North America, *Radiology Info—News From the RSNA Journal Radiology—Contrast Mammography Reveals Hard-to-Find Cancers*, [online], last modified June 2005, cited September 26, 2005, from <www.radiologyinfo.org/content/news/target.cfm?ID=147>.
21. J. Parikh, "Digital Mammography: Current Capabilities and Obstacles," *Journal of the American College of Radiology* 2, 9 (September 2005): pp. 759–767.
22. Ontario Ministry of Health and Long-Term Care, The Medical Advisory Secretariat, *Health Technology Scientific Literature Review: Scintimammography* (Toronto: Ministry of Health and Long-Term Care, 2003).
23. S. R. C. Benson et al., "Ultrasound Is Now Better Than Mammography for the Detection of Invasive Breast Cancer," *The American Journal of Surgery* 188 (May 2004): pp. 381–385.
24. American College of Radiology and The Radiological Society of North America, *Radiology Info—News From the RSNA Media Briefing—New Breast-Imaging Technology Could Save More Women's Lives*, [online], last modified June 2005, cited September 26, 2005, from <www.radiologyinfo.org/content/news/target.cfm?ID=196>.
25. C. K. Kuhl et al., "Surveillance of 'High Risk' Women With Proven or Suspected Familial (Hereditary) Breast Cancer" (abstract), *American Society of Clinical Oncology* 22 (2003): p. 2.

26. M. Kriege et al., "Efficacy of MRI and Mammography for Breast-Cancer Screening in Women With a Familial or Genetic Predisposition," *The New England Journal of Medicine* 351, 5 (2004): pp. 427–437.

27. E. Warner et al., "Surveillance of BCRA1 and BCRA2 Mutation Carriers With Magnetic Resonance Imaging, Ultrasound, Mammography, and Clinical Breast Examination," *Journal of the American Medical Association* 292, 11 (September 2004): pp. 1317–1325.

28. W. A. Berg et al., "Diagnostic Accuracy of Mammography, Clinical Examination, US, and MR Imaging in Preoperative Assessment of Breast Cancer," *Radiology* 233, 3 (December 2004): pp. 830–849.

29. F. Sardanelli et al., "Sensitivity of MRI Versus Mammography for Detecting Foci of Multifocal Multicentric Breast Cancer in Fatty and Dense Breasts Using the Whole-Breast Pathologic Examination as Gold Standard," *American Journal of Roentgen Ray Society* 183 (October 2004): pp. 1149–1157.

30. M. J. Yaffe and J. G. Mainprize, "Detector for Digital Mammography," *Technology in Cancer Research & Treatment* 3, 4 (August 2004): pp. 309–324.

31. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Digital Mammography Versus Film-Screen Mammography: Technical, Clinical and Economic Assessments*, Technology Report Issue 30 (Ottawa: CCOHTA, 2002).

32. J. M. Lewin, C. J. D'Orsi and R. E. Hendrick, "Digital Mammography," *Radiologic Clinics of North America* 42 (2004): pp. 871–884.

33. R. L. Morin and A. D. A. Maidment, "Technology Talk—Digital Mammography: Coming of Age," *Journal of the American College of Radiology* 2, 9 (September 2005): pp. 798–801.

34. American College of Radiology and The Radiological Society of North America, *Radiology Info—News From the RSNA Journal Radiology—New Digital Technique Improves Mammography Results*, [online], last modified June 2005, cited September 26, 2005, from <www.radiologyinfo.org/content/news/target.cfm?ID=145>.

35. J. M. Lewin et al., "Dual-Energy Contrast-Enhanced Digital Subtraction Mammography Feasibility," *Radiology* 229, 1 (October 2003): pp. 261–268.

36. M. Koomen et al., "Future Directions in Breast Imaging," *Journal of Clinical Oncology* 23, 8 (March 2005): pp. 1674–1677.

37. E. D. Pisano et al., "Diagnostic Performance of Digital Versus Film Mammography for Breast-Cancer Screening," (to coincide with presentation at a meeting of the America College of Radiology Imaging Network, this article was published online on September 16, 2005 at <content.nejm.org/> and in the October 27, 2005, issue of *The New England Journal of Medicin*e).

38. S. A. Butler et al., "Computer-Aided Detection in Diagnostic Mammography, Detection of Clinically Unsuspected Cancers," *American Journal of Roentgen Ray Society* 183 (November 2004): pp. 1511–1515.

39. American College of Radiology and The Radiological Society of North America, *Radiology Info—News From the RSNA Media Briefing—Computers Significantly Increase Breast Cancer Detection Rate*, [online], last modified June 2005, cited September 26, 2005, from <www.radiologyinfo.org/content/news/target.cfm?ID=197>.
40. E. M. Rohren, T. G. Turkington and R. E. Coleman, “Clinical Applications of PET in Oncology,” *Radiology* 231, 2 (May 2004): pp. 305–332.
41. Statistics Canada, Health Services Access Survey 2001 and 2003.
42. Canadian Heart and Stroke Foundation, *Incidence of Cardiovascular Disease*, [online], cited September 26, 2005, from <ww2.heartandstroke.ca/Page.asp?PageID=33&ArticleID=1077&Src=news&From=SubCategory>.
43. The Medical Advisory Secretariat, Ontario Ministry of Health and Long-Term Care, *Multi-Detector Computed Tomography Angiography for Coronary Artery Disease*, Health Technology Literature Review, completed April 2005, [online], cited September 26, 2005, from <www.health.gov.on.ca/english/providers/program/mas/reviews/docs/multi_angio_0505.pdf>.
44. American Heart Association, *Tests to Diagnose Heart Disease*, [online], cited September 26, 2005, from <www.americanheart.org/presenter.jhtml?identifier=4739>.
45. Canadian Heart and Stroke Foundation, *Coronary Artery Disease*, [online], cited September 26, 2005, from <ww2.heartandstroke.ca/Page.asp?PageID=110&ArticleID=486&Src=heart>.
46. Canadian Coordinating Office for Health Technology Assessment, “Intravascular Coronary Ultrasound (IVUS)” Pre-assessment No. 23 (Ottawa: CCOHTA, 2003), [online], cited September 26, 2005, from <www.ccohta.ca/publications/pdf/266_No23_Intravascular_ultrasound_preassess_e.pdf>.
47. F. P. Dussault, V. H. Nguyen and F. Rachet, *La tomographie par émission de positrons au Québec* (Montréal: Agence d’évaluation des technologies et des modes d’intervention et santé [AÉTMIS], 2001).
48. A. Laupacis, *Health Technology Assessment of Positron Emission Tomography: Executive Summary* (Toronto: Institute for Clinical Evaluative Sciences, 2001), [online], from <www.ices.on.ca/PDFs/TechnicalReports/PET-ExSum.pdf>.
49. American Heart Association, *Computer Imaging/Tomography*, [online], cited September 26, 2005, from <www.americanheart.org/presenter.jhtml?identifier=4554>.
50. M. J. Budoff et al., “ACCF/AHA Clinical Competence Statement on Cardiac Imaging With Computed Tomography and Magnetic Resonance—A Report of the American College of Cardiology Foundation/American Heart Association/American College of Physicians Task Force on Clinical Competence and Training,” *Journal of the American College of Cardiology* 46, 2 (July 2005): pp. 383–402.

51. V. Foerster et al, *CT and MRI for Selected Clinical Disorders: A Systematic Review of Clinical Systematic Reviews,* Technology Report No. 59 (Ottawa: Canadian Coordinating Office for Health Technology Assessment, October 2005), [online], cited October 24, 2005, from <www.ccohta.ca/publications/pdf/322_ctmri_tr_e.pdf>.
52. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Multislice/Spiral Computed Tomography for Screening for Coronary Artery Disease*, Issues in Emerging Health Technologies, Issue 43 (February 2003), [online], cited September 26, 2005, from <ccohta.ca/publications/pdf/211_Ct_Scanning_Cetap_e.pdf>.
53. A. Keller, Ontario Ministry of Health and Long-Term Care, Ontario's Wait Time Strategy, *MRI and CT Expert Panel Phase I Report* (Toronto: Ontario Ministry of Health and Long-Term Care, 2005), [online], cited September 26, 2005, from <www.health.gov.on.ca/transformation/wait_times/wt_reports/mri_ct.pdf>.
54. J. C. Weinreb et al., "ACR Clinical Statement on Noninvasive Cardiac Imaging," *Journal of the American College of Radiology* 2, 6 (June 2005): pp. 471–477.
55. The Medical Advisory Secretariat, Ontario Ministry of Health and Long-Term Care, *Functional Cardiac Magnetic Resonance Imaging in the Assessment of Myocardial Viability and Perfusion—Health Technology Scientific Literature Review* (Toronto: Ontario Ministry of Health and Long-Term Care, 2003), [online], cited September 26, 2005, from <www.health.gov.on.ca/english/providers/program/mas/reviews/docs/card_mri_1103.pdf>.
56. J. P. Borgstede, "ACR Chair's Memo—Cardiac Imaging Is in Your Future," *Journal of the American College of Radiology* 2, 3 (March 2005): pp. 203–204.
57. American College of Radiology, *Acute Chest Pain, Suspected Myocardial Ischemia* (2005), [online], cited September 26, 2005, from <www.acr.org/s_acr/bin.asp?TrackID=&SID=1&DID=11740&CID=1208&VID=2&DOC=File.PDF>.
58. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Selected Health Technologies in Canada*, Technology Brief, Issue 5.2 (March 1993) (Ottawa: CCOHTA, 1993).
59. Statistics Canada, Annual Hospital Statistics Collected Through the *Annual Return of Health Care—Hospitals, Part One, 1983–84* (Ottawa: Statistics Canada, 1984).
60. The Canadian Coordinating Office for Health Technology Assessment, *Selected Health Technologies in Canada,* Technology Brief, Issue 5.3 (January 1994) (Ottawa: CCOHTA, 1994).
61. Canadian Institute for Health Information, National Survey of Selected Medical Imaging Equipment, 2003.
62. Canadian Institute for Health Information, National Survey of Selected Medical Imaging Equipment, 2005.

63. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Multi-Slice/Helical Computed Tomography for Lung Cancer Screening*, Issues in Emerging Health Technologies, Issue 48 (June 2003), [online], cited September 26, 2005, from <ccohta.ca/publications/pdf/213_Ct_Cetap_e.pdf>.

64. European Commission, Directorate-General for the Environment, *Referral Guidelines for Imaging*, Radiation Protection 118, (2000), [online], cited September 26, 2005, from <www.europa.eu.int/comm/environment/radprot/118/rp-118-en.pdf>.

65. D. P. Frush and K. Applegate, "Computed Tomography and Radiation: Understanding the Issues," *Journal of the American College of Radiology* 1, 2 (February 2004): pp. 113–119.

66. J. E. Aldrich and J. Williams, "Change in Patient Doses From Radiological Examinations at the Vancouver General Hospital, 1991–2002," *The Canadian Association of Radiologists Journal* 56, 2 (April 2005): pp. 94–99.

67. M. F. McNitt-Gray and R. L. Morin, "Selecting a New Computed Tomography Scanner: Things to Consider," *Journal of the American College of Radiology* (January 2004): pp. 69–70.

68. Canadian Cancer Society, Colorectal Cancer, [online], last modified July 13, 2005, cited September 26, 2005, from <info.cancer.ca/E/CCE/cceexplorer.asp?tocid=13>.

69. D. Leddin et al., "Canadian Association of Gastroenterology and the Canadian Digestive Health Foundation: Guidelines on Colon Cancer Screening," *Canadian Journal of Gastroenterology* 18, 2 (February 2004): pp. 93-99, [online], cited September 26, 2005, from <www.cag-acg.org/guidelines/pdf/Colorectal%20cancer%20screening%202004.pdf>.

70. American Cancer Society, *Detailed Guide: Colon and Rectum Cancer—Do We Know What Causes Colorectal Cancer?,* [online], last modified May 24, 2005, cited September 26, 2005, from <www.cancer.org/docroot/CRI/content/CRI_2_4_2X_Do_we_know_what_causes_colon_and_rectum_cancer.asp?rnav=cri>.

71. Ontario Ministry of Health and Long-Term Care, Medical Advisory Secretariat, *Computed Tomographic Colonography [Virtual Colonoscopy] Heath Technology Literature Review* (Toronto: Ministry of Health and Long-Term Care, 2003).

72. Canadian Cancer Society, Colorectal Cancer Screening Tests, [online], last modified August 15, 2005, cited September 26, 2005, from <www.cancer.ca/ccs/internet/standard/0,3182,3172_10175_6308814_langId-en,00.html>.

73. American College of Gastroenterology, Colorectal Cancer Screening, [online], cited September 26, 2005, from <www.acg.gi.org/patients/gihealth/colon.asp>.

74. R. E. Van Gelder et al., "CT Colonography and Colonoscopy: Assessment of Patient Preference in a 5-week Follow-up Study," *Radiology* 233, 2 (November 2004): pp. 328–337.

75. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Virtual Colonoscopy,* Pre-assessment No 39 (November 2004), [online], cited September 26, 2005, from <www.ccohta.ca/publications/pdf/300_No39_virtualcolonesocpy_preassess_e.pdf>.

76. J. Sosna et al., "CT Colonography of Colorectal Polyps: A Metaanalysis," *American Journal of Roentgenology* 181, 6 (December 2003): pp. 1593–1598.

77. E. P. Steinberg, J. E. Sisk and K. E. Locke, "The Diffusion of Magnetic Resonance Imagers the United States and Worldwide," *International Journal of Technology Assessment in Health Care* 1, 3 (1985): pp. 499–514.

78. R. N. Rankin, "Magnetic Resonance Imaging in Canada: Dissemination and Funding," *Canadian Association of Radiologists Journal* 50, 2 (April 1999): pp. 89–92.

79. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Magnetic Field Strength Issues in Magnetic Resonance Imaging (MRI)* (Ottawa: CCOHTA, 1993).

80. American College of Radiology and The Radiological Society of North America, *Radiology Info—MR Imaging (MRI) Body*, [online], last modified June 21, 2005, cited September 26, 2005, from <www.radiologyinfo.org/content/mr_of_the_body.htm>.

81. Comité d'évaluation et de diffusion des innovations technologiques (CEDIT), Les recommandations IRM 3 Tesla, réf. 04.08/Av1/04, [online], cited September 26, 2005, from <cedit.aphp.fr/servlet/siteCedit?Destination=reco&numArticle=04.08/Av1/04>.

82. C. M. Carroll-Callahan and L. A. Andersson, "MRI: Are You Playing Your System Like a Fiddle or a Stradivarius?—Where We Are Headed and How to Keep Up," *Radiology Management* (March/April 2004): pp. 36–41.

83. Information Services for the Health Care and Scientific Markets, Inc., *Benchmark Report MRI 2004* (Des Plaines, Illinois: IMV Medical Information Division, Inc., 2004).

84. The Canadian Coordinating Office for Health Technology Assessment (CCOHTA), *Magnetic Resonance Spectroscopy (MRS) in the Management of Localized Prostate Cancer*, Emerging Technology List, No 17 (September 2003), [online], cited September 26, 2005, from <www.ccohta.ca/publications/pdf/152_No17_mrs_etech_e.pdf>.

85. Information Services for the Health Care and Scientific Markets, IMV Medical Information Division, Inc., *Latest IMV Study Shows MRI Clinical Utilization Expanding* (news release) (April 2005), [online], cited September 26, 2005, from <www.imvlimited.com/PDF/2005/MID/Press%20Release/MRI04%20Release%20April05.pdf>.

86. England Department of Health, *Imaging and Radiodiagnostics, NHS Organisations in England, 2000–01 to 2004–05*, [online], last modified September 30, 2005, cited September 30, 2005, from <www.performance.doh.gov.uk/hospitalactivity/data_requests/imaging_and_radiodiagnostics.htm>.

87. G. Robert and R. Milne, “Positron Emission Tomography: Establishing Priorities for Health Technology Assessment,” *Health Technology Assessment* 3, 16 (July 1999): pp. 1–54.

88. D. W. Townsend, “From 3-D Positron Emission Tomography to 3-D Positron Emission Tomography/Computed Tomography: What Did We Learn?” *Molecular Imaging and Biology* 6, 5 (2004): pp. 275–290.

89. E. Adams et al., On behalf of INAHTA, *Positron Emission Tomography: Experience With PET and Synthesis of the Evidence* (Stockholm: International Network of Agencies for Health Technology Assessment (INAHTA), 1999).

90. Information Services for the Health Care and Scientific Markets, IMV Medical Information Division, Inc., *Latest IMV PET Census Shows Fast Growth in PET/CT Installations*, (news release) (November 2004), [online], cited September 26, 2005, from <www.imvlimited.com/mid/pdf/News/1104/PET03%20ReleaseV2-Nov%202004.pdf>.

91. Bio-Tech Systems, Inc. (BTSI), *Report 220: Market for PET Radiopharmaceuticals and PET Imaging*, (news release) (June 19, 2005), [online], cited September 26, 2005, from <www.biotechsystems.com/newsletters/Newsletter-PET_Report.pdf>.

92. Provincial and Territorial Ministers of Health, *Understanding Canada’s Health Care Costs—Final Report* (August 2000), [online], cited September 26, 2005, from <www.health.gov.on.ca/english/public/pub/ministry_reports/ptcd/ptcd_doc_e.pdf>.

93. B. Morland, *Positron Emission Tomography (PET)—Diagnostic and Clinical Use*, (Oslo: SMM, The Norwegian Centre for Health Technology Assessment, 2003).

94. B. Morland, The Norwegian Centre for Health Technology Assessment, *Policy implementation of PET in Norway*, Presentation at the 1st Annual Meeting of Health Technology Assessment International, Krakow, Poland, May 30 to June 2, 2004, [online], cited September 26, 2005, from <www.kunnskapssenteret.no/filer/MOR_Krakow_PET.pdf>.

95. Ontario Ministry of Health, Ontario Health Technology Advisory Committee (OHTAC), *Indication for Positron Emission Tomography [PET] Imaging of a Single Pulmonary Nodule [SPN] (*May 2004), [online], cited September 26, 2005, from <www.health.gov.on.ca/english/providers/program/mas/reviews/docs/recommend_pet_spn_051204.pdf>.

96. L. Currey, CurryCorp Inc., *Imaging the Future* (Ottawa: The Canadian Association of Radiologists, 2004).

97. H. Sokoloff, “Provincial Delays Slow Tests of PET-CT Technology,” *The Ottawa Citizen*, March 16, 2005.

98. Calgary Health Region, *New PET Scanner a ‘Huge Boost’ for Cancer Patients*, (news release) (June 29, 2005), [online], cited September 26, 2005, from <www.crha-health.ab.ca/newslink/nl_062905petscanner.html>.

99. British Columbia Ministry of Health, *New Media Technology Advances Patient Care*, (news release) (July 25, 2005), [online], cited September 26, 2005, from <www.bccancer.bc.ca/ABCCA/NewsCentre/2005/pet.htm>.

100. Manitoba Government, *Canada and Manitoba Provide $32.5 Million for International Centre of Medical Research Excellence in Winnipeg*, (news release) (March 17, 2004), [online], cited September 26, 2005, from <www.gov.mb.ca/chc/press/top/2004/03/2004-03-17-02.html>.
101. New Brunswick Government, *PET/CT Scanners for Dr-Georges-L.-Dumont and Saint John Regional Hospitals*, (news release) (June 13, 2005), [online], cited September 26, 2005, from <www.gnb.ca/cnb/news/hw/2005e0733hw.htm>.
102. Gouvernement du Québec*, Le ministre Philippe Couillard annonce une forte accélération du déploiement de la tomographie par émission de positrons*, (news release) (November 14, 2005), [online], cited November 14, 2005, from <communiques.gouv.qc.ca/gouvqc/communiques/GPQF/Novembre2005/14/c4748.html>.
103. Editorial, "Some Historical Remarks on Picture Archiving and Communication Systems," *Computerized Medical Imaging and Graphics* 27 (2003): pp. 93–99.
104. E. Samei et al., AAPM/RSNA Tutorial on Equipment Selection: PACS Equipment Overview—General Guidelines for Purchasing and Acceptance Testing of PACS Equipment—*Radiology Society of North America (RSNA)* 24, 1 (January–February 2004): pp. 313–334.
105. Integrating the Healthcare Enterprise (IHE), [online], <www.ihe.net>.
106. C. Creighton, A Literature Review on Communication Between Picture Archiving and Communication Systems and Radiology Information Systems and/or Hospital Information Systems, *Journal of Digital Imaging* 12, 3 (August 1999): pp. 138–143.
107. The Canadian Association of Radiologists, *PACS for Canadians—Canadian Association of Radiologists—PACS Position Paper,* The Canadian Radiological Foundation (October 2003), [online], from <www.car.ca/politics/equipment/PACS.pdf>.
108. R. Khorasani, "Is PACS Worth the Investment? It Depends on Your Perspective," *Journal of The American College of Radiology* (April 2004): pp. 284–285.
109. A. Mehta et al., "Do Picture Archiving and Communication Systems Improve Report Turnaround Times?" *Journal of Digital Imaging* 13, 2, Suppl 1 (May 2000): pp. 105–107.
110. P. Lawrence, "Preparing a Cultural Strategy for PACS," *Radiology Management* (January-February 2005): pp. 21–29.
111. Canadian Institute for Health Information (CIHI), *Medical Imaging in Canada, 2004* (Ottawa: CIHI, 2005).
112. E. Siegel and B. Reiner, "Work Flow Redesign: The Key to Success When Using PACS," *American Journal of Radiology* 178 (March 2002): pp. 563–566.
113. G. Wiley, "Province-Wide PACs: Prince Edward Island, Canada," *Journal of Imaging Technology Management* (September 2005), [online], from <www.imagingeconomics.com/library/200405-18.asp>.

114. Canada Health Infoway Inc., *Creating Healthy Connections, Canada Health Infoway Inc. Annual Report* (2004–2005), [online], from <www.infoway.ca/pdf/CHI-fullAR-en.pdf>.

115. Canada Health Infoway Inc., *Canada Health Infoway Partners With Hospitals in British Columbia and Southwestern Ontario to Accelerate Access to Diagnostic Imaging Systems*, (news release) (July 8, 2003), [online], from <www.infoway-inforoute.ca/news-events/index.php?loc=20030708&lang=en>.

116. Connecting the Continuum of Care, *Southwest Ontario Digital Imaging Network Project* Overview, [online], from <www.c3project.ca/di/overview.pdf>.

117. Fraser Valley Health, News Release—*New Partnership Helps Support Regional Diagnostic Imaging System* (July 8, 2003), [online], from <www.fraserhealth.ca/News/NewsReleases/2003Archive/2003-07-08.htm>.

118. Canada Health Infoway Inc., Press Release—*$189 Million to Digitize X-rays, CT and MRI Scans*, (Edmonton: July 25, 2005), [online], from <www.infoway-inforoute.ca/news-events/index.php?loc=20050725&lang=en>.

119. C. A. Vandebeek and P. Brownrigg, Fraser Health PACS Project: Learning From Experience in Planning—*Healthcare Quarterly* 4, 1 (2005): pp. 104–108.

Chapter 2

Imaging Technologies—Supply and Costs

The appropriate numbers and types of equipment needed to supply Canadians with medical imaging services are hotly debated. This chapter addresses the availability of medical imaging equipment and how much it costs. The supply of machines needs to be considered in the context of many factors. For example, an important factor is how imaging machines are used to provide care. Other factors include the number and mix of medical imaging professionals, as well as the context in which imaging technologies are used.

HOW MANY ARE THERE?

Many different kinds of imaging machines are used in clinical practice today, from new equipment that is still in development to well-established technologies. Overall, we know more about the numbers and distribution of some newer technologies than about several of the more common ones, such as X-ray and ultrasound.

CIHI's recent National Survey of Selected Medical Imaging Equipment tracked six types of imaging equipment. As of January 1, 2005, it counted:

- 659 nuclear medicine cameras;
- 176 magnetic resonance imaging (MRI) scanners;
- 361 computed tomography (CT) scanners;
- 105 cardiac catheterization laboratories;
- 173 angiography suites; and
- 18 positron emission tomography (PET) scanners.

These imaging technologies were introduced into clinical practice at different times, and their diffusion rates vary. For example, the number of CT and MRI scanners has grown significantly since they were introduced (in 1973 and 1982 respectively). Figure 15 reports that from 1990 to 2005, the number of CT scanners has grown by 163 (82%), whereas the number of MRIs has grown by 157 (826%). Since 1997, more MRI scanners than CT scanners were installed.

What accounts for the variations in the speed with which different innovative technologies are adopted and diffused? A number of factors may be involved, including the functional capability of the innovation, usefulness and cost of the new equipment, practice patterns, health policies, funding mechanisms and attitudes toward new technologies.[1–3]

About the National Survey of Selected Medical Imaging Equipment

Over a period of many years, the Canadian Coordinating Office for Health Technology Assessment (CCOHTA) conducted surveys on the number, distribution and key characteristics of selected imaging technologies in Canadian hospitals. Following discussions with CCOHTA, CIHI has conducted similar surveys since 2003. Basic information on the CIHI surveys is provided below. For more information, see CIHI's Web site, at www.cihi.ca.

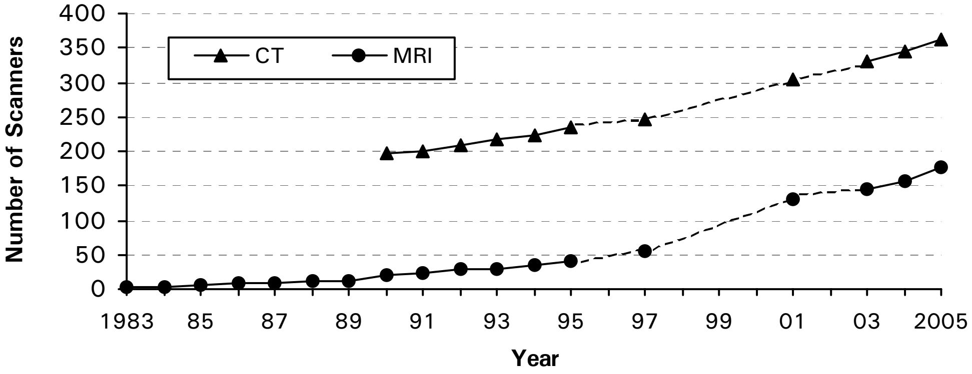
What's Included: The CIHI 2003, 2004 and 2005 surveys tracked data on equipment installed in Canadian hospitals and free-standing imaging facilities (sometimes also called "non-hospital," "community-based" and/or "private" facilities) as of January 1. The imaging equipment covered by the surveys (angiography suites, catheterization labs, CT scanners, MRI scanners, nuclear medicine cameras and PET scanners) was the same as that surveyed by CCOHTA in 2001.

The Survey Process: CIHI retained the services of ProMed Associates Ltd. to coordinate data collection. ProMed contacted health regions and hospitals and relevant free-standing imaging facilities across Canada. Various medical and technical organizations, and provincial and territorial ministries of health, were asked to encourage participation in the survey. Most respondents completed the survey through a bilingual Web site. To maximize response rates, ProMed Associates Ltd completed several rounds of follow-up with respondents.

Validating the Results: To ensure that the coverage was as complete as possible, responses to the 2005 survey were cross-checked against results from CIHI's 2004 survey, lists provided by medical imaging technology manufacturers, published lists of equipment (for example, research reports and health directories) and data reported by hospitals and health regions to CIHI's Canadian MIS Database. Provincial and territorial ministries of health were also asked to validate overall equipment counts.

In addition, ProMed Associates Ltd reviewed information submitted and contacted participants for follow-up where required.

Figure 15. Numbers of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Scanners, Canada, 1983 to 2005



Sources: OECD Health Data 2002, OECD (for the years 1983 to 1990); National Inventory of Selected Imaging Equipment, Canadian Coordinating Office for Health Technology Assessment (for the years 1991 to 2001); National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information (for the years 2003 to 2005).

Notes:

a) The numbers of MRI and CT scanners in free-standing imaging facilities were imputed for years prior to 2003 based on data collected in the 2003 National Survey of Selected Medical Imaging Equipment.

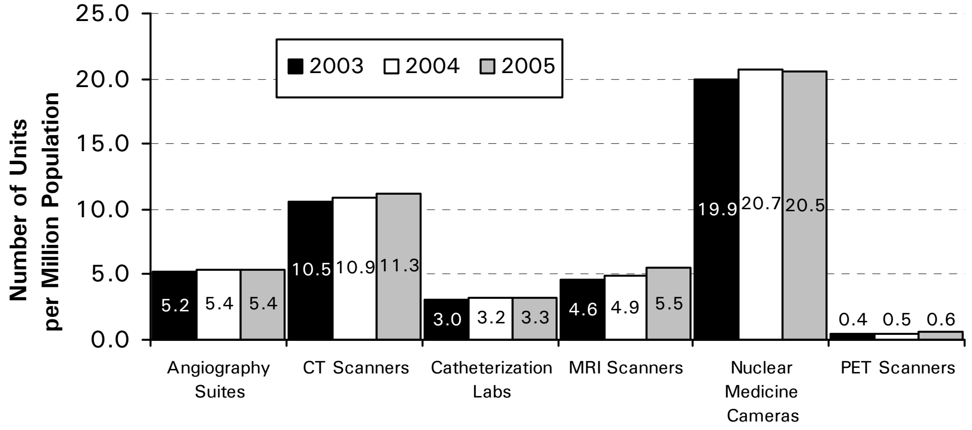
b) Inventories were not conducted annually. A dotted line is drawn between data points spanning two years or more.

c) Quebec data were incomplete for 2000; therefore, all 2000 data are excluded.

THE SUPPLY OF IMAGING TECHNOLOGIES IN CANADA

Most Canadians receive imaging services in the province or territory where they live, although some travel within their jurisdiction or to other parts of the country for care. All provinces now have nuclear medicine cameras, angiography suites, CT scanners and MRI machines, as well as other imaging technologies, such as X-ray and ultrasound services. Figure 16 reports the numbers of machines per million population in Canada by type of technology for the last three years.

Figure 16. Numbers of Selected Medical Imaging Equipment per Million Population, Canada, as of January 1, 2003 to 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Numbers of machines per million population vary across the country. For example, Table 2 indicates that as of January 1, 2005, Ontario, with the largest population among the jurisdictions, had the largest number of CT scanners (108). Yet it had the fewest CT machines per million population (8.7). In contrast, with one CT scanner, the Yukon Territory has the largest ratio (32).

Table 2. Number of Machines (#) and Number of Machines per Million Population (Rate) of Selected Imaging Technologies, by Jurisdiction, as of January 1, 2005

Jurisdiction	Nuclear Medicine Cameras		CT Scanners		Angiography Suites		MRI Scanners		Catheterization Labs		PET Scanners	
	#	Rate	#	Rate	#	Rate	#	Rate	#	Rate	#	Rate
N.L.	12	23.2	10	19.3	3	5.8	1	1.9	2	3.9	0	--
P.E.I.	2	14.5	3	21.8	0	--	1	7.3	0	--	0	--
N.S.	26	27.7	15	16.0	6	6.4	5	5.3	5	5.3	0	--
N.B.	18	24.0	11	14.6	7	9.3	5	6.7	2	2.7	0	--
Que.	167	22.1	106	14.0	41	5.4	49	6.5	25	3.3	5	0.7
Ont.	266	21.4	108	8.7	72	5.8	58	4.7	41	3.3	8	0.6
Man.	18	15.3	17	14.5	4	3.4	6	5.1	4	3.4	0	--
Sask.	17	17.1	13	13.1	5	5.0	3	3.0	4	4.0	0	--
Alta.	65	20.2	30	9.3	14	4.3	25	7.8	11	3.4	3	0.9
B.C.	68	16.1	46	10.9	21	5.0	23	5.5	11	2.6	2	0.5
Y.T.	0	--	1	32.0	0	--	0	--	0	--	0	--
N.W.T.	0	--	1	23.3	0	--	0	--	0	--	0	--
Nun.	0	--	0	--	0	--	0	--	0	--	0	--
Canada	**659**	**20.5**	**361**	**11.3**	**173**	**5.4**	**176**	**5.5**	**105**	**3.3**	**18**	**0.6**

Notes:

“--“ = Not applicable.

a) Includes medical imaging equipment in both hospitals and free-standing facilities.

Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

In some cases, it is also helpful to consider the mix of equipment available in a jurisdiction. For example, although the capabilities of MRIs and CTs differ for specific applications, there are areas where the modalities overlap. As a result, some suggest that a high availability of CT services might reduce the acquisition of MRIs.[4] Interestingly, Table 2 reports that Newfoundland and Labrador, the province with the fourth-highest number of CTs per million population (19.3), has the lowest rate of MRIs (1.9). On the other hand, Alberta has the most MRIs per million population (7.8) but fewer CTs (9.3) than most jurisdictions.

Table 3 provides data comparing the ratio of MRIs to CTs. As of January 1, 2005, there was one MRI for every 2.1 CTs in Canada. Newfoundland and Labrador had the lowest ratio of MRIs to CTs (1:10.0), while Alberta had the highest ratio, with one MRI scanner for every 1.2 CTs.

Table 3. Ratios of Magnetic Resonance Imaging (MRI) to Computed Tomograpny (CT) in Hospitals and Free-Standing Imaging Facilities, by Jurisdiction, as of January 1, 2005

Jurisdiction	MRI:CT Ratio
N.L.	1:10.0
P.E.I.	1:3.0
N.S.	1:3.0
N.B.	1:2.2
Que.	1:2.2
Ont.	1:1.9
Man.	1:2.8
Sask.	1:4.3
Alta.	1:1.2
B.C.	1:2.0
Y.T.	-
N.W.T.	-
Nun.	-
Canada	**1:2.1**

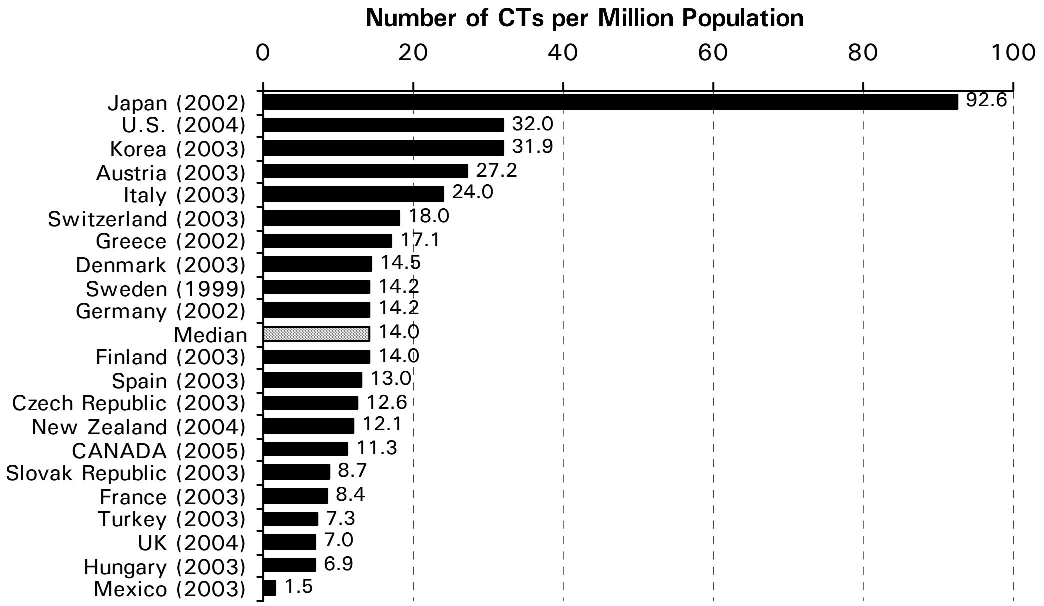
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

THE INTERNATIONAL CONTEXT

Internationally, the Organisation for Economic Co-operation and Development (OECD) has reported large variations in the supply of medical imaging technologies among member countries. According to available data, Japan has a much higher supply of high-technology medical imaging equipment than other countries. Even among the other countries, the variation is considerable. For instance, Figure 17 indicates that, in 2004, the per million population ratio of CT machines for the United States was almost triple that of Canada and more than four times that of the United Kingdom. Figure 18 illustrates a similar picture for MRIs.

The level of national income and health spending and differences in payment methods to hospitals have been found to influence the diffusion of medical technology in OECD countries. A recent study, based on data from 30 OECD countries, found that the number of CT and MRI scanners is positively correlated with health expenditure per capita and that certain payment methods (for example, those based on reimbursements on a per case or per diem basis) are associated with a greater diffusion of scanners.[5]

Figure 17. Number of Computed Tomography (CT) Scanners per Million Population in Selected OECD Countries With a Population of One Million or More and the Year for Which Rates Were Reported



Sources: OECD Health Data 2005, OECD; National Inventory of Selected Imaging Equipment, 2005; Information Services for the Health Care and Scientific Markets (IMV) (data for the United States).

Notes:

a) Countries for which only data prior to 1999 were available are not shown.

b) In Mexico, only scanners located in public institutions are included.

c) In Canada, units located both in hospitals and in free-standing imaging facilities are included. Data is as of January 1, 2005.

d) In Japan, only units located in hospitals and general clinics are counted.

e) In Greece, CT scanners from military hospitals and private diagnostic centres are also included.

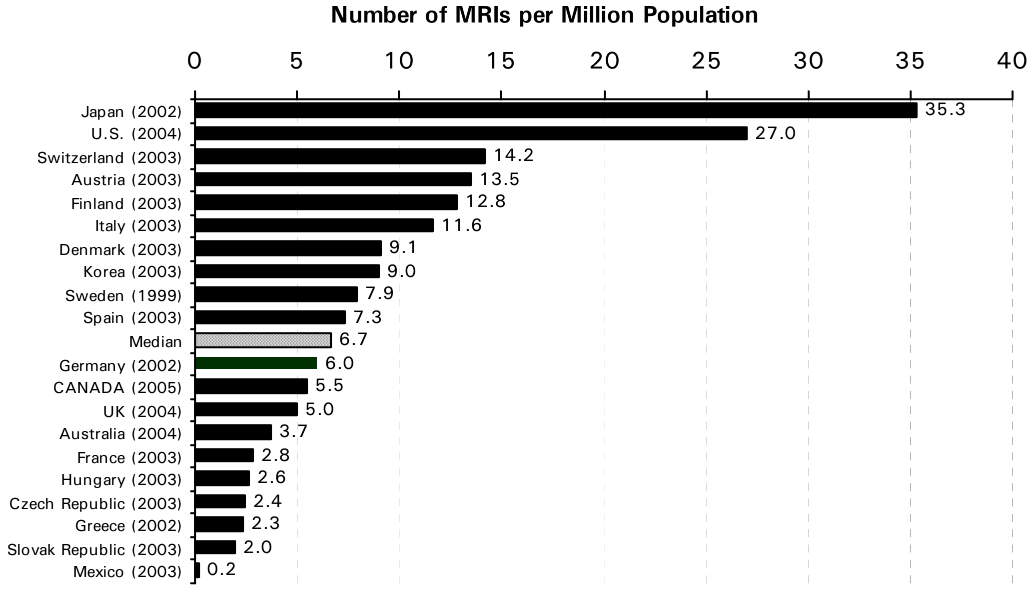
f) In the UK, raw numbers of CT units for England and Wales have been increased by the OECD Secretariat to provide an estimate for the UK. The private sector is not included in the data.

g) In the U.S., units located both in hospitals and in non-hospital sites are included. Mobile CT units are not included. IMV was used as the data source, because it counts the number of CTs, whereas OECD figures are a count of the number of hospitals that report having at least one scanner.

h) In Germany, data on medical technology includes equipment installed in acute care hospitals and in prevention and rehabilitation homes. The figure comprises CT units as well as PET units.

i) In Hungary, military hospitals and the health institutes of Hungarian State Railways are not included.

Figure 18. Number of Magnetic Resonance Imaging (MRI) Scanners per Million Population in Selected OECD Countries With a Population of One Million or More and the Year for Which Rates Were Reported



Sources: OECD Health Data 2005, OECD; National Inventory of Selected Imaging Equipment, 2005; Information Services for the Health Care and Scientific Markets (IMV) (data for the United States).

Notes:

a) Countries for which only data prior to 1999 were available are not shown.

b) In Mexico, only scanners located in public institutions are included.

c) In Canada, units located both in hospitals and in free-standing imaging facilities are included. Data is as of January 1, 2005.

d) In Japan, only units located in hospitals and general clinics are counted.

e) In the UK, raw numbers of MRI units for England and Wales have been increased by the OECD Secretariat to provide an estimate for the UK. The private sector is not included in the data.

f) In the U.S., units located both in hospitals and in non-hospital sites are included. IMV was used as the data source because it counts the number of MRIs, whereas OECD figures are a count of the number of hospitals that report having at least one scanner.

g) In Greece, MRI units from military hospitals and private diagnostic centres are also included.

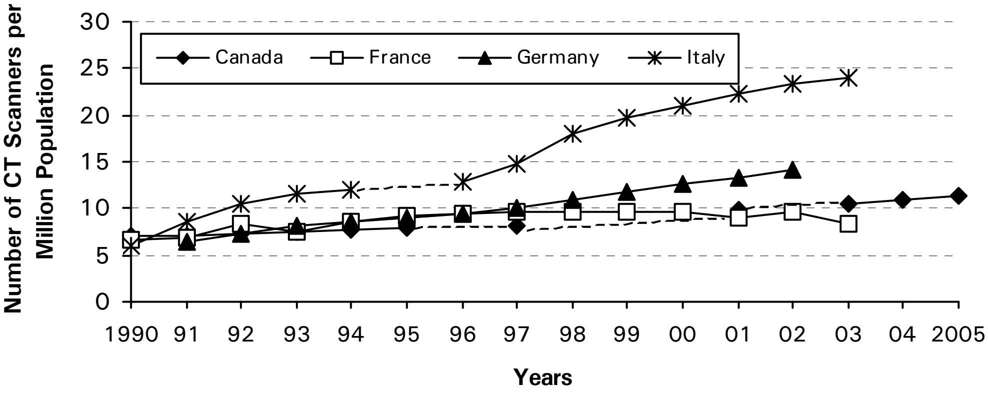
h) In Germany, data on medical technology include equipment installed in acute care hospitals and in prevention and rehabilitation homes.

i) In Australia, units approved for billing to Medicare only are included. In 1999, these units represented about 60% of the total units. The proportion in 2004 in unknown.

A wide range of factors may explain the variations in the international supply pattern of medical imaging services and technologies. In the case of Japan, for example, the high rate of MRIs per million population (35.3 in 2002) has been partly attributed to the market situation of the medical engineering industry, as well as sociocultural factors such as a bias towards new technologies.[6] Furthermore, decisions by individual countries about which types of imaging technology to invest in, and how many machines to acquire, may depend on a variety of domestic factors, including the state of the assessment of the appropriateness of a particular technology's use in different clinical situations and environments.

All OECD countries where data are available report more CTs and MRIs over time, but some have acquired the technologies at a faster rate than others. For example, Figure 19 reports that, throughout the 1990s, the number of CT scanners per million population in Canada grew less quickly than in Italy, but at about the same rate as in other developed countries, such as France and Germany.

Figure 19. Number of Computed Tomography (CT) Scanners per Million Population in Selected G8 Countries for Which Time Series Were Available, 1990 to 2005



Sources: OECD Health Data 2005, OECD; National Survey of Selected Medical Imaging Equipment (2003, 2004 and 2005), Canadian Institute for Health Information.

Notes:

a) Annual data on the number of machines are not available for every country. A dotted line is drawn between data points spanning two years or more.

b) The UK was not included due to varying geographical coverage across years.

c) Japan reported very high numbers of CT scanners per million population (55.2 in 1990 and 92.6 in 2002, representing a 68% growth between the two years). Japan is not shown in Figure 19 in order to improve clarity of trend comparisons of countries with similar values by removing the effect of the very high numbers on the data scale.

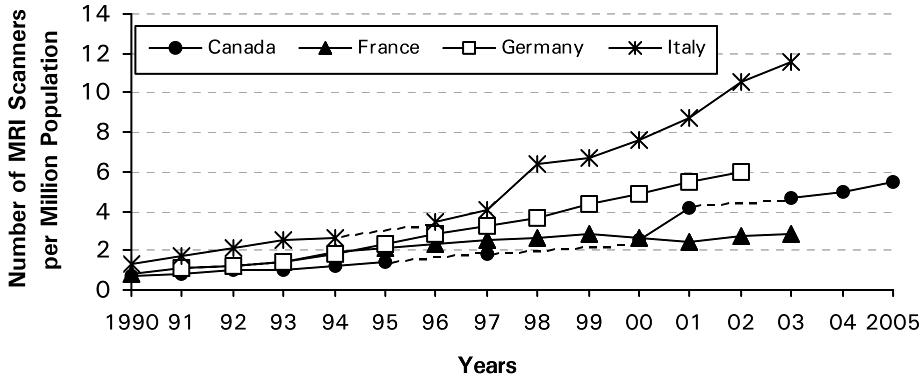
d) The U.S. was not included because its figures submitted to the OECD refer to the number of hospitals reporting at least one scanner rather than total number of scanners.

e) Russia was not included, as data were unavailable.

f) Units located both in hospitals and in free-standing imaging facilities are included for Canada for all years. The number of CT scanners in free-standing imaging facilities was imputed for years prior to 2003, based on data collected in the 2003 National Survey of Selected Medical Imaging Equipment.

Figure 20 reports that the growth of MRI scanners in Canada was similar to that in France and Germany from 1990 to 2001. The number of MRI scanners in Italy was growing at a more rapid rate than the number in Canada, Germany and France.

Figure 20. Number of Magnetic Resonance Imaging (MRI) Scanners per Million Population in Selected G8 Countries for Which Time Series Were Available, 1990 to 2005



Sources: OECD Health Data 2005, OECD; National Survey of Selected Medical Imaging Equipment (2003, 2004 and 2005), Canadian Institute for Health Information.

Notes:

a) Annual data on the number of machines are not available for every country. A dotted line is drawn between data points spanning two years or more.

b) The UK was not included due to varying geographical coverage across years.

c) Japan reported high numbers of MRI scanners per million population (6.1 in 1990 and 35.3 in 2002). Japan is not shown in Figure 20 in order to improve clarity of trend comparisons of countries with similar values by removing the effect of the high numbers on the data scale. Also, there is a break in the Japanese series, as MRIs installed in the clinics are included in 2002 but not in earlier years.

d) The U.S. was not included because its figures submitted to the OECD refer to the number of hospitals reporting at least one scanner rather than total number of scanners.

e) Russia was not included, as data were unavailable.

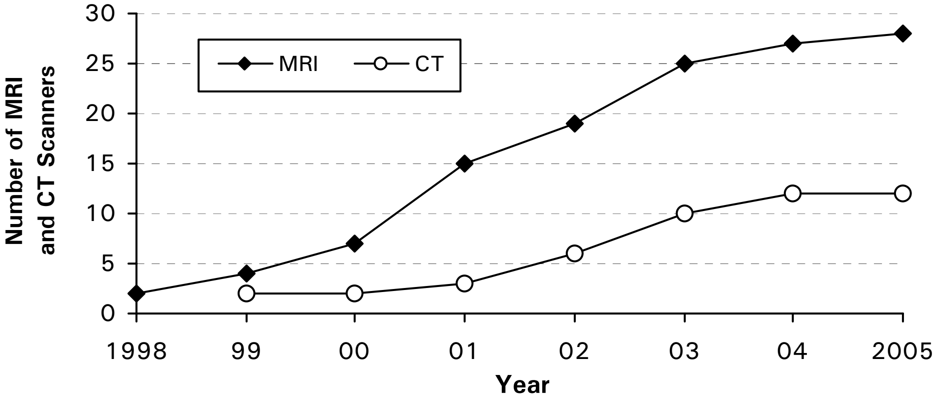
f) In Canada, units located both in hospitals and in free-standing imaging facilities are included for all years. The number of MRI scanners in free-standing imaging facilities was imputed for years prior to 2003, based on data collected in the 2003 National Survey of Selected Medical Imaging Equipment.

WHERE IMAGING TECHNOLOGIES ARE LOCATED

Hospitals typically offer a range of medical imaging services, but some types of imaging are also available elsewhere. For example, in Canada there is a well-established practice of free-standing facilities offering X-ray and ultrasound services.

The extent to which imaging services are available outside of hospitals varies by imaging modality. Services such as CT and MRI, for example, tend to be located in densely populated areas and are often found in teaching and large community hospitals. Figure 21 reports that the number of MRIs in free-standing (or non-hospital) imaging facilities has grown every year since 1998. The number of CT scanners in free-standing facilities grew from 2000 to 2004 and then remained unchanged in 2005. As of January 2005, about 3% of CTs and 16% of MRIs were in free-standing facilities. (For provincial/territorial distributions of selected imaging modalities across Canada, please see Appendix A, Table A.7.)

Figure 21. Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Scanners in Free-Standing Imaging Facilities, Canada, 1998 to 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

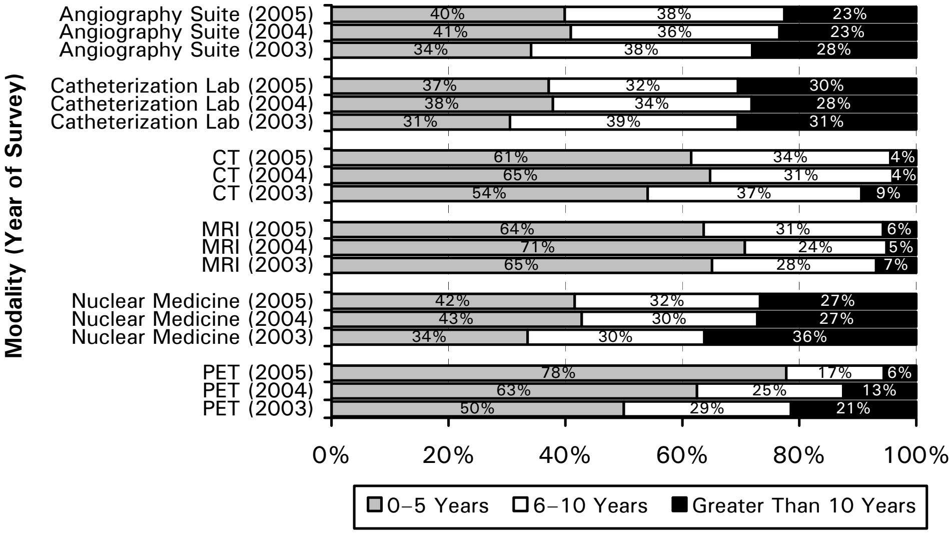
Note:
The numbers of MRI and CT scanners were imputed for years prior to 2003, based upon data for year of installation reported in the 2003 survey, except where private clinics were later identified in the 2004 or 2005 survey(s). If it was determined that these clinics were in operation prior to 2003, the numbers (counts) have been modified accordingly.

AGEING AND RENEWAL OF MEDICAL IMAGING TECHNOLOGIES

Results from the last three iterations of the National Survey of Selected Medical Imaging Equipment indicate that the age of Canada's imaging technology equipment varies considerably across the selected modalities (Figure 22). For the expensive high-end imaging modalities, such as CT, MRI and PET, a higher proportion of equipment (greater than 60%) has been installed within the last five years. This is a possible indication of the increasing use and acceptance of these technologies in the health sector. The survey reports that, while about 37% of catheterization labs were under five years old at the beginning of 2005, 64% of MRIs and 61% of CTs were in this age cohort.

Although more CT and MRI scanners were installed in 2005, the proportion of CTs and MRIs in the 0-to-5-year age cohort decreased. This decrease is a result of ageing machines moving from the 0-to-5 age cohort in 2004 to the 6-to-10 age cohort in 2005, increasing the share of the 6-to-10 age cohort.

Figure 22. Distribution of Selected Medical Imaging Equipment, by Age Cohort Since Installation, by Survey Year, Canada



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health

Note:
Age cohorts are calculated based on the year of the survey minus the year of equipment installation.

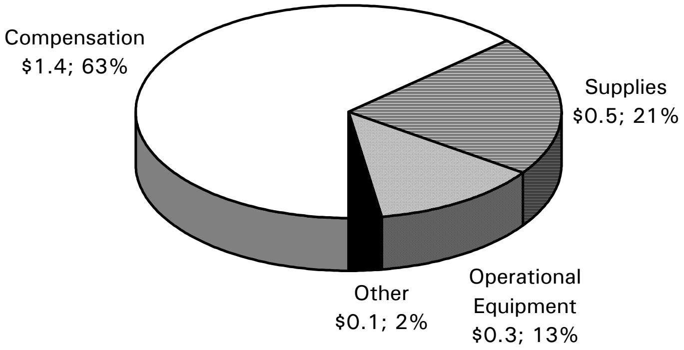
The age of equipment may matter for a number of reasons. According to the Canadian Association of Radiologists, outdated equipment may carry a higher risk of failure or breakdown, which may disrupt imaging services.[7] Furthermore, the association suggests that it may be more difficult to obtain spare parts for older equipment, that there may be cost implications (that is, maintenance fees) involved when updating older equipment and that older machines may produce poorer quality images. At the same time, upgrading or replacing equipment can be costly, both in terms of capital costs and for other reasons, such as retraining staff.

THE COST OF IMAGING

Operating Costs

Canadians spend billions of dollars each year on imaging services. The professionals who operate and maintain the equipment must be paid, related parts and supplies must be purchased and overhead costs must be included. In 2003–2004, Canadian hospitals reported an estimated $2.3 billion for the operation of diagnostic imaging services; this is up from the $1.6 billion reported in 1999–2000. Figure 23 outlines the distribution of these expenses for 2003–2004 across four broad areas of expenditure.

Figure 23. Distribution of Diagnostic Imaging Operating Expenses in Canadian Hospitals, 2003–2004
($' billions)



Source: Canadian MIS Database, Canadian Institute for Health Information.

In Ontario alone, it is estimated that in 2003–2004 more than $900 million was spent by hospitals on operating selected medical imaging equipment. This is an increase of more than $250 million since 1999–2000.

This includes payments to Ontario physicians who receive professional fees for performing and/or interpreting medical imaging tests on hospital outpatients. The utilization of outpatient MRI scans in Ontario, as well as the related professional fees, have both increased over time.[8]

Total operating costs vary widely, depending on the type of imaging, the complexity of the images required, salary and fee levels and other factors. Although medical imaging technologies have become essential tools in health care, there is little comparable information on the costs of providing these services across the country.

Where the Money Comes From

Many imaging facilities are located in hospitals (public and private), but there is also a well-established tradition in Canada of free-standing imaging facilities, which may be for-profit or not-for-profit. In some cases, they are led by entrepreneurs, often the health professionals delivering the services, who need not answer to shareholders; in others, they are owned by corporate organizations that must provide returns on investment to their shareholders.[9, 10]

Free-standing imaging facilities range from specialized services run by physicians, radiologists, dentists, chiropractors or mammography programs to broad-based imaging centres offering a wide range of tests. The use of hospital-based and free-standing imaging facilities differs slightly among imaging modalities. For example, according to the Statistics Canada Health Services Access Survey, 83% of Canadians who reported having had a non-emergency angiography in 2003 said that they underwent their test in a hospital or public clinic. The proportion was higher for CT scans (96%) and MRIs (90%).[11]

Irrespective of the type of facility in which the examination occurs, funding can come from a variety of sources, such as provincial and territorial health insurance programs, other public payers (for example, workers' compensation boards or the federal government) and/or individuals or their insurance plans. Who pays for the services can depend on many factors: for instance, why the examination is required, what type of examination is needed and where the facility is located.

Most funding for medical imaging comes from provincial and territorial governments, but funding approaches vary by technology and jurisdiction. In some cases, there are also differences between how physicians' professional fees are funded and payments for hospital or other facility operating costs. For example, physicians may receive fee-for-service payments for their professional services, while other operating costs may be included in hospital/health region global budgets. Alternatively, the fee-for-service payment may include both a professional and a technical component, covering all operating costs.

According to the 2005 National Survey of Selected Medical Imaging Equipment, both hospital-based and free-standing imaging services receive operating funding from various sources, but the mix of funding differs. For hospital-based equipment captured in the survey, funding for operating costs comes primarily from provincial and territorial governments. Additional secondary funding sources also exist. For example, some hospitals provide CT and MRI services funded by other payers in off-hours. In contrast, the private sector (private health insurance and households) provides most of the funds to finance the operation of machines housed in free-standing imaging facilities.

Table 4. Percentage Distribution of Operating Revenue by Source for Selected Types of Medical Imaging Equipment and Total Number of Machines Installed in Hospitals and Free-Standing Imaging Facilities, Canada, as of January 1, 2005

Sources of Operating Funds	Hospitals			Free-Standing Facilities		
	CT	MRI	Nuclear Medicine	CT	MRI	Nuclear Medicine
Provincial Government	93.3%	85.6%	93.2%	0.0%	4.2%	16.7%
Workers' Compensation Board	0.2%	1.4%	0.1%	1.5%	1.3%	1.3%
Private Health Insurance, Other Private Insurance, Out-of-Pocket Payments	0.7%	1.2%	0.6%	78.5%	77.8%	82.1%
Other Types of Funding	5.8%	11.8%	6.1%	20.0%	16.8%	0.0%
Total Number of Machines	**293**	**110**	**477**	**10**	**24**	**48**

Notes:

a) Data pertain only to facilities reporting sources of funds.

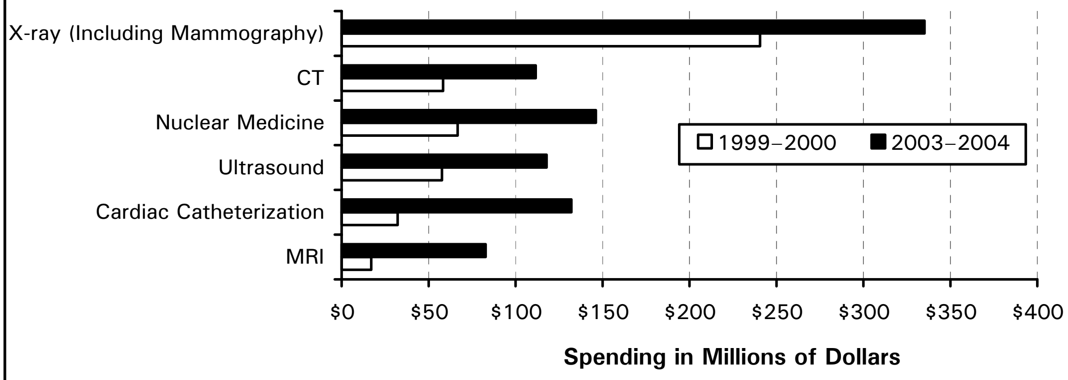
b) Numbers may not add due to rounding.

Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Where the Money Goes

Medical imaging tests vary greatly in their complexity and the resources required to perform them. In most hospitals, common tests account for the bulk of overall operating expenditures on diagnostic imaging. According to the best available provincial and territorial data in CIHI's Canadian MIS Database (CMDB), in 2003–2004, hospitals in Ontario spent about $335 million on X-rays and mammography exams—approximately three times as much as on either ultrasound, cardiac catheterization or nuclear medicine. Other services—such as CTs and MRIs—cost more per test than X-rays, but fewer people receive them. Ontario hospitals, for example, spent about $112 million for CT scans and $83 million for MRI scans in 2003–2004, as shown in Figure 24.

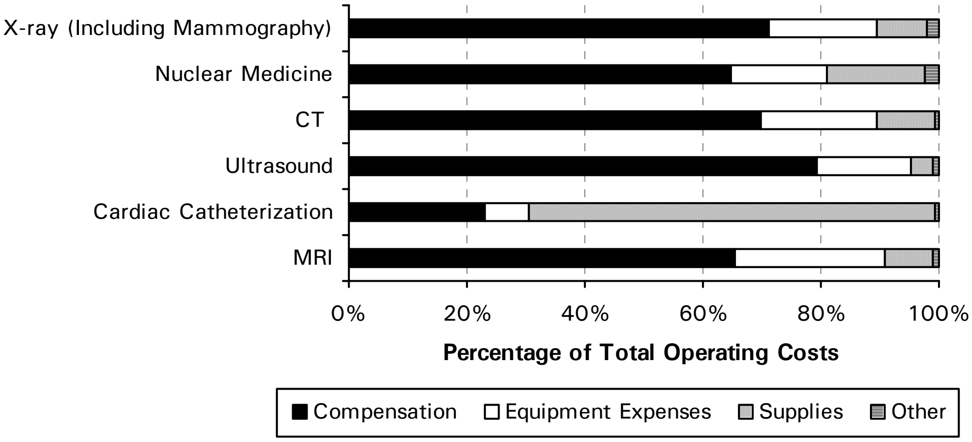
Figure 24. Total Hospital Operating Expenses for Selected Types of Medical Imaging Equipment, Ontario, 1999–2000 and 2003–2004



Source: Canadian MIS Database, Canadian Institute for Health Information.

Types of operating expenses also vary according to imaging modalities. As reported in Figure 25, for all imaging technologies (with the exception of cardiac catheterization), salaries paid to health professionals account for more than 60% of total operating costs. For cardiac catheterization, medical supplies used to perform the procedure ake up the majority of spending (69%). The share of operational equipment expenses is the highest for MRI (25%).

Figure 25. Distribution of Hospital Operating Expenses for Selected Types of Medical Imaging Equipment, Ontario, 2003–2004



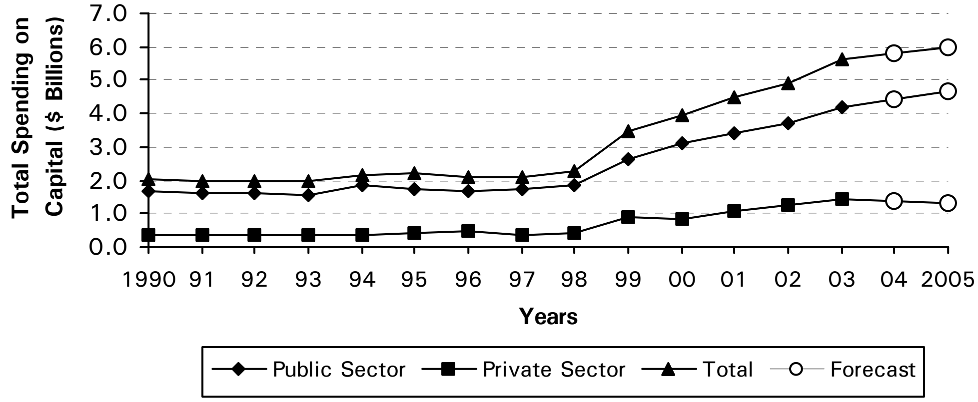
Source: Canadian MIS Database, Canadian Institute of Health Information.

Note:
"Other" includes sundries, referred-out services and building and grounds expenses.

Capital Costs

In 2005, Canada spent $5.9 billion on construction, machinery and major equipment in the health sector.[12] Capital costs represented about 4.5% of total health spending (2004 forecast). Most (77%) came through provincial and territorial governments; about 23% came from the private sector. Both sources of funds and levels of capital spending have fluctuated over time. After a comparatively lean period in the 1990s, spending has risen steadily in recent years (Figure 26).

Figure 26. Total Capital Expenditures on Construction, Machinery and Equipment of Hospitals, Clinics, First-Aid Stations and Residential Care Facilities, by Public and Private Sector Payers, Canada, 1990 to 2005



Source: National Health Expenditure Database, Canadian Institute for Health Information.

Medical imaging equipment accounts for an important, but unknown, share of total capital spending. Expensive technologies such as MRI and CT scanners have high initial costs compared to common technologies such as X-rays and ultrasounds. An MRI scanner costs over CAN $2 million, whereas the average cost of a CT scanner is about CAN $1 million according to the UK Audit Commission.[13] Viewed in another way, for the cost of one MRI scanner it would be possible to buy about five X-ray machines at about $340,000 each or 12 ultrasound machines at about $160,000 each. Of course, making these choices would affect which types of patients would benefit, operating costs and many other factors. PET scanners are much more expensive: about $2.5 million to $4.6 million, depending on whether a cyclotron is present.[14]

Canada's total spending on medical imaging equipment is a fraction of worldwide sales, which are estimated at $14.5 billion in 2002.[15] The majority of the devices used in Canada, as well as the parts to maintain them, come from outside the country. The bulk of our imports come from the U.S., Germany and Japan. The U.S. alone accounted for 57% of MRI, 50% of radiography and radiotherapy X-ray, 66% of ultrasound and 53% of CT apparatus imports in 2002.[16] The three major vendors that supply medical imaging equipment to Canada are General Electric, Siemens and Phillips.

Domestically, the medical imaging/radiotherapy sector includes sales of equipment for X-ray, ultrasound, MRI, nuclear medicine, etc., by about 15 different companies in Canada in 2000, according to Statistics Canada's Medical Devices Industry Survey. This sector had just over $115 million in net sales of medical devices in 1999. Firms forecast that sales would grow to $194 million by 2002.[17]

Funding to buy medical imaging equipment comes from many sources. Many provincial and territorial governments fund the purchase and replacement of non-major equipment through regular health region/hospital operating funds.[18] Funds for specific larger projects, on the other hand, may be allocated directly by the ministry of health or through regional health authorities. Such purchases are often also funded at least partly through non-governmental sources such as hospital foundations and private funding agencies, among others. Some are also partly or wholly paid for by research grants. For example, a study of funding sources for MRI equipment in Canada in 1997 reported that about 23% of the capital spending for the national inventory of MRI machines was provided by direct government grants.[19] Free-standing imaging facilities may also invest in or lease the equipment that they use. Part of what they charge for their services goes towards recovering capital costs.

In recent years, the federal government has also played a role in funding imaging and other equipment. Table 5 reports that a $1 billion medical equipment fund allocated over two years was established in the 2001 Health Accord to assist provinces and territories with purchasing and installing equipment. Another $1.5 billion over the subsequent three years was added to the fund in the 2003 Health Accord. This additional money was earmarked to support specialized staff training and equipment, and to improve access to publicly funded diagnostic services.[20] In the 2004 Accord, First Ministers agreed to add to the fund an additional $500 million for the purchase of diagnostic and medical imaging equipment, bringing the fund to a total of $3.0 billion over five years.[21, 22]

Table 5. Federal Government Funding Commitments for Medical Equipment in the 2001, 2003 and 2004 Health Accords

Fiscal Year	2001 Accord	2003 Accord	2004 Accord
	($ billions)		
2000–2001	0.5		
2001–2002	0.5		
2003–2004		0.5	
2004–2005		0.5	0.5
2005–2006		0.5	
Total	**1.0**	**1.5**	**0.5**

Note:
The expenditure above includes dollars spent on accessories and upgrades.

Source: Department of Finance, Government of Canada, federal budgets, 2001, 2003 and 2004.

REFERENCES

1. M. Amendola and J. Gaffard, *The Innovative Choice: An Economic Analysis of the Dynamics of Technology* (Oxford: Basil Blackwell Limited, 1988).
2. M. Dodgson and J. Bessant, *Effective Innovation Policy: A New Approach* (London, UK: International Thompson Business Press, 1996).
3. R. N. Battista, R. Jacob and M. S. Hedge, *Health Care Technology in Canada (With Special Reference to Quebec)* (Washington, DC: U.S. Government Printing Office, 1995), [online], from <www.wws.princeton.edu/ota/disk1/1995/9562/956205.PDF>.
4. Australian Diagnostic Imaging Association, *Review of Magnetic Resonance Imaging* (1999), [online], from <www.adia.asn.au/pdfs/blandfordsubmission.pdf>.
5. E. H. Oh, Y. Imanaka and E. Evans, "Determinants of the Diffusion of Computed Tomography and Magnetic Resonance Imaging," *International Society for Technology Assessment in Health Care* 21, 1 (2005): pp. 73–80.
6. A. Hisashige, "The Introduction and Evaluation of MRI in Japan," *International Journal of Technology Assessment in Health Care* 10, 3 (1994): pp. 392–405.
7. Canadian Association of Radiologists, *Special Ministerial Briefing—Outdated Radiology Equipment: A Diagnostic Crisis* (Montréal: Canadian Association of Radiologists, 2000).
8. K. Ion, A. Laupacis and R. K. Przybysz, Institute for Clinical and Evaluative Sciences*,* *Access to MRI in Ontario: Addressing the Information Gap* (2003), [online], from <www.ices.on.ca/webpage.cfm?site_id=1&org_id=68>.
9. R. B. Deber, Commission on the Future of Health Care in Canada, *Discussion Paper No.17—Delivering Health Care Services: Public, Not-For-Profit, or Private?* (2002), [online], from <epe.lac-bac.gc.ca/100/200/301/pco-bcp/commissions-ef/future_health_care-ef/discussion_paper-e/no17/17_e.pdf>.
10. P. J. Devereaux et al., "A Systematic Review and Meta-Analysis of Studies Comparing Mortality Rates of Private for-Profit and Private Not-for-Profit Hospitals," *Canadian Medical Association Journal* 166, 11 (2002): pp. 1399–1406.
11. Statistics Canada, *Health Services Access Survey* (Canada: Statistics Canada, 2003).
12. Canadian Institute for Health Information, *National Health Expenditure Trends, 1975–2004* (Ottawa: CIHI, 2004).
13. The Audit Commission, *Radiology: Acute Hospital Portfolio—Review of National Findings* (London, UK: The Audit Commission, 2002), [online], from <www.healthcarecommission.org.uk/assetRoot/04/00/02/43/04000243.pdf>.
14. Agency for Health Services and Technology Assessment (AETMIS), *Positron Emission Tomography in Québec* (2001), [online], from <www.aetmis.gouv.qc.ca/fr/publications/scientifiques/imagerie_medicale/2001_03_en.pdf>.
15. Medtech Insight, *The Worldwide Market for Diagnostic Imaging Equipment* (2002), [online], from <www.medtechinsight.com/Report1491.html>.

16. Industry Canada, *Trade Data Online* (2003), [online], last modified 2005, from <strategis.ic.gc.ca/sc_mrkti/tdst/engdoc/tr_homep.html>.
17. Statistics Canada, *Medical Devices Industry Survey 2000* (Ottawa: Statistics Canada, 2001).
18. I. McKillop, G. H. Pink and L. M. Johnson, *The Financial Management of Acute Care in Canada: A Review of Funding, Performance Monitoring, and Reporting Practices* (Ottawa: Canadian Institute for Health Information, 2001) [online], from <secure.cihi.ca/cihiweb/products/finmanAC.pdf>.
19. R. N. Rankin, "Magnetic Resonance Imaging in Canada: Dissemination and Funding,“ *Canadian Association of Radiologists Journal* 50, 2 (1999): pp. 89–92.
20. Canadian Medical Association, *Whither the Medical Equipment Fund?—Background Paper and Technical Notes* (2002), [online], from <www.ftlcomm.com/ensign/editorials/LTE/robinson_CTF/robinsonlist/robinson022/MedicalEquipmentFund.pdf>.
21. Department of Finance, *Investing in Canada's Health Care System* (2003), [online], from <www.fin.qc.ca/budget03/booklets/bkheae.htm>.
22. Department of Finance, *Delivering on Commitments: The 10-Year Plan to Strengthen Health Care* Source (2005), [online], from <www.fin.gc.ca/budget05/bp/bpc3e.htm#health>.

Chapter 3
Utilization of Imaging Services

When addressing the waiting time issue for diagnostic imaging in Canada, most people refer to the availability of equipment. However, this is only one dimension of the problem. More machines do not necessarily mean more imaging services. The machines could be under-used for a variety of reasons, such as funding limitations, human resources constraints, etc. Hence, the importance of considering the level of utilization of the imaging equipment and of assessing the efficiency of its operation. This chapter first presents the total number of MRI and CT exams, in each province and territory, and the rates per 1,000 population. It reports on three measures of utilization and workload for MRI and CT: the number of exams per machine per year, the number of hours in operation per machine per week and the number of exams per full-time equivalent (FTE) technologist. These performance indicators are then compared to those in the United States and in England. Finally, the chapter examines possible factors limiting access to MR and CT exams.

NUMBER OF MRI AND CT EXAMS BY JURISDICTION

The number of exams[i] was collected only for MRI and CT in the 2004 and 2005 National Surveys of Selected Medical Imaging Equipment. Respondents who indicated that their facility had an MRI or a CT scanner were asked to report the number of MRI or CT exams performed during the fiscal year (April 1 to March 31).

Table 6 presents the total number of MRI and CT exams by jurisdiction and for Canada, for the fiscal years 2003–2004 and 2004–2005.

---

[i] An exam is defined as a technical investigation using an imaging modality to study one body structure, system or anatomical area that yields one or more views for diagnostic and/or therapeutic purposes (that is, one exam can include more than one scan). Exceptions include routinely ordered multiple body structures that by common practice or protocol are counted as one exam.

Table 6. Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Exams, by Jurisdiction and Canada, 2003–2004 and 2004–2005

Jurisdiction	MRI Exams		CT Exams	
	2003–2004	2004–2005	2003–2004	2004–2005
N.L.	5,856	4,375	52,428	51,751
P.E.I.	2,200	2,218	9,970	14,240
N.S.	44,758	46,269	122,717	112,206
N.B.	22,801	23,030	101,461	101,291
Que.	146,770	164,337	653,908	681,125
Ont.	324,186	340,958	909,813	988,037
Man.	17,825	24,360	105,298	134,148
Sask.	12,628	16,113	82,079	89,072
Alta.	85,096	117,557	254,637	291,652
B.C.	52,283	77,295	268,675	329,350
Y.T.	n/a	n/a	1,500	1,276
N.W.T.	n/a	n/a	1,750	1,830
Nun.	n/a	n/a	n/a	n/a
Canada	**714,403**	**816,512**	**2,564,236**	**2,795,978**

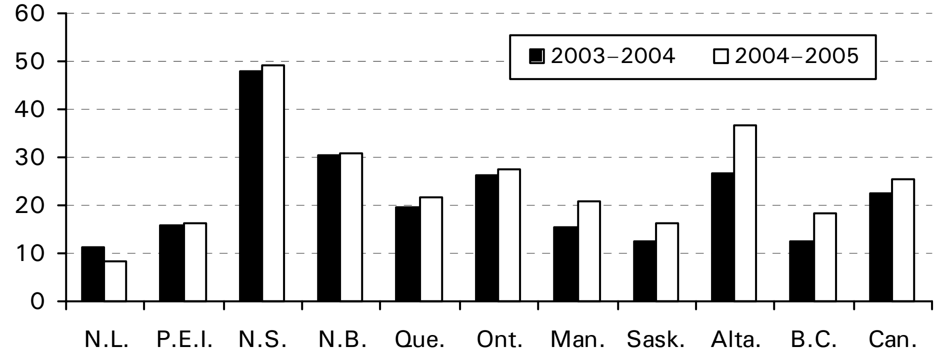
Note:
n/a = not applicable

Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

There were 816,512 MRI exams and 2,795,978 CT exams in Canada in 2004–2005. About 60% of these exams were performed in Ontario and Quebec, the two most populous provinces. In 2004–2005, the numbers of MRI exams were higher than in 2003–2004 in all provinces except for Newfoundland and Labrador. CT exams increased in 2004–2005 in all jurisdictions with the exception of three of the Atlantic provinces and the Yukon Territory. At the national level, MRI and CT exams increased by 14.3% and 9.0% respectively.

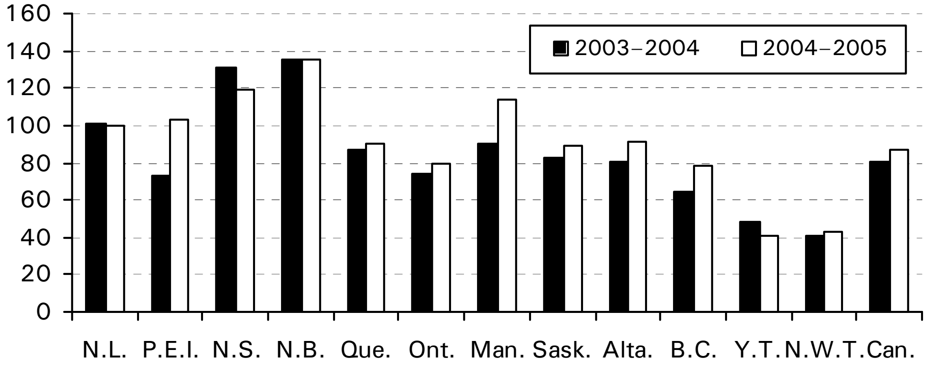
Figures 27 and 28, respectively, report the number of MRI and CT exams per 1,000 population.

Figure 27. Number of Magnetic Resonance Imaging (MRI) Exams per 1,000 Population, by Jurisdiction and Canada, 2003–2004 and 2004–2005



Sources: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information; Statistics Canada.

Figure 28. Number of Computed Tomography (CT) Exams per 1,000 Population, by Jurisdiction and Canada, 2003–2004 and 2004–2005



Sources: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information; Statistics Canada.

In 2004–2005, MRI exams per 1,000 population ranged from 8.5 in Newfoundland and Labrador[ii] to 36.6 in Alberta.[iii] The Canadian average was 25.5, which represents an increase of 13.3% from 2003–2004. This increase may reflect a higher number of exams per user or a higher number of users among the general population, or a combination of both factors. Unfortunately, available data do not permit us to disentangle these two factors.

CT exams per 1,000 population, among the provinces, ranged from 78.2 in British Columbia to 134.8 in New Brunswick, in 2004–2005. The Canadian average reached 87.3,[iv] an increase of 8.0% from 2003–2004.

ARE MEDICAL IMAGING MACHINES OPERATED INTENSIVELY?

Medical imaging equipment is generally associated with a large amount of capital and operating expenses, particularly for MRI and CT scanners. Given this fact, this equipment should operate at an intensive level of capacity. In order to assess the level of intensity in the use and operation of the pool of medical imaging equipment in each jurisdiction and in Canada, three indicators of utilization and workload are used:

- Average number of exams per machine per year;
- Average number of hours of operation per machine per week; and
- Average number of exams per full-time equivalent (FTE) technologist.

Average Number of MRI and CT Exams per Machine per Year

Number of exams per machine can be computed only for MRI and CT because information on number of exams is not available for the other types of equipment. Average number of exams per scanner for a given jurisdiction is computed by dividing the total number of exams in the jurisdiction by the number of scanners for which any exam was reported.[v] Figures 29 and 30, respectively, show the number of MRI and CT exams per machine for 2003–2004 and 2004–2005.

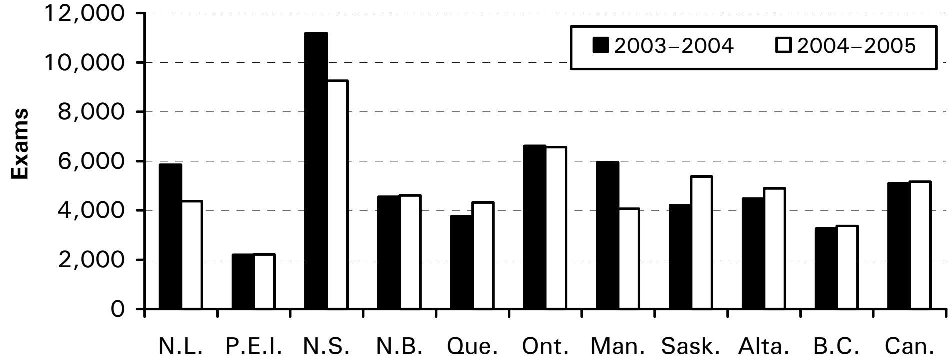
[ii] A particularly low rate of MRI scanners per million population and a labour dispute that lasted almost a month help explain the low number of MRI exams per 1,000 population in Newfoundland and Labrador in 2004–2005.

[iii] The number of MRI exams per 1,000 population in Nova Scotia was 49.3 in 2004–2005, substantially higher than in any other jurisdiction. Further investigation revealed that the two facilities from the Nova Scotia's QE II Health Sciences Centre, the Victoria General Hospital and the Halifax Infirmary, reported the number of MRI exams from their physician billing system, which provides a higher count of exams than the count based on the exam definition provided in the survey for the last two years. Revised figures based on the definition in the survey could not be calculated in time for publication.

[iv] Due to their younger population, the territories have a low number of CT exams per 1,000 population. The territories are excluded from the range, but are included in the computation of the national average.

[v] A mobile scanner is always counted as one scanner even though exams for this scanner may be reported by more than one site.

Figure 29. Average Number of Magnetic Resonance Imaging (MRI) Exams per Machine per Year, by Jurisdiction and Canada, 2003–2004 and 2004–2005



Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

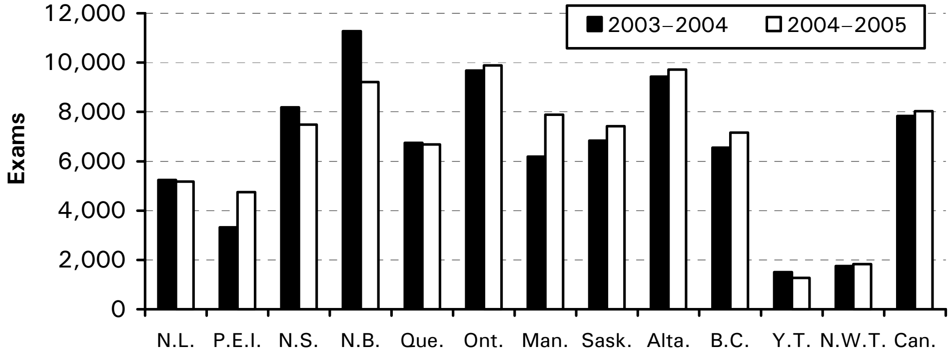
The average number of MRI exams performed per machine in Canada was 5,168 in 2004–2005. This represents a substantial increase from the 1997 average (3,563) reported by Richard N. Rankin in the April 1999 issue of the *Canadian Association of Radiologists Journal*.[1] Among the provinces, average numbers ranged from 2,218 in Prince Edward Island to 6,557 in Ontario.[vi] In 2003–2004, the Canadian average was about the same as in 2004–2005 and the same two provinces held the lower and the upper limits of the range.

In 2004–2005, the number of exams per machine decreased considerably in Newfoundland and Labrador, Nova Scotia and Manitoba. In two provinces, this was due to an increase in the denominator (the number of MRI scanners)—from four to five in Nova Scotia and from four to six in Manitoba. However, in the case of Newfoundland and Labrador, the decline in the ratio was due to a decrease in the numerator (the number of exams).[vii]

[vi] The number of MRI exams per machine in Nova Scotia was 9,254, substantially higher than in any other jurisdiction. Further investigation revealed that the two facilities from the Nova Scotia's QE II Health Sciences Centre, the Victoria General Hospital and the Halifax Infirmary, reported the number of MRI exams from their physician billing system, which provides a higher count of exams than the count based on the exam definition provided in the survey for the last two years. Revised figures based on the definition in the survey could not be calculated in time for publication.

[vii] This decrease in number of exams could be partially explained by a labour dispute that lasted almost a month during the 2005 reporting period.

Figure 30. Average Number of Computed Tomography (CT) Exams per Machine per Year, by Jurisdiction and Canada, 2003–2004 and 2004–2005



Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

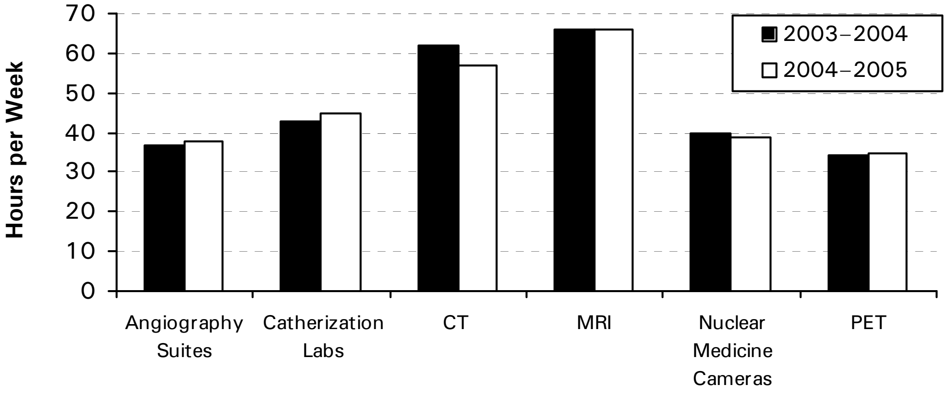
The average number of CT exams per machine in Canada was 8,034 in 2004–2005. Among the provinces, the numbers ranged from 4,747 in Prince Edward Island to 9,880 in Ontario. In 2003–2004, the Canadian average was 7,842 exams per machine with the lower and the upper limits among the provinces being held respectively by P.E.I. and New Brunswick.

Average Hours of Operation of Medical Imaging Machines per Week

The average operating time per week is another indicator of the level of utilization of medical imaging machines. This information was collected in the National Survey of Selected Medical Imaging Equipment by asking respondents to report, for each type of equipment, the average number of hours the equipment was in operation on a weekly basis.

Average number of hours of operation by type of equipment per week for a given jurisdiction is computed by summing the average number of hours of operation per week reported for each machine and dividing by the total number of machines for which any hour of operation was reported. Figure 31 shows the average number of hours of operation per week by type of equipment in Canada. Table 7 provides the same information for each jurisdiction.

Figure 31. Average Number of Hours of Operation per Week, Selected Medical Imaging Technologies, Canada, 2003–2004 and 2004–2005



Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

Table 7. Average Number of Hours of Operation per Week, Selected Medical Imaging Technologies, by Jurisdiction and Canada, 2003–2004 and 2004–2005

Jurisdiction	Angiography Suites		Catheterization Labs		CT Scanners		MRI Scanners		Nuclear Medicine Cameras		PET Scanners	
	2003–2004	2004–2005	2003–2004	2004–2005	2003–2004	2004–2005	2003–2004	2004–2005	2003–2004	2004–2005	2003–2004	2004–2005
N.L.	40	40	50	50	56	47	84	90	38	35	n/a	n/a
P.E.I.	10	n/a	n/a	n/a	37	43	40	40	45	45	n/a	n/a
N.S.	37	36	37	37	49	50	78	71	37	37	n/a	n/a
N.B.	29	29	40	40	45	45	43	49	41	41	n/a	n/a
Que.	35	35	41	45	67	55	58	55	41	40	33	34
Ont.	38	39	44	45	70	65	84	82	37	37	32	33
Man.	30	33	38	38	66	55	88	88	42	40	n/a	n/a
Sask.	50	50	44	44	46	49	52	61	40	40	n/a	n/a
Alta.	43	43	41	44	57	57	56	62	43	42	40	40
B.C.	37	40	49	54	52	52	54	54	43	44	28	34
Y.T.	n/a	n/a	n/a	n/a	35	35	n/a	n/a	n/a	n/a	n/a	n/a
N.W.T.	n/a	n/a	n/a	n/a	38	38	n/a	n/a	n/a	n/a	n/a	n/a
Nun.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Canada	**37**	**38**	**43**	**45**	**62**	**57**	**66**	**66**	**40**	**39**	**34**	**35**

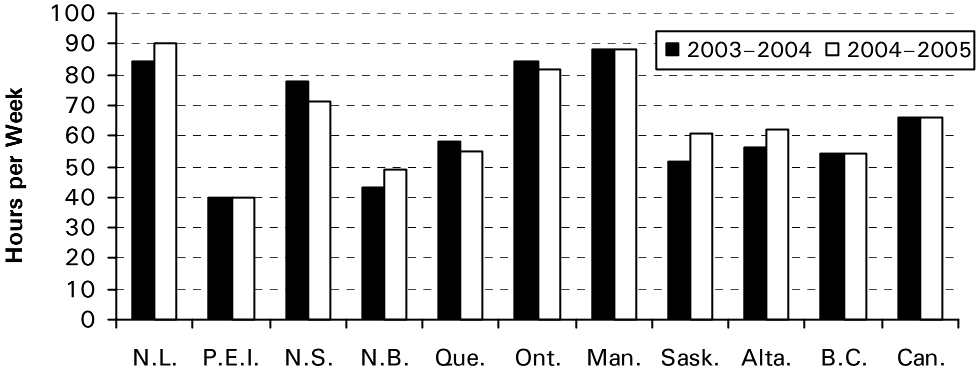
Note:
n/a = not applicable

Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

At the national level, the average number of hours of operation per week is generally higher for MRI and CT scanners than for the other types of equipment. For nuclear medicine cameras, angiography suites and catheterization labs, it tends to gravitate around a typical full-time workweek, while it is slightly lower for PET scanners. The pattern is similar for 2003–2004 and 2004–2005.

Figures 32 and 33 present, respectively, the average number of hours of operation per week for MRI and CT scanners in 2003–2004 and 2004–2005 by jurisdiction.

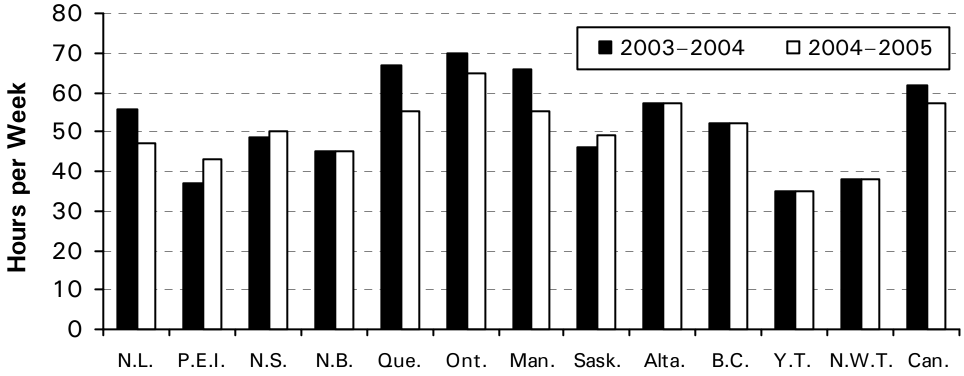
Figure 32. Average Number of Hours of Operation per Week, Magnetic Resonance Imaging (MRI) Scanners, by Jurisdiction and Canada, 2003–2004 and 2004–2005



Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

The average number of hours of operation per week for MRI scanners in 2004–2005 ranged from 40 hours in P.E.I. to 90 hours in Newfoundland and Labrador. The Canadian average (66 hours) remained almost the same as the 1997 average (64 hours) reported in the April 1999 issue of the *Canadian Association of Radiologists Journal*.[1] There is less variability in the number of hours of operation per week for CT scanners among provinces. In 2004–2005, the provincial averages ranged from 43 hours in P.E.I. to 65 hours in Ontario, with a national average of 57 hours.

Figure 33. Average Number of Hours of Operation per Week, Computed Tomography (CT) Scanners, by Jurisdiction and Canada, 2003–2004 and 2004–2005



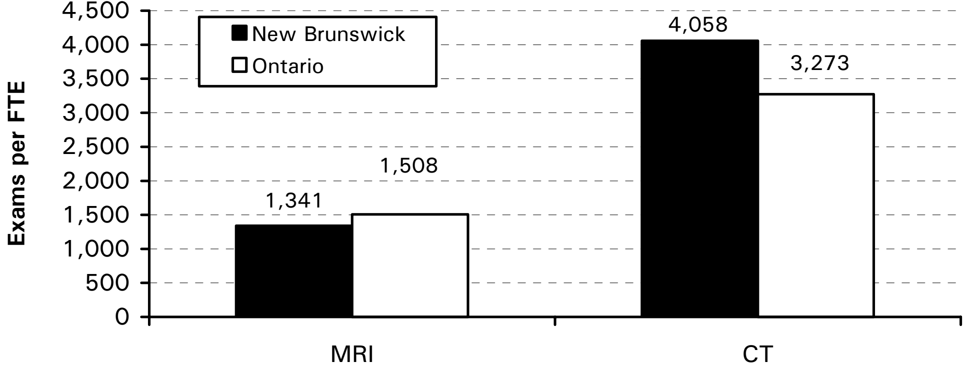
Source: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information.

Jurisdictions with lower numbers of scanners per million population in 2004–2005 generally had longer hours of operation per week than jurisdictions with higher numbers of scanners per million population. This negative relationship between the number of machines per million population and average hours of operation per week is stronger for CT than for MRI.[viii]

Average Number of Exams per FTE Technologist

Average number of exams per FTE technologist is a workload indicator that combines the efficiency of medical imaging equipment and the skills of medical imaging professionals. Average number of MRI exams per FTE for a given jurisdiction is the total number of MRI exams for a one-year period in the jurisdiction divided by the total number of FTE technologists working in the MRI service.[ix] Total number of FTE working in the MRI service is obtained from the Canadian MIS Database (CMDB) by summing earned hours of MRI technologists for a one-year period divided by 1950 (based on a 37.5-hour workweek and 52 weeks per year). The same method applies for CT. Figure 34 shows average number of MRI and CT exams per FTE technologist for New Brunswick and Ontario for the fiscal year 2003–2004. Only these two provinces submit data on earned hours for unit producing personnel by occupations in the CMDB. At the time of the analysis, CMDB data for 2004–2005 were not available.

Figure 34. Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Exams per FTE Technologist, New Brunswick and Ontario, 2003–2004



Sources: National Survey of Selected Medical Imaging Equipment (2004)
Canadian Institute for Health Information; Canadian MIS Database (2003–2004).

Ontario has an average of 1,508 MRI exams per FTE technologist in 2003-2004, slightly higher than New Brunswick (1,341). This situation is reversed with regard to CT: New Brunswick leads with an average of 4,058 CT exams per FTE technologist, compared to an average of 3,273 in Ontario.

---

viii. Based on a linear regression of the two variables, the coefficient of determination (R^2) = 0.79 for CT and 0.42 for MRI.

ix. According to the 2004 National Survey of Selected Medical Imaging Equipment, there were no free-standing facilities in New Brunswick or Ontario. Therefore, this analysis is based on FTE counts from the Canadian MIS Database and exam counts from the survey, in hospitals only.

International Comparisons

While the chapter on supply of medical imaging technologies provides comparisons on number of machines in OECD countries for which data were available, this chapter on utilization compares indicators with only the U.S. and England because most of the indicators are not available in other countries.

Table 8 compares MRI and CT exams per 1,000 population, per scanner and per FTE diagnostic imaging technologist, as well as hours of operation of scanners per week, between the U.S.,[2, 3] England [4] and Canada.

Table 8. Average Number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) Exams per 1,000 Population, per Scanner, per FTE Technologist, and Average Number of Hours of Operation of Scanners per Week in the U.S., England and Canada, 2004–2005 or Latest Year

Country	Exams per 1,000 Population		Exams per Scanner		Exams per FTE		Hours of Operation per Scanner per Week	
	MRI	CT	MRI	CT	MRI	CT	MRI	CT
United States	83.2	172.5	3,412[a]	5,298[b]	1,195[a]	1,790	70.0	57.6
England[e]	19.0	43.0	3,513	--	517	1,173	--	--
Canada	**25.5**	**87.3**	**4,666[f]**	**7,745[f]**	**1,341[c]/1,508[d]**	**4,058[c]/3,273[d]**	**66.0**	**57.0**

Notes:

"--" = not available.

a) Based on exams performed in hospital sites with fixed MRI scanners.

b) Based on the total number of CT exams and total number of fixed CT scanners. It is implicitly assumed that the 1.8% of sites (130 out of 7,355) using mobile scanners perform a negligible number of exams.

c) Rate for New Brunswick in 2003–2004. New Brunswick and Ontario are the only two provinces that submit data to the CMDB on earned hours of technologists.

d) Rate for Ontario in 2003–2004. Ontario and New Brunswick are the only two provinces that submit data to the CMDB on earned hours of technologists.

e) Includes exams in the public sector only.

f) For improved international comparability, average number of exams per scanner in Canada was calculated by dividing the total number of exams by the total number of scanners installed, including scanners installed but not yet in operation. This differs from the calculation method used for interprovincial comparisons in Figures 29 and 30, where the total number of exams was divided by the number of scanners for which any exam was reported.

Sources: UK: KH12 returns, UK Department of Health, Hospital Activity Statistics, 2004–2005; **U.S.**: IMV, Medical Information Division, Benchmark MRI and CT Reports, 2004; **Canada**: National Survey of Selected Medical Imaging Equipment (2004 and 2005), Canadian Institute for Health Information; Canadian MIS Database (CMDB), 2003–2004.

Although the U.S. has almost five times as many MRI scanners per million population as Canada (see Figure 18), the number of MRI exams per 1,000 population performed in the U.S.[x] was just over three times that in Canada. The number of MRI exams per scanner was 37% higher in Canada than in the U.S, explaining the smaller difference between the two countries in exams per 1,000 population than in scanners per million population. The number of MRI exams per FTE technologist was also somewhat higher in two Canadian provinces

---

x. A definition of exams is not provided in the U.S. report. However, further investigation suggests that an exam in the U.S. is defined as the number of scans relating to one body part.

than in the U.S. With regard to CT, the number of exams per 1,000 population in the U.S. was almost twice that in Canada. However, the number of CT exams per scanner was 46% higher in Canada than in the U.S. The number of CT exams per FTE technologist was also substantially higher in two Canadian provinces than in the U.S. For both MRI and CT, the data indicate that even though the U.S. has more scanners per million population than Canada, the scanners are used more intensively in Canada. There is evidence of oversupply of some medical technology equipment in the U.S., including MRI and CT scanners.[5, 6]

The number of scanners and exams reported for England in Table 8 is for the public sector only. According to data reported in the section on Sources and Methods of *OECD Health Data 2005,*[7] fewer than 5% of scanners were in the private sector (at the most, 12 MRI and 3 CT scanners). Therefore, in Table 8, there is a small under-estimation of scanners in England. These considerations should be taken into account in the comparison with England.

About 34% more MRI exams per 1,000 population were performed in Canada than in England, even though the two countries had about the same number of MRI scanners per million population. There were about one third more MRI exams per scanner in Canada than in England.[xi] As of January 1, 2004, Canada had about 60% more CT scanners per million population than the UK (within the UK, a separate count of CT scanners for England was unavailable). The number of CT exams per 1,000 population in Canada was about twice that in England.

The number of weekly hours MRI scanners are in operation in Canada is about 6% lower than in the U.S., while CT scanners are in operation about the same number of hours in both countries.

The European Association of Radiologists (EAR) and the Union européenne des médecins spécialistes (UEMS) reported on MRI and CT utilization. Utilization rates vary extensively among EU countries: MRI exams per 1,000 population ranged from 5 in Poland to about 60 in Austria, and CT exams per 1,000 population ranged from about 17 in Poland to 120 in Belgium.[8]

POSSIBLE FACTORS LIMITING ACCESS TO MRI AND CT EXAMS

In spite of the fact that on average, Canada uses its MRI and CT scanners more intensively than the U.S. and England, in some jurisdictions, both average number of exams and average number of hours in operation seem to indicate an underutilization of MRI and CT machines (see Figures 29 to 33). Many factors might explain the low number of exams performed per scanner: insufficient operating funds, staffing unavailability, age of equipment, technical problems, etc. This raises the question, “Do we need more machines (or newer machines) or do we need more funding and staff to operate the existing machines?” This issue is examined in the following pages with a discussion of capital funding, operating funding and human resources. Most examples or evidence refer to Ontario, because more studies are available for this province.

[xi] A definition of exams is not provided in the imaging and radio-diagnostics annual statistics for England. However, further investigation suggests that the data should be reported as one unit of activity for each time the machine is operated.

Capital Funding

In general, the newer the machine, the faster it can perform exams per unit of time. Therefore, it is important to know how frequently the existing imaging technologies are renewed in Canada.

More high-level MRI and CT scanners are probably required to meet the needs of the growing and ageing population in some jurisdictions. More up-to-date technologies can improve access to care either by replacing more invasive and thereby more risky procedures, or by providing images of higher quality with better anatomical detail, which results in less need for repeat tests and more accurate diagnosis. It follows that the productivity of radiologists and technologists could improve with newer machines.

Figure 22 in chapter 2 shows the percentage distribution of machines by age cohort for selected medical imaging equipment. State-of-the-art technology is rather predominant in the medical imaging field, particularly for MRI and CT, where, as of January 2005, only respectively 6% and 4% of the scanners were older than 10 years.

Although some of the machines are more than 10 years old, standards for evaluating ageing equipment in Canada have not been developed. These standards exist for other countries. For example, the European Coordination Committee of the Radiological and Electromedical Industries has rules for the evaluation of medical equipment (see Table 9).

Table 9. Rules for the Evaluation of Medical Equipment

Age of Equipment	Rules
Up to 5 Years Old	■ Reflects current state of technology ■ Offers economic and reasonable upgrade measures ■ At least 60% of the installed equipment base should be younger than 5 years
6 to 10 Years Old	■ Still fit for use but requires replacement strategies to be developed ■ Not more than 30% of the installed equipment base should be between 6 and 10 years old
Older Than 10 Years	■ No longer state-of-the-art technology ■ Not more than 10% of the installed base can be tolerated to be older than 10 years ■ Replacement is essential

Source: European Coordination Committee of the Radiological and Electromedical Industries (Reproduced from the Ontario *MRI and CT Expert Panel Phase I Report*, April 2005).

Chapter 2 of this report has already reported on recent commitments by the federal government for the funding of medical equipment. At the provincial level, initiatives or implementations are also underway. For example, in the context of the wait time strategy, the Ontario government announced investment to upgrade MRI and CT scanners:[9]

- $21 million to replace old MRI scanners at seven hospitals, delivering 18,581 new exams a year; and
- $45.3 million to replace old CT scanners at 23 hospitals, delivering 81,268 more exams a year.

Because these investments do not line up with any replacement standard and are rather ad hoc, the MIT and CT Expert Panel recommended that the Ontario Ministry of Health and Long-Term Care (OMHLTC) establish a regular upgrade and replacement schedule for outdated equipment.

Along with appropriate capital funding, adequate operating funding and sufficient human resources are required to meet the demand for MRI and CT services.

Operating Funding

MRI scanners, in particular, seem to suffer from operating funding limitations as echoed by the MRI and CT Expert Panel Report commissioned by the Ontario's Wait Time Strategy agency;[10] the most comprehensive examination of MRI and CT utilization ever undertaken in Ontario. The report concludes that, while some hospitals with MRI scanners are at 161% efficiency, others operate only at 28% efficiency—the average efficiency being 72%. It recommends an increase in funding so that MRI machines can operate a minimum of 16 hours a day, seven days a week. The authors of the report warn against rushing to buy more MRI and CT scanners. They suggest operating the ones available at maximum capacity first.

As part of its wait time strategy, the Ontario government aims to shorten wait times for five key health services, including diagnostic imaging. The government has invested $5 million to extend the hours of operation of existing MRIs in 29 hospitals, which should be translated into the delivery of 19,000 more exams in 2004–2005.[9] For 2005–2006, the government is targeting funding through this wait time plan to deliver 39,500 more MRI exams than in 2004–2005.[11]

Human Resources

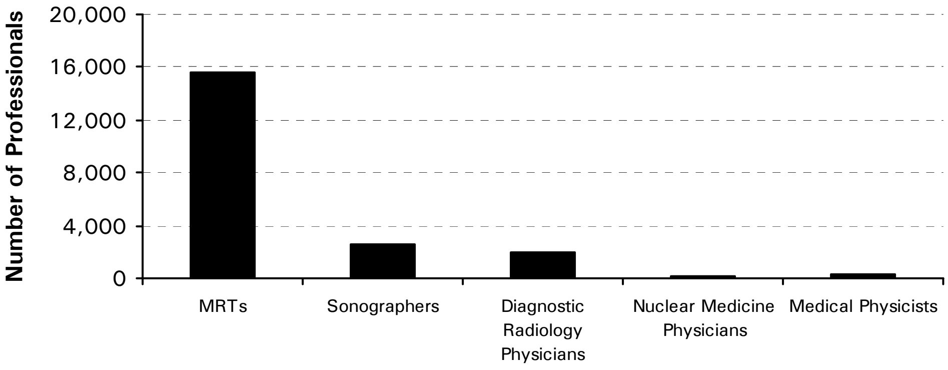
Today's sophisticated imaging technologies require skilled professionals in sufficient numbers to guide patients through the testing process, operate the machines and interpret test results. A lack of medical imaging professionals could limit access to MRI and CT services.

The Medical Imaging Workforce

Medical imaging professionals are a diverse group. The size, composition, distribution and interrelationships among these professionals can vary depending on the characteristics of the imaging facility, such as the geographic location and the procedures being performed. Figure 35 shows the number of selected medical imaging professionals in Canada.

The 15,667 medical radiation technologists (MRTs) make up the bulk of the medical imaging workforce in 2004. They include radiological, nuclear medicine, radiation therapy and magnetic resonance technologists (for detailed information and the role of these technologists, see *Medical Imaging in Canada, 2004*).

Figure 35. Number of Selected Medical Imaging Professionals, Canada, 2004



Sources: Labour Force Survey, Statistics Canada (sonographer data); Southam Medical Database, CIHI (physician data); Health Personnel Database, CIHI (medical physicists and MRT data).

Notes:

a) The MRT category includes radiological technologists, magnetic resonance technologists, nuclear medicine technologists and radiation therapists.

b) The estimate for sonographers should be used with caution due to small size of survey sample.

c) Physician data are as of December 31, 2004, and include physicians in clinical and/or non-clinical practice. Data exclude residents and physicians who are not licensed to provide clinical practice and those who have requested to the Business Information Group (formerly Southam Medical Group) that their data not be published. Specialty is based on most recent certified specialty, and data may differ from other sources of provincial/territorial physician data that categorize physicians on some other basis (for example, functional specialty, payment specialty or provisional licences). Diagnostic radiology and nuclear medicine physicians include certificants of the Royal College of Physicians and Surgeons of Canada or the Collège des médecins du Québec.

d) Data for medical physicists include only those registered with the Canadian Organization of Medical Physicists.

There were approximately 2,600 sonographers (also known as ultrasonographers) practising across Canada in 2004. In Quebec, they are grouped with MRTs and are regulated accordingly, while in the rest of Canada, they are considered a separate professional group.

The rest of the medical imaging workforce is relatively small and made up of diagnostic radiology physicians (1967), nuclear medicine physicians (218) and medical physicists (297).

The question is whether this represents an appropriate supply of medical imaging personnel. Looking at the employment of MRTs could shed some light on this question.

Employment of Medical Imaging Professionals

While the supply of medical imaging professionals has been monitored for some time in Canada, few studies discuss their employment. The employment issue is examined below based on different sources of information: a study from the Canadian Association of Medical Radiation Technology (CAMRT),[12] the Labour Force Survey from Statistics Canada, some health personnel databases from CIHI and the MRI and CT Expert Panel Phase I Report chaired by Dr. A. Keller.[10]

In a survey conducted by the Canadian Association of Medical Radiation Technology, radiation therapy exam candidates reported the highest full-time employment rate of all MRTs, after their graduation (96% in 2004). They were followed by nuclear medicine and magnetic resonance candidates with level of full-time employment reaching 80% and 77%, respectively.

However, the job prospect was not that bright for other imaging professionals: for example, radiological technology had the lowest percentage of candidates finding full-time employment (41%). Also, 25% of all exam candidates were unemployed and seeking work in their field at exam time.

Moreover, there is a substantial difference between males and females when it comes to being employed on a permanent full-time basis. Of men reporting that they had some form of employment when they wrote the exams in 2004, 61% indicated that they had obtained permanent full-time work; only 43% of women were in the same situation.

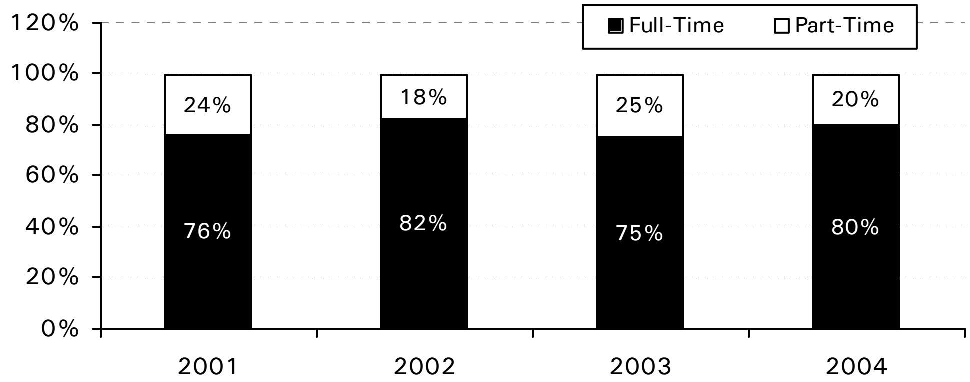
Women have consistently reported finding more casual/on-call work arrangements than men. Unfortunately, the survey did not ask exam candidates if they were satisfied with the type of work (full-time, part-time or casual/on-call) that they had obtained or if they would prefer another work arrangement. This is an important consideration since, according to the 2001 Census from Statistics Canada, 80% of the medical radiation technologists are women.

A Health Canada report[13] noted that, for a number of reasons, employers perceive casual and part-time work as an effective approach to delivery of service. Casual employees are less costly as they do not receive benefits. The authors also suggested that evening and weekend demands for diagnostic imaging services might be more easily alleviated with part-time/casual positions.

Also, full-time technologists in hospitals are unionized, which means that employers must offer full-time work to the senior staff. Female physicians tend to have different practice patterns from their male colleagues. In the case of female MRTs, it is not known whether the different work pattern is preferred or not.

Another source of information for employment of MRTs is the Labour Force Survey, from Statistics Canada. Figure 36 reports the percentage of MRTs working full-time in Canada from 2001 to 2004. In all years, at least 75% of MRTs worked full-time. This is in line with the CAMRT survey. Note that the fluctuations between years could be due to small sample size.

Figure 36. Percentage of Medical Radiation Technologists (MRTs) Working Full-Time/Part-Time, Canada, 2001 to 2004



Source: Labour Force Survey, Statistcs Canada.

Note:
Percentage estimates should be used with caution due to the small sample size of the survey.

From these sources, it is difficult to conclude whether there is a labour shortage among the medical imaging professionals. However, for some fields such as radiation therapy, some provinces such as Newfoundland and Labrador and Nova Scotia sponsor education in return for a signed work contract. Saskatchewan uses this strategy for magnetic resonance education. This is an indication of the scarcity of professionals in these fields.

The Ontario MRI and CT Expert Panel Report suggests a shortage of radiologists in Ontario. The report stated:

> "The hospital survey indicated that the number of radiologists impeded expansion of MRI and CT activities in 43% of MRI centres and 50% of CT centres. As well, 49 out of 71 hospitals reported trying to recruit radiologists. There are neither enough practising nor replacement radiologists coming on stream in Ontario. Older radiologists, with little or no training in MRI and CT, have tended to restrict their practices to other imaging modalities. The increasing demand for MRI and CT falls on only a proportion of the radiology workforce."

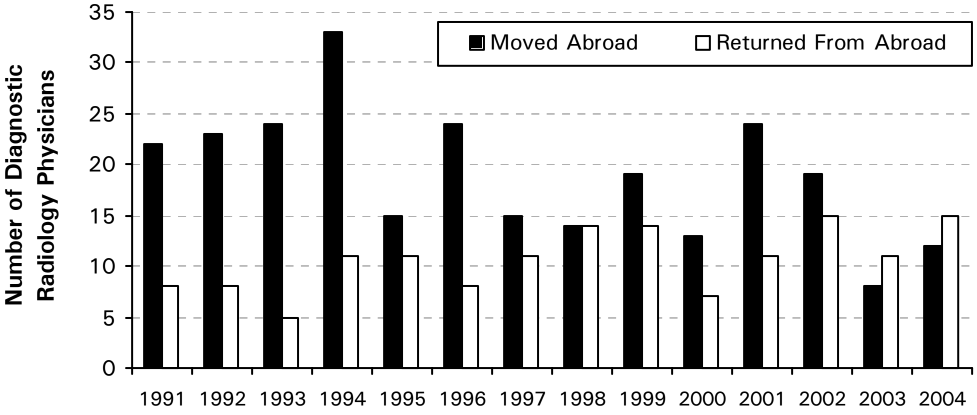
Other provinces are likely facing a similar situation as Ontario, because CT training has been in Canadian Diagnostic Radiology educational programs for just over 20 years, and MRI training for just over a decade. Moreover, the actual level of training in these areas varies slightly among the programs in the different provinces, even though all have been required to meet the basic mandatory educational goals for CT and MRI, as outlined in the Royal College of Physicians and Surgeons standards.[xii]

[xii] Personal communication with Dr. Edna Becker, Chair of the National Specialty Training Committee for Diagnostic Radiology.

It follows that CT and MRI skills of radiologists vary across the country. This relates not only to their level of training, but also to opportunities to use and maintain their skills.

Data on employment or practice are not available for medical imaging professionals other than MRTs. However, CIHI's Southam Medical Database tracks the number of diagnostic radiology physicians who moved abroad and returned from abroad, a significant indicator of the job market. Figure 37 shows these numbers for the last 14 years.

Figure 37. Total Number of Diagnostic Radiology Physicians Who Moved/Returned From Abroad, Canada, 1991 to 2004



Source: Southam Medical Database, Canadian Institute of Health Information.

Notes:

a) Data are as of December 31 of given year and include physicians in clinical and/or non-clinical practice. Data exclude residents and physicians who are not licensed to provide clinical practice and those who have requested to the Business Information Group (formerly Southam Medical Group) that their data not be published. Specialty is based on most recent certified specialty, and data may differ from other sources of provincial/territorial physician data that categorize physicians on some other basis (for example, functional specialty, payment specialty or provisional licence). Diagnostic radiology physicians include certificants of the Royal College of Physicians and Surgeons of Canada and the Collège des médecins du Québec.

b) Data from 2000 do not reflect annual updates from the Government of the Yukon and the College of Physicians and Surgeons of Alberta.

c) Data from 2002 do not reflect 4 of 12 monthly updates (September to December, 2002) from the College of Physicians and Surgeons of Ontario.

d) Does not include foreign physicians who have not previously practised in Canada.

In 2004, for the second consecutive year in more than a decade, more diagnostic radiology physicians returned to Canada than moved abroad. However, over the period from 1991 to 2004, there is a net loss of 116 physicians (265 diagnostic radiology physicians moved from Canada, while 149 returned from abroad), or 6% of the total supply of diagnostic radiology physicians in 2004.

REFERENCES

1. R. N. Rankin, "Magnetic Resonance Imaging in Canada: Dissemination and Funding," *Canadian Association of Radiologists Journal* 50, 2 (April 1999): pp. 89–92.

2. Information Services for the Health Care and Scientific Markets *Benchmark Report MRI 2004* (Des Plaines, Illinois: IMV Medical Information Division, Inc., 2005).

3. Information Services for the Health Care and Scientific Markets *Benchmark Report CT 2004* (Des Plaines, Illinois: IMV Medical Information Division, Inc., 2005).

4. United Kingdom Department of Health, Hospital Activity Statistics—Number of Imaging and Radiodiagnostics Examinations or Tests, NHS Organizations in England, [online], last modified October 15, 2004, cited September 13, 2005, from <www.performance.doh.gov.uk/hospitalactivity/data_requests/download/imaging_and_radiodiagnostics/imag_04.xls>.

5. P. B. Ginsburg and J. M. Grossman, "When The Price Isn't Right: How Inadvertent Payment Incentives Drive Medical Care," *Health Affairs*—Web Exclusive (August 9, 2005): pp. 376–384.

6. C. L. Bryce and K. E. Cline, "The Supply and Use of Selected Medical Technologies," *Health Affairs* 17, 1 (January/February 1998): pp. 213–24.

7. Organisation for Economic Co-operation and Development, *OECD Health Data 2005* (CD-ROM) (October 2005 version).

8. I. W. McCall, *Benchmarking Radiological Services in Europe*, [online], cited July 26, 2005, from <www.ear-online.org/download/Benchmarking_radiological_services_in_Europe.pdf>.

9. Government of Ontario, *Ministry of Health and Long-Term Care—McGuinty Government Reduces Wait Times By Delivering 119,865 Additional MRI, CT, Cancer and Cardiac Procedures*, [online], cited July 24, 2005, from <ogov.newswire.ca/ontario/GPOE/2005/02/03/c0243.html?1match=&lang=_e.html>.

10. A. Keller, Ontario Ministry of Health and Long-Term Care, Ontario's Wait Time Strategy, *MRI and CT Expert Panel Phase I Report* (Toronto: Ontario Ministry of Health and Long-Term Care, 2005), [online], cited July 22, 2005 from <www.health.gov.on.ca/transformation/wait_times/wt_reports/mri_ct.pdf>.

11. Government of Ontario, Ministry of Health and Long-Term Care—*Backgrounder: Improving Access to 5 Key Healthcare Surgeries and Procedures*, [online], cited August 4, 2005, from <ogov.newswire.ca/ontario/GPOE/2005/05/27/c4378.html?lmatch=&lang=_e.html>.

12. A. Wenzl and R. Lauzon (CAMRT), “Employment of Medical Radiation Technology National Exam Candidates in Canada, 2000–2004,” *The Canadian Journal of Medical Radiation Technology* 36, 1 (2005): pp. 3–11.

13. Health Canada, *Assessment Strategies, An Environmental Scan of the Human Resource Issues Affecting Medical Laboratory Technologists and Medical Radiation Technologists 2001* (Ottawa: Health Canada, 2002), [online], cited September 13, 2005 [online], from <www.hc-sc.gc.ca/hppb/healthcare/pdf/environment_scan.pdf>.

Appendix A

Fast Facts

Medical Imaging in Canada, 2005

List of Appendix A Data Tables

A.1 Number of Magnetic Resonance Imaging (MRI) Scanners, by Province/Territory, Canada, 1991 to 2005 .... A–1

A.2 Number of Computed Tomography (CT) Scanners, by Province/Territory, Canada, 1991 to 2005 .... A–2

A.3 Number of Nuclear Medicine Physicians, by Province/Territory, Canada, 1993 to 2004 .... A–3

A.4 Number of Diagnostic Radiologists, by Province/Territory, Canada, 1993 to 2004 .... A–4

A.5 Number of Members of Medical Radiation Technologists' Associations in the Discipline of Nuclear Medicine, by Province/Territory, Canada, 1993 to 2004 .... A–5

A.6 Number of Members of Medical Radiation Technologists' Associations in the Discipline of Radiological Technology, by Province/Territory, Canada, 1993 to 2004 .... A–6

A.7 Distribution of Imaging Technologies for Hospitals (H) and Free-Standing Imaging Facilities (FS), by Survey Year, by Province/Territory, Canada A–7

A.8 Results From the Health Services Access Surveys, 2001 and 2003 .... A–8

List of Appendix A Figures

A.1 Angiography Suites in Hospitals and Free-Standing Facilities Across Canada, 2005 .... A–9

A.2 Cardiac Catheterization Laboratories in Hospitals and Free-Standing Facilities Across Canada, 2005 .... A–9

A.3 Computed Tomography (CT) Scanners in Hospitals and Free-Standing Facilities Across Canada, 2005 .... A–10

A.4 Computed Tomography (CT) Scanners per Million Provincial Population and Exams per 1,000 Provincial Population, 2003, 2004 and 2005 .... A–11

A.5 Magnetic Resonance Imaging (MRI) Scanners in Hospitals and Free-Standing Facilities Across Canada, 2005 .... A–12

A.6 Magnetic Resonance Imaging (MRI) Scanners per Million Provincial Population and Exams per 1,000 Provincial Population, 2003, 2004 and 2005 .... A–13

A.7 Nuclear Medicine Cameras in Hospitals and Free-Standing Facilities Across Canada, 2005 .... A–13

A.8 Positron Emission Tomography (PET) Scanners in Hospitals and Free-Standing Imaging Facilities Across Canada, 2005 .... A–14

Table A.1. Number of Magnetic Resonance Imaging (MRI) Scanners, by Province/Territory, Canada, 1991 to 2005

	N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.	N.W.T.	Nun.	Can.
1991	0	0	1	0	4	10	1	1	2	3	0	0		22
1992	0	0	1	0	4	11	1	1	5	5	0	0		28
1993	1	0	1	0	5	11	1	1	5	5	0	0		30
1994	1	0	1	0	8	12	0	1	6	6	0	0		35
1995	1	0	1	1	10	12	1	1	6	7	0	0		40
1996	--	--	--	--	--	--	--	--	--	--	--	--		--
1997	1	0	1	1	12	23	1	1	6	9	0	0		55
1998	--	--	--	--	--	--	--	--	--	--	--	--		--
1999	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2000	1	0	2	2	--	42	3	3	13	10	0	0	0	76
2001	1	0	2	5	35	44	3	3	23	14	0	0	0	130
2002	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2003	1	0	4	5	38	50^{R}	3	3	24^{R}	18	0	0	0	146
2004	1	1	4	5	42^{R}	52	4^{R}	3	24^{R}	21^{R}	0	0	0	157
2005	1	1	5	5	49	58	6	3	25	23	0	0	0	176

Notes:
"--" = not available; "R" = data are revised.

a) Surveys were not carried out in 1996, 1998, 1999 and 2002.

b) CCOHTA notes that Quebec data were incomplete for 2000; therefore, they are not included.

c) Units located both in hospitals and in free-standing imaging facilities are included for Canada for all years. The number of MRI scanners in free-standing imaging facilities was imputed for years prior to 2003 based on data collected in the 2003 National Survey of Selected Medical Imaging Equipment.

d) 2005 data are as of January 1. Some additional equipment has subsequently been installed.

Sources: National Inventory of Selected Imaging Equipment, Canadian Coordinating Office for Health Technology Assessment (MRIs in hospitals, 1991–2001); National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information (2003, 2004 and 2005).

Table A.2. Number of Computed Tomography (CT) Scanners, by Province/Territory, Canada, 1991 to 2005

	N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.	N.W.T.	Nun.	Can.
1991	5	1	7	6	58	65	8	5	22	23	0	0		200
1992	5	1	8	7	60	68	8	6	22	23	0	0		208
1993	6	1	8	7	60	72	9	6	24	23	0	0		216
1994	6	1	8	7	62	76	10	6	23	24	0	0		223
1995	6	1	9	7	68	79	10	6	23	25	0	0		234
1996	--	--	--	--	--	--	--	--	--	--	--	--		--
1997	6	1	9	8	69	84	10	7	23	28	0	0		245
1998	--	--	--	--	--	--	--	--	--	--	--	--		--
1999	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2000	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2001	9	2	14	9	92	91	13	9	25	38	0	1	0	303
2002	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2003	10	2	15	9	97^{R}	97^{R}	14	11^{R}	30	44	1	1	0	331
2004	10	3	15	9	102^{R}	102^{R}	17	12^{R}	30	44	1	1	0	346
2005	10	3	15	11	106	108	17	13	30	46	1	1	0	361

Notes:

"--" = not available; "R" = data are revised.

a) Surveys were not carried out in 1996, 1998 to 2000, and 2002.

b) Units located both in hospitals and in free-standing imaging facilities are included for Canada for all years. The number of CT scanners in free-standing imaging facilities was imputed for years prior to 2003 based on data collected in the 2003 National Survey of Selected Medical Imaging Equipment.

c) 2005 data are as of January 1. Some additional equipment has subsequently been installed.

Source: National Inventory of Selected Imaging Equipment, Canadian Coordinating Office for Health Technology Assessment (CTs in hospitals, 1991–2001); National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information (2003, 2004 and 2005).

Table A.3. Number of Nuclear Medicine Physicians, by Province/Territory, Canada, 1993 to 2004

	N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.	N.W.T.	Nun.	Can.
1993	2	0	2	2	78	56	8	5	7	15	0	0		175
1994	2	0	3	2	83	57	8	3	10	21	0	0		189
1995	2	0	3	3	88	59	7	3	11	21	0	0		197
1996	2	0	3	3	88	62	7	4	13	20	0	0		202
1997	2	0	3	3	88	66	8	3	14	19	0	0		206
1998	2	0	3	3	89	67	8	3	13	21	0	0		209
1999	2	0	4	3	87	74	8	3	15	22	0	0	0	218
2000	2	0	4	3	87	74	8	3	14	22	0	0	0	217
2001	2	0	5	3	85	75	6	3	13	22	0	0	0	214
2002	2	0	6	3	84	71	7	3	15	21	0	0	0	212
2003	2	0	6	3	84	73	7	3	15	20	0	0	0	213
2004	3	0	5	3	87	71	7	4	16	22	0	0	0	218

Notes:

a) Data exclude residents and physicians who are not licensed to provide clinical practice and have requested to the Business Information Group (formerly Southam Medical Group) that their data not be published.

b) Data as of December 31 of a given year include physicians in clinical and/or non-clinical practice, including research, teaching or administration. Specialty is based on most recent certification with the Royal College of Physicians and Surgeons of Canada or the Collège des médecins du Québec. Results may differ from other sources of provincial and territorial physician data that categorize physicians on some other basis (for example, functional specialty, payment specialty or provisional licences). For example, the Newfoundland Medical Board includes provisionally licensed, non-certified specialists in its specialist physician counts. The provisional licence information for these physicians is not available in the Southam Medical Database and these physicians are, therefore, excluded from the diagnostic radiology and nuclear medicine physician counts presented in this report.

c) Caution must be exercised when comparing Northwest Territories data prior to 1999 with Northwest Territories data after 1998, since some of the change may be attributable to the creation of the new territory of Nunavut.

d) Yukon Territory and Alberta data in 2000 (and subsequently the Canada total) do not reflect the annual update from the Government of the Yukon or the College of Physicians and Surgeons of Alberta, respectively.

e) Ontario data in 2002 do not reflect 4 of 12 monthly updates (September to December, 2002) from the College of Physicians and Surgeons of Ontario.

f) Nuclear Medicine physicians include certificants of the Royal College of Physicians and Surgeons of Canada and the Collège des médecins du Québec.

Source: Southam Medical Database, Canadian Institute for Health Information.

Table A.4. Number of Diagnostic Radiologists, by Province/Territory, Canada, 1993 to 2004

	N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.	N.W.T.	Nun.	Can.
1993	27	4	70	38	437	661	60	45	149	228	0	2		1,721
1994	25	5	71	41	462	666	57	48	150	224	0	1		1,750
1995	27	5	69	41	473	656	62	50	150	229	0	1		1,763
1996	27	4	66	43	484	650	62	50	153	233	0	1		1,773
1997	27	6	69	43	493	666	65	51	159	242	0	2		1,823
1998	30	6	73	44	505	675	63	50	168	236	0	2		1,852
1999	31	6	79	44	504	689	64	49	182	234	0	2	0	1,884
2000	31	6	81	46	500	702	63	51	180	236	0	2	0	1,898
2001	30	6	70	42	506	721	60	45	192	230	0	1	0	1,903
2002	31	4	70	41	495	733	57	45	205	231	0	1	0	1,913
2003	32	5	70	41	486	726	56	41	214	235	0	0	0	1,906
2004	30	6	69	48	507	746	58	45	224	234	0	0	0	1,967

Notes:

a) Data exclude residents and physicians who are not licensed to provide clinical practice and have requested to the Business Information Group (formerly Southam Medical Group) that their data not be published.

b) Data as of December 31 of a given year include physicians in clinical and/or non-clinical practice, including research, teaching or administration. Specialty is based on most recent certification with the Royal College of Physicians and Surgeons of Canada or the Collège des médecins du Québec. Results may differ from other sources of provincial and territorial physician data that categorize physicians on some other basis (for example, functional specialty, payment specialty or provisional licenses). For example, the Newfoundland Medical Board includes provisionally licensed, non-certified specialists in its specialist physician counts. The provisional licence information for these physicians is not available in the Southam Medical Database and these physicians are, therefore, excluded from the diagnostic radiology and nuclear medicine physician counts presented in this report.

c) Caution must be exercised when comparing Northwest Territories data prior to 1999 with Northwest Territories data after 1998, since some of the change may be attributable to the creation of the new territory of Nunavut.

d) Yukon and Alberta data in 2000 (and subsequently the Canada total) do not reflect the annual update from the Government of the Yukon or the College of Physicians and Surgeons of Alberta, respectively.

e) Ontario data in 2002 do not reflect 4 of 12 monthly updates (September to December, 2002) from the College of Physicians and Surgeons of Ontario.

Source: Southam Medical Database, Canadian Institute for Health Information.

Table A.5. Number of Members of Medical Radiation Technologists' Associations in the Discipline of Nuclear Medicine, by Province/Territory, Canada, 1993 to 2004

	N.L.	P.E.I.	N.S.	N.B.	Que.*	Ont.†	Man.	Sask.	Alta.	B.C.	Terr.	Can.
1993	14	3	63	26	--	525‡	45	26	125	153	--	980
1994	15	3	63	29	--	577	44	27	126	171	--	1,055
1995	17	3	70	32	--	572	45	27	124	169	--	1,059
1996	15	2	65	34	--	593	44	29	120	171	--	1,073
1997	16	3	66	36	--	593	44	25	117	178	--	1,078
1998	15	4	68	36	--	604	46	27	125	181	--	1,106
1999	15	5	64	38	--	604	47	32	121	180	--	1,106
2000	14	5	62	42	--	615	45	30	140	186	--	1,139
2001	16	5	63	43	395	638	44	33	142	191	--	1,570
2002	13	6	73	47	403	647	45	35	151	192	--	1,612
2003	17	4	75	48	419	655	44	40	197	207	--	1,706
2004	17	5	75	53	424	663	44	38	224	209	--	1,752

Notes:
"--" = not available.

Members qualifying in other disciplines are counted in other disciplines.

† Ontario data represent active registered members of the College of Medical Radiation Technologists of Ontario.

‡ The 1993 data were generated by the Board of Radiological Technicians and include members other than "active"; therefore, the data are not comparable with data from after 1993.

* Quebec data represent active registered members of the Ordre des technologues en radiologie du Québec.

Source: Health Personnel Database, Canadian Institute for Health Information.

Table A.6. Number of Members of Medical Radiation Technologists' Associations in the Discipline of Radiological Technology, by Province/Territory, Canada, 1993 to 2004

	N.L.	P.E.I.	N.S.	N.B.	Que.[*]	Ont.[†]	Man.	Sask.	Alta.	B.C.	Terr.	Can.
1993	239	67	457	368	--	4,594[‡]	548	351	1,204	1,258	--	9,086
1994	240	62	446	378	--	4,346	567	368	1,142	1,292	--	8,841
1995	245	63	432	388	--	4,319	580	360	1,128	1,298	--	8,813
1996	235	64	414	393	--	4,198	570	355	1,093	1,315	--	8,637
1997	236	62	428	382	--	4,118	537	356	1,101	1,350	--	8,570
1998	235	67	411	399	--	4,158	543	356	1,151	1,337	--	8,657
1999	234	63	405	403	--	4,133	530	356	1,153	1,319	--	8,596
2000	237	60	399	398	--	4,136	526	369	1,187	1,352	--	8,664
2001	249	64	383	393	2,991	4,163	509	377	1,208	1,316	--	11,653
2002	251	62	391	409	2,999	4,202	511	369	1,226	1,290	--	11,710
2003	265	65	408	396	3,130	4,167	511	395	1,354	1,361	--	12,052
2004	263	71	408	415	3,201	4,155	537	376	1,410	1,393	--	12,229

Notes:
"--" = not available.

Members qualifying in other disciplines are counted in other disciplines.

[†] Ontario data represent active registered members of the College of Medical Radiation Technologists of Ontario.

[‡] The 1993 data were generated by the Board of Radiological Technicians and include members other than "active"; therefore, the data are not comparable with data from after 1993.

[*] Quebec data represent active registered members of the Ordre des technologues en radiologie du Québec.

Source: Health Personnel Database, Canadian Institute for Health Information.

Table A.7. Distribution of Imaging Technologies for Hospitals (H) and Free-Standing Imaging Facilities (FS), by Survey Year, by Province/Territory, Canada

Modality		N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.	N.W.T.	Nun.	Can.
As of January 1, 2003															
Nuclear Medicine Cameras	H	11	2	23	18	153	248	18	15	41	61	0	0	0	590
	FS	0	0	0	0	2	12	0	0	22	0	0	0	0	36
CT Scanners	H	10	2	15	9	91	97	14	11	27	43	1	1	0	321
	FS	0	0	0	0	6	0	0	0	3	1	0	0	0	10
Angiography Suites	H	3	1	5	9	38	66	3	4	15	20	0	0	0	164
	FS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MRI Scanners	H	1	0	3	5	24	50	3	3	18	14	0	0	0	121
	FS	0	0	1	0	14	0	0	0	6	4	0	0	0	25
Catheterization Labs	H	2	0	3	2	22	36	4	4	11	11	0	0	0	95
	FS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PET Scanners	H	0	0	0	0	4	6	0	0	2	1	0	0	0	13
	FS	0	0	0	0	0	0	0	0	0	1	0	0	0	1
As of January 1, 2004															
Nuclear Medicine Cameras	H	12	2	25	19	151	262	19	17	43	68	0	0	0	618
	FS	0	0	1	0	4	14	0	0	22	0	0	0	0	41
CT Scanners	H	10	3	15	9	96	102	17	10	27	43	1	1	0	334
	FS	0	0	0	0	6	0	0	2	3	1	0	0	0	12
Angiography Suites	H	3	0	6	7	41	71	4	5	14	20	0	0	0	171
	FS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MRI Scanners	H	1	1	3	5	27	52	4	3	18	16	0	0	0	130
	FS	0	0	1	.	15	0	0	0	6	5	0	0	0	27
Catheterization Labs	H	2	0	5	2	23	40	4	4	11	12	0	0	0	103
	FS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PET Scanners	H	0	0	0	0	4	7	0	0	3	1	0	0	0	15
	FS	0	0	0	0	0	0	0	0	0	1	0	0	0	1
As of January 1, 2005															
Nuclear Medicine Cameras	H	12	2	25	18	157	253	18	17	41	68	0	0	0	611
	FS	0	0	1	0	10	13	0	0	24	0	0	0	0	48
CT Scanners	H	10	3	15	11	99	108	17	13	27	44	1	1	0	349
	FS	0	0	0	0	7	0	0	0	3	2	0	0	0	12
Angiography Suites	H	3	0	6	7	41	72	4	5	14	21	0	0	0	173
	FS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MRI Scanners	H	1	1	4	5	34	58	6	3	19	17	0	0	0	148
	FS	0	0	1	0	15	0	0	0	6	6	0	0	0	28
Catheterization Labs	H	2	0	5	2	25	41	4	4	11	11	0	0	0	105
	FS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PET Scanners	H	0	0	0	0	4	8	0	0	3	1	0	0	0	16
	FS	0	0	0	0	1	0	0	0	0	1	0	0	0	2

Notes:

a) H = number of selected imaging technologies in hospitals.

b) FS = number of selected imaging technologies in free-standing imaging facilities.

c) Data are as of January 1, 2005. Some additional equipment has subsequently been installed.

Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information (2003, 2004 and 2005).

Table A.8. Results From the Health Services Access Surveys, 2001 and 2003

Selected parameters for Canadians aged 15 and over who reported receiving a non-emergency angiography, CT or MRI in 2001 and 2003.

Parameter	Angiography		CT		MRI	
	2001	2003	2001	2003	2001	2003
Approximate number age 15 + who had a test[†]	220,000*	242,000	787,000	962,000	647,000	892,000
% of population age 15 + who had a test	0.9%*	0.9%	3.1%	3.7%	2.6%	3.4%
Age distribution of test recipients						
% under 45 years	--	26%*	33%	38%	40%*	37%
% age 45–64	52%*	32%	41%	36%	40%	48%
% age 65+	37%*	42%	26%	26%	19%*	15%
% of test recipients who were male	48%*	54%	50%	45%	53%	48%
Reason for test						
Heart or stroke disease	77%	66%	7%*	7%*	--	9%*
Cancer	--	--	13%*	9%	--	6%*
Joints or fractures	--	--	13%*	16%	18%*	35%
Neurological or brain disorders	--	--	29%	19%	12%*	14%
Other/Not specified	--	28%*	37%	48%	46%	35%
Place of test						
Hospital/Public Clinic	98%	83%	96%	96%	92%	90%
Other[‡]	2%	17%*	4%	4%*	8%	9%
% who reported any difficulties in accessing the test	--	--	17%*	14%	15%*	21%

Notes:

"--" = data are suppressed due to extreme sampling variability.

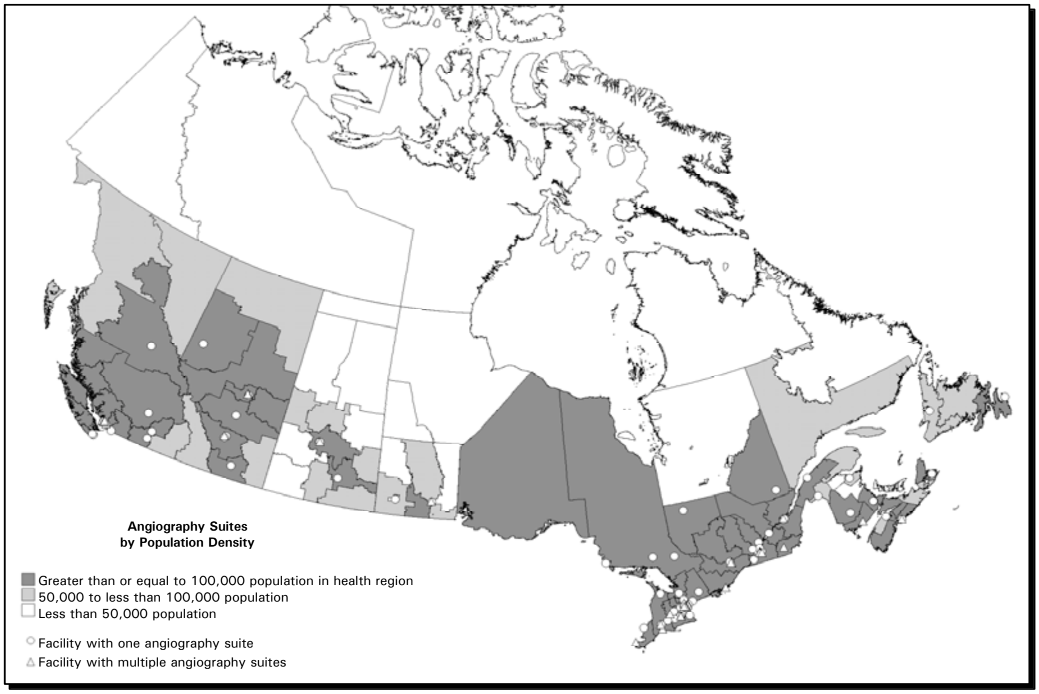
"*" = interpret with caution due to high sampling variability.

[†] Rounded to the nearest 1,000 persons.

[‡] "Other" includes private clinics and other locations not specified.

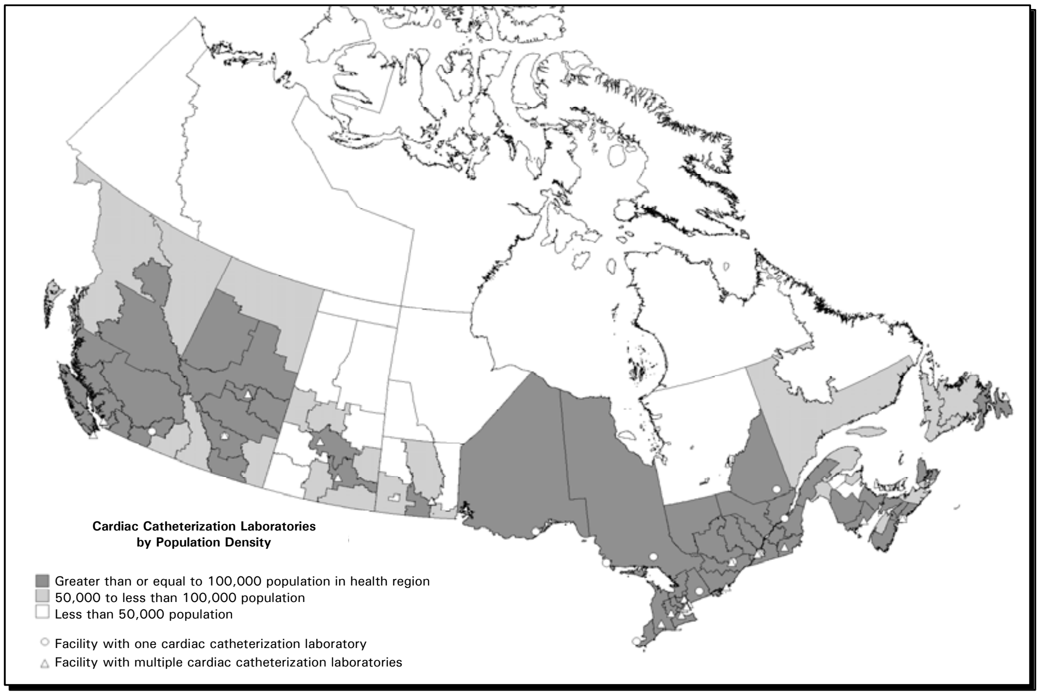
Sources: Health Services Access Surveys 2001 and 2003, Statistics Canada.

Figure A.1. Angiography Suites in Hospitals and Free-Standing Facilities Across Canada, 2005



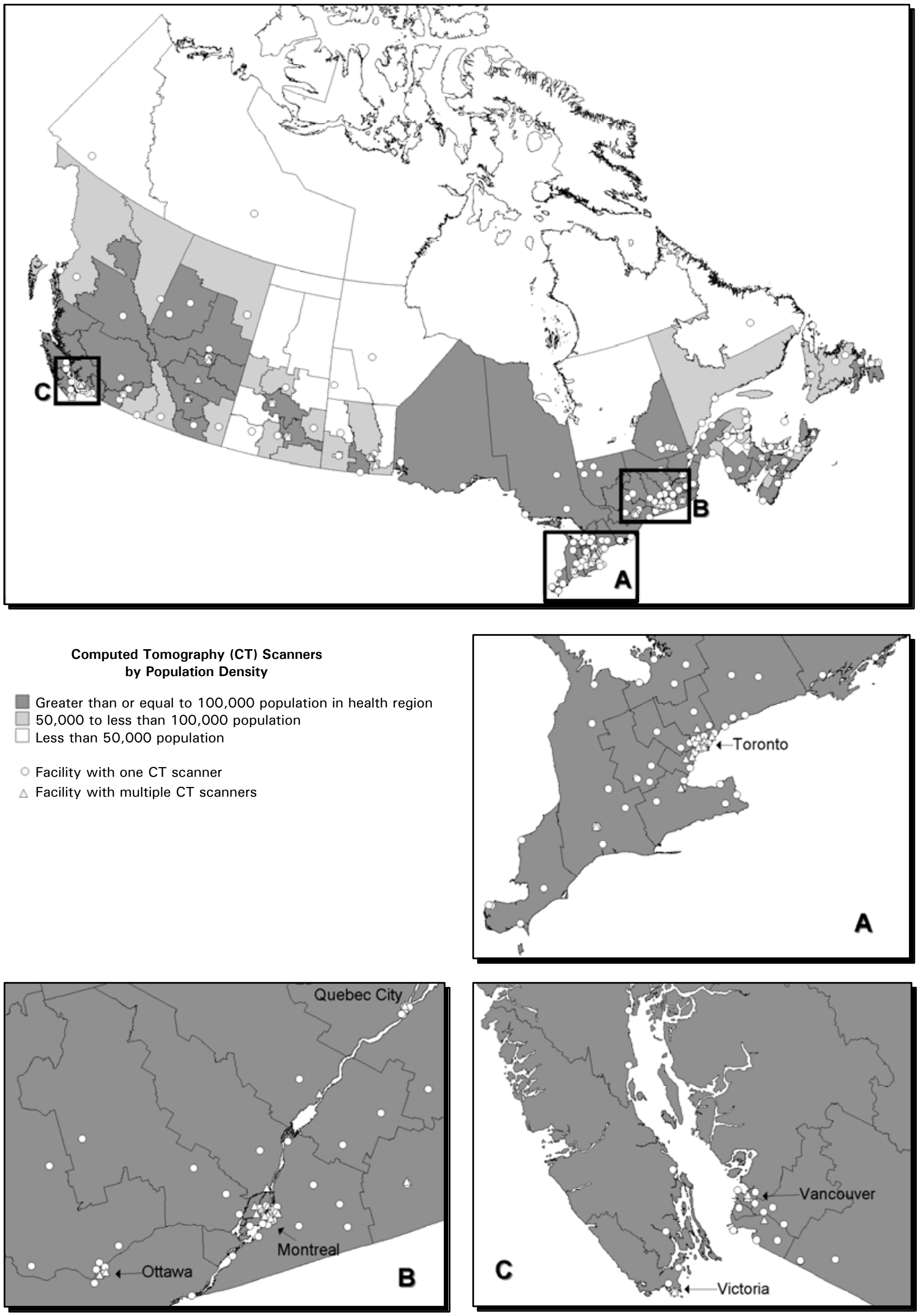
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.2. Cardiac Catheterization Laboratories in Hospitals and Free-Standing Facilities Across Canada, 2005



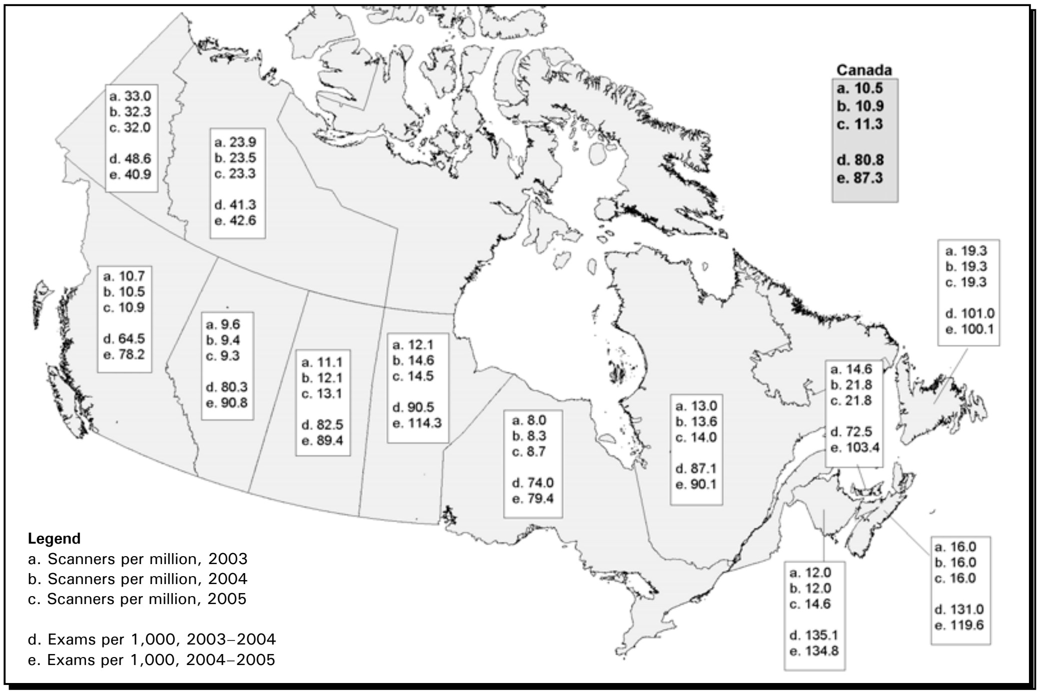
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.3. Computed Tomography (CT) Scanners in Hospitals and Free-Standing Facilities Across Canada, 2005



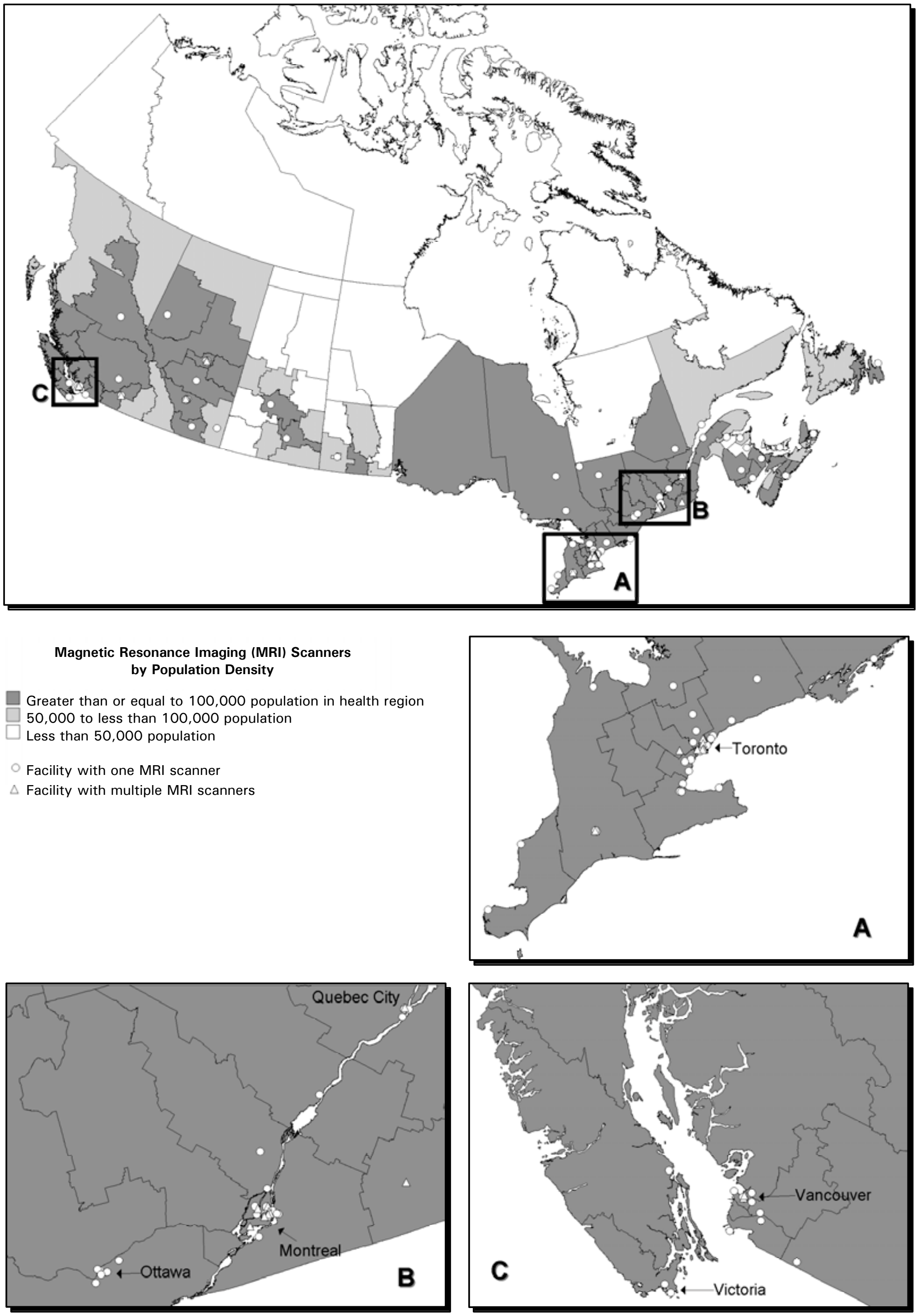
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.4. Computed Tomography (CT) Scanners per Million Provincial Population and Exams per 1,000 Provincial Population, 2003, 2004 and 2005



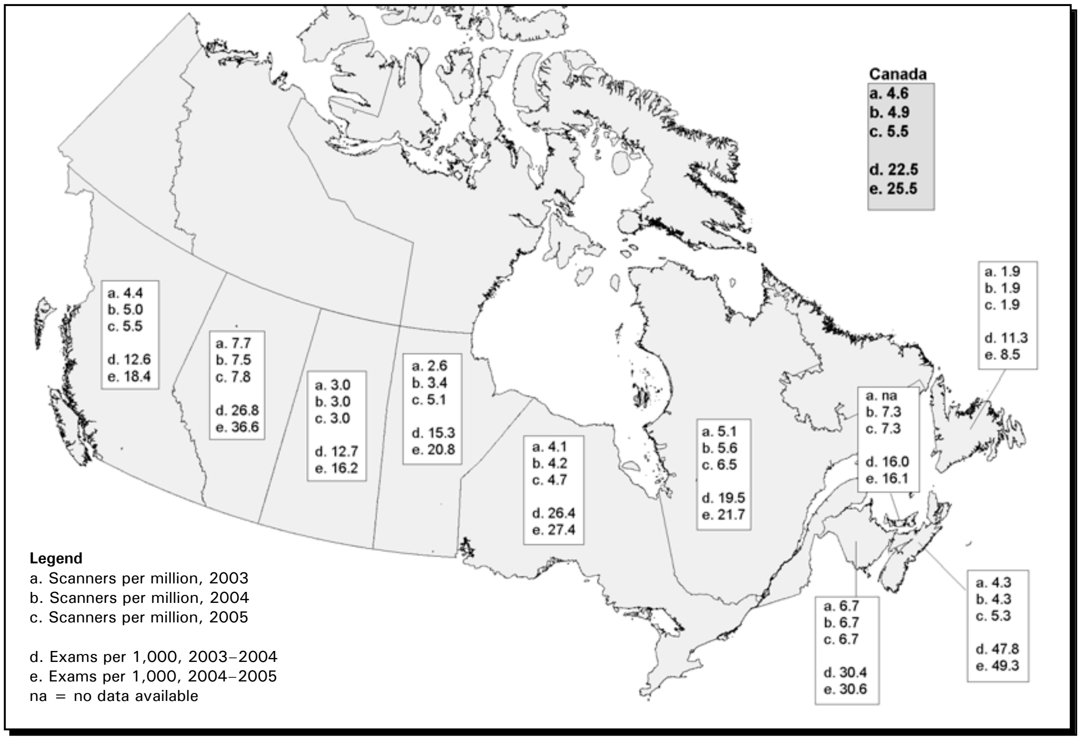
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.5. Magnetic Resonance Imaging (MRI) Scanners in Hospitals and Free-Standing Facilities Across Canada, 2005



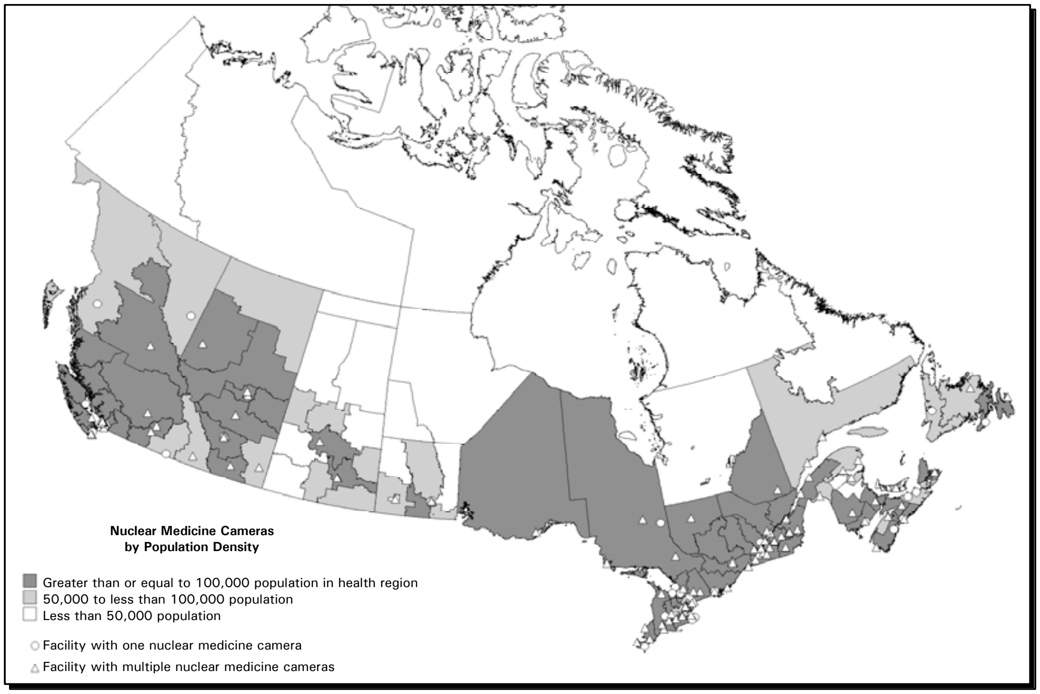
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.6. Magnetic Resonance Imaging (MRI) Scanners per Million Provincial Population and Exams per 1,000 Provincial Population, 2003, 2004 and 2005



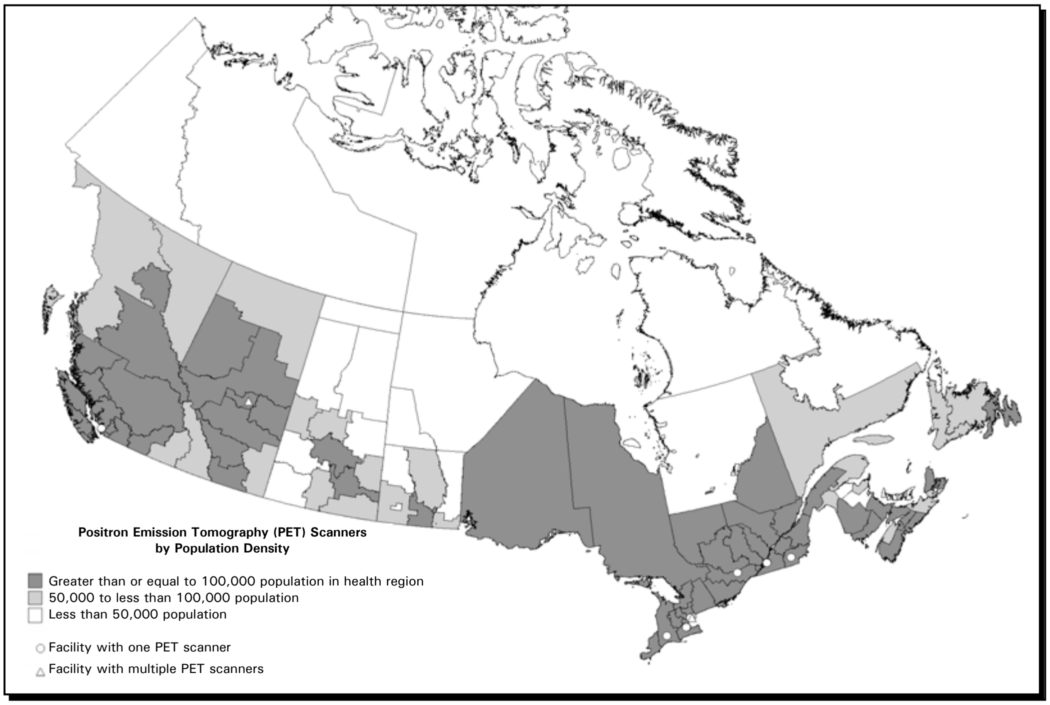
Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.7. Nuclear Medicine Cameras in Hospitals and Free-Standing Facilities Across Canada, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Figure A.8. Positron Emission Tomography (PET) Scanners in Hospitals and Free-Standing Imaging Facilities Across Canada, 2005



Source: National Survey of Selected Medical Imaging Equipment, Canadian Institute for Health Information.

Appendix B

Methodological Notes

Methodological Notes

INTRODUCTION

The Canadian Institute for Health Information (CIHI) aims to provide accurate and timely data and information to help shape Canada's health policies, improve health, strengthen our health care system and assist leaders in the health sector and Canadians to make informed decisions. As part of this goal, in 2003, CIHI undertook an annual national survey of selected high-technology medical imaging equipment. The National Survey of Medical Imaging Equipment is intended to monitor changes in the national inventory of seven select modalities of medical imaging and treatment equipment so as to inform Canadians about the distribution and use of these technologies.

The CIHI survey is based on a similar survey and process that was last conducted by the Canadian Coordinating Office for Health Technology Assessment (CCOHTA) in June 2001. CIHI first ran the survey in 2003 and released a report that included the results in September 2003. Both CIHI and CCOHTA have worked together to build upon the database and ensure a smooth transition. As was done for the 2001 CCOHTA survey, CIHI retained the services of ProMed Associates Ltd., a diagnostic imaging consulting firm headquartered in Vancouver, to run and coordinate the surveys for 2003, 2004 and 2005.

This section of the report is intended to provide important information that will help users of the National Survey of Selected Medical Imaging Equipment data to judge the extent to which the data may be used for their particular needs. Users who require information beyond what is provided here are encouraged to contact the Canadian MIS Database section of CIHI, by phone at (613) 241-7860, by fax at (613) 241-8120 or by email at cmdb@cihi.ca.

CONCEPTS AND DEFINITIONS

Population

The 2005 National Survey of Selected Medical Imaging Equipment collected data from all identifiable health care facilities (public and private) in each province and territory in Canada that had one or more of seven specific types of equipment. The types of medical imaging equipment that were included in the scope of the survey were magnetic resonance imaging scanners, computed tomography scanners, positron emission tomography scanners, angiography suites, catheterization laboratories and nuclear medicine cameras. Data were also collected on a seventh modality of equipment, lithotripters.

The survey was carried out between May 9, 2005, and July 31, 2005, with follow-up to the end of October 2005. Participants were asked to identify the technologies, described above, which were installed and operational prior to January 1, 2005.

Variables and Concepts

The data elements that were collected were consistent with the data elements requested in previous surveys, and included the following:

- name of province or territory;
- health region;
- hospital (facility);
- the number of units (to establish current distribution);
- type of equipment (only equipment operational as of January 1, 2005 could be included in the survey);
- classification data (identified individual data elements for each type of technology, see listing below);
- source of operating funding/revenue from April 1, 2004, to March 31, 2005 (sources of funding and the percentage distribution of those sources);
- year installed (to determine age);
- was this the initial year of service;
- original equipment manufacturer (OEM);
- site address and postal code for each piece of equipment; and
- confidential contact information for further follow-up.

In line with the 2004 questionnaire, participants were asked to respond to several additional questions that included the following elements:

1) the average weekly hours the equipment was in use;
2) the percentage of time that the equipment was in use for clinical purposes only;
3) whether film was used to record exams, or whether images were stored on electronic media (film, electronic, or both);
4) whether images acquired with this equipment were routed to a picture archive and communications system (PACS);
5) whether PACS images were accessible in strategic areas of the hospital (that is, care areas/clinics);
6) whether key images that were stored were available on a departmental image viewing system; and
7) number of examinations[i] in a fiscal year (asked of CT and MRI only).

---

[i] The definition of an examination is from the Guidelines for Management Information Systems in Canadian Health Service Organizations (MIS Guidelines). Examinations are defined as a technical investigation using an imaging modality to study one body structure, system or anatomical area that yields one or more views for diagnostic and/or therapeutic purposes. Exceptions include routinely ordered multiple body structures that by common practice or protocol are counted as one exam. Source: MIS Guidelines.

The additional questions asked for each specific type of technology involved:

Angiography suites:

i) Select applications: general angio/cardiac angio/neurological angio;
ii) Main purpose: diagnostic/interventions/both; and
iii) Type: single plane/bi-plane.

Cardiac angiography—catheterization laboratory:

i) Configuration: single plane/bi-plane;
ii) Dynamic study recording: conventional (cine)/digital (electronic);
iii) Main purpose: diagnostic/interventions/both; and
iv) Dedicated to physiologic procedures (device implant and cardiac electrical conduction evaluation studies): yes/no.

Computerized tomography (CT):

i) Scanning mode: spiral/non-spiral;
ii) Multidetectors: identify level of CT technology (that is, 4-slice, 16-slice or enter 0 if no multidetectors);
iii) Capable of fluoroscopy: yes/no;
iv) Mobile CT: the names of the sites that shared the unit (or no if the installation is fixed);
v) Applications: diagnostic/interventions/both;
vi) Whether the CT is also used for some treatment simulations; and
vii) For the fiscal year beginning April 1, 2004, and ending March 31, 2005, the total number of CT examinations performed at your facility/site.

Lithotripsy:

i) Shockwave generation technology: electromagnetic/electrohydraulic/piezoelectric; and
ii) Imaging source: X-ray/ultrasound/both.

Magnetic resonance imaging (MRI):

i) Field strength (Tesla);
ii) Configuration: closed bore/open bore;
iii) Mobile MRI: If mobile, the names of the sites that shared the unit (or no if the installation is fixed); and
iv) For the fiscal year beginning April 1, 2004, and ending March 31, 2005, the total number of MRI examinations performed at your facility/site.

Nuclear medicine—bone densitometer:

i) Type: peripheral scanner/axial scanner.

Nuclear medicine—gamma camera:

i) Number of scanning heads (detectors): single head/dual head/triple head.

Nuclear medicine—positron emission tomography (PET):

i) Imaging scope: head only/full body;
ii) Type of practice: dedicated to research/dedicated to clinical purposes/both; and
iii) Does your facility operate a cyclotron? yes/no.

Nuclear medicine—SPECT:

i) Number of scanning heads (detectors): single head/dual head/triple head.

Definitions

Angiogram: An X-ray of a blood vessel that has been injected with a contrast agent.

Angiography: A technique that enables blood vessels to show up on X-rays. A dense contrast agent (X-ray dye) is injected into the blood vessel, and an X-ray is taken. This outlines the blood vessel, revealing blockages or other abnormalities.

Angioplasty: The use of a small balloon on the tip of a catheter inserted into a blood vessel to open up an area of blockage inside the vessel.

Bone density: A diagnostic test that measures the amount of mineral in bones. The most commonly used test is dual energy X-ray absorptiometry (DXA), a low dose X-ray beam that scans the spine or the hip, or both.

Cardiac catheterization: A form of coronary angiography used to image the blood vessels in the heart, to examine the function of the heart and to dilate narrowed blood vessels that are not supplying adequate amounts of blood to heart muscles.

CAT: See *computed tomography scan*.

Computed tomography scan (CT) or computed assisted or axial tomography (CAT) scan: A diagnostic technique that uses X-rays and computer technology to produce cross-sectional images of the body (often called slices), both horizontally and vertically. A CT scan can show detailed images of various parts of the body, including the bones, muscles, fat and organs. They are more detailed than general X-rays.

Contrast media: A radiopaque substance used during an X-ray exam (or some other exams) to provide visual contrast in the pictures of different tissues and organs. This substance can be given orally or intravenously (by injection).

Contrast resolution: The ability of an imaging method to distinguish one tissue from another, or diseased from normal tissue.

Coronary angiography: A diagnostic technique used to image coronary arteries. A catheter is used to inject the arteries with a contrast agent (X-ray dye), and an X-ray is taken.

CT: See *computed tomography scan*.

Digital Imaging and Communications in Medicine (DICOM): An industry-recognized standard that dictates what digital image information is shared between two or more devices, as well as how that information is shared. DICOM limitations may restrict the ease of interfacing devices or the type of information that can be exchanged.

Doppler ultrasound: Measures change in echo frequency to calculate how fast an object is moving, thus permitting measurement of the velocity and direction of blood flow.

Evaluation of cancer diagnostic tests: Four indices are used to assess the sensitivity, specificity and accuracy of a diagnostic test. Administering the test to one group of persons who have the cancer and to another group who do not, and then comparing the results, can assess the sensitivity and specificity of a diagnostic test.

> **True positive:** Those who tested positive and have cancer.
>
> **True negative:** Those who tested negative and do not have cancer.
>
> **False positive:** Those who tested positive but do not have the cancer.
>
> **False negative:** Those who tested negative but in fact have the cancer.
>
> **Sensitivity:** The division of the number of true positives by the total number of patients who have the cancer.
>
> **Specificity:** The number of true negatives divided by the number of patients who do not have the cancer.
>
> **Accuracy:** The sum of true positives and true negatives divided by the total number of the patients tested.

Exam: A defined technical investigation using an imaging modality to study one body structure, system or anatomical area that yields one or more views for diagnostic and/or therapeutic purpose. Exceptions include routinely ordered multiple body structures that by common practice or protocol are counted as one exam.

Fluoroscopy: A study of moving body structures, a sort of X-ray "movie." A continuous X-ray beam is passed through the body part being examined, and is transmitted to a TV-like monitor so that the body part and its motion can be seen in detail.

Free-standing imaging facility: Ranges from specialized services run privately by physicians, radiologists, dentists and chiropractors, to mammography programs and broad-based imaging centres offering a wide range of tests.

Gamma camera: A device used in nuclear medicine to scan patients who have been injected with small amounts of radioactive materials.

Health Level-7 (HL7): A standard that was developed to allow the transfer of text data between different information systems in health care.

Hospital: An institution where patients are accommodated on the basis of medical need and are provided with continuing medical care and supporting diagnostic and therapeutic services. Hospitals are licensed or approved as hospitals by a provincial/territorial government, or are operated by the government of Canada, and include those providing acute care, extended and chronic care, rehabilitation and convalescent care and psychiatric care.

Hospital information system (HIS): An information system used to manage patient information, including reports, schedules, text data and billing.

Interventional radiology: An area of specialty within the field of radiology that uses various radiology techniques (such as X-ray, CT scans, MRI scans and ultrasounds) to place wires, tubes or other instruments inside a patient to diagnose or treat an array of conditions.

Ionizing radiation: Produces charged particles (ions) in matter. The particles are produced by unstable atoms, which have an excess of energy or mass or both, and are said to be radioactive. Radiation is the emission of this excess energy or mass needed to reach stability.

Lithotripsy: The crushing of a stone in the renal pelvis, ureter, or bladder, by mechanical force or sound waves.

Magnetic resonance imaging (MRI): A diagnostic technology that uses a large magnet, radio waves and a computer to scan a patient’s body and produce two- or three-dimensional images of tissues and organs.

Magnetic resonance spectroscopy (MRS): A type of MRI that measures concentrations of metabolites to produce images of chemical processes.

Mammography: Uses low-dose X-ray with high contrast, high-resolution film to create detailed images of the breast.

Modality: A treatment, or method of examination (for example, X-ray, ultrasound, CT scan, MRI).

MRI: See *magnetic resonance imaging*.

MRS: See *magnetic resonance spectroscopy*.

Non-emergency diagnostic test: A booked or planned diagnostic test provided on an outpatient or inpatient basis. Does not refer to tests provided through admission to the hospital emergency room as a result of, for example, an accident or life-threatening situation.

Nuclear medicine: A medical specialty where organ function and structure are examined by administering small amounts of radioactive contrast materials to the patient and taking scans with a gamma camera or other device for the purpose of diagnosing and treating disease.

Operating expense: Operating expenses include compensation, supplies, equipment, sundry, referred-out services and traceable supplies and other expenses. Operating expenses do not include the capital cost of purchasing major equipment, such as medical imaging equipment.

PACS: See *picture archiving and communications system*.

PET: See *positron emission tomography*.

Picture archiving and communications system (PACS): A system that acquires, transmits, stores, retrieves and displays digital images and related patient information from a variety of imaging sources and communicates the information over a network.

Positron emission tomography (PET): A non-invasive diagnostic technology that measures the metabolic activity of cells.

RAD: See *radiation absorbed dose*.

Radiation: The emission and flow of energy in the form of high-speed particles and electromagnetic waves. For example, visible light and radio, television, ultraviolet (UV) and microwaves are made up of electromagnetic waves.

Radiation absorbed dose (RAD): A unit that measures radiation in terms of the absorbed dose. For radiological procedures it is equivalent to the REM, and the two units are used interchangeably.

Radiograph: A photographic image produced on a radiosensitive surface by radiation other than visible light (especially by X-rays or gamma rays).

Radiography: The process of making a radiograph.

Radiology: The scientific discipline of medical imaging using ionizing radiation, radionuclides, nuclear magnetic resonance and ultrasound for the diagnosis and treatment of disease.

Radiology information system (RIS): An information system used to schedule radiological procedures, generate reports of clinical findings and bill.

REM: See *Roentgen equivalent man*.

Roentgen equivalent man (REM): A unit used to derive a quantity called "equivalent dose," which relates the absorbed dose in human tissue to the effective biological damage of the radiation.

Radiopharmaceutical (tracer or radionuclides): Basic radioactively tagged compound necessary to produce a nuclear medicine image.

Roentgen (R): A unit used to measure a quantity called “exposure“ and which can be used only to describe an amount of gamma and X-rays, and only in air. This unit measures the ionizations of the molecules in a mass of air.

Single photon emission computed tomography (SPECT): A type of nuclear medicine. It measures the concentration of radionuclides introduced into a patient’s body. One or more gamma cameras rotate around the patient and take pictures from many angles; a computer then uses the pictures to form a tomographic (cross-sectional) image.

Sonography: See *ultrasound imaging*.

SPECT: See *single photon emission computed tomography*.

Spatial resolution: The ability of an imaging method to resolve anatomic detail.

Teleradiology: Teleradiology is a means of electronically transmitting radiographic patient images and consultative text from one location to another.

Temporal resolution: The ability of an imaging method to reflect changing physiological events such as cardiac motion, disease remission or progression as a function of time.

Tomography: A method whereby a three-dimensional image of the internal structures of the human body is produced.

Ultrasound imaging (sonography): Uses high-frequency sound waves to make pictures of the body organs. Echoes from the sound waves are recorded and displayed as a real-time, visual image.

X-ray (radiograph): A small amount of radiation (electromagnetic waves) directed toward a specific part of the body to produce an image on a film on the other side of the body. Radiologists study the X-ray images to detect and diagnose disease or injury. Common X-ray methods and procedures include fluoroscopy, mammography and angiography.

MAJOR DATA LIMITATIONS

The survey, which includes public and privately funded facilities and their equipment, relied on the participation of diagnostic imaging medical heads and managers, as primary sources of information, to ensure that accurate data were collected across Canada. Secondary sources were also employed in order to verify data submitted by primary data providers, and to identify sites where these technologies may be located, but were unidentifiable through primary sources.

The survey also relies on the consistency of the approach with previous surveys, including consistent data elements, question types and process management, to ensure comparability of the information over time. However, as with previous surveys, there was no mandatory requirement for sites to participate. It was only through continued encouragement that many sites participated in the survey.

The information obtained from the survey will provide users with an accurate “snapshot“ of selected imaging technologies in Canada. The survey did not include any questions on general radiology equipment, ultrasound and therapeutic equipment (except for lithotriptors), and only a few questions on radiology information systems (RIS) and picture archiving and communication systems (PACS), and other information technology. For this reason, it cannot be considered a complete data source for all medical imaging equipment.

Private facilities were hesitant, in general, to participate in the survey process, and were often willing to identify “private or other“ as a source of funding, but were generally unwilling to identify specific sources of funding. Overall, responses to the funding questions were limited, since some participants did not identify more than one source of funding. For 2005, 272 respondents (18.2%) did not report any sources of funding, and of the 1,226 that did respond, 13 (1.1%) did not do so accurately.

Each time the survey is conducted, it offers an opportunity to update information that was captured in previous years. However, there were areas of perceived potential underreporting. For instance, new or merged facilities since the 2004 survey needed to be identified through the primary and secondary sources, and extensive research was undertaken and completed to locate these changes in the frame. Contact lists also needed constant updating due to shifting roles, new personnel and changing organizational structures at the provincial/territorial, regional, hospital and clinic levels.

The information from the survey is also limited by the quality of participants’ responses, since it is generally based on their first-hand knowledge of the technologies. Also, there is no known comprehensive baseline study or report in the literature to validate the survey information, other than the existing 2001 CCOHTA and the 2003 and 2004 CIHI survey results.

There were some provincial issues that may also have impacted the results. For instance, at the time of the survey, Ontario had no provincially established organizational framework for health regions. As a result, there was confusion at times regarding the official names of health regions and/or health facilities. Respondents often used abbreviated forms of region/ facility names when completing the survey, making it difficult to match with the contact lists.

The survey was designed to change automatically, depending on the type of modality the respondent was entering. For instance, if a respondent was entering information on a CT scanner, there would be four more questions than there would be for an angiography suite. As a result, some respondents seemed to be confused by the addition or change in questions when entering more than one type of technology.

COLLECTION AND NON-RESPONSE

The following notes briefly describe some of the major technical points associated with the compilation of the 2005 National Survey of Selected Medical Imaging Equipment and report. Additional information can be obtained by contacting the Canadian MIS Database section, by phone at (613) 241-7860, by fax at (613) 241-8120 or by email at cmdb@cihi.ca.

General Methods

Based on experience with previous surveys, a primary process and a secondary process for collecting data were developed; these processes were performed concurrently.

The primary process began with the distribution of introductory and instructional information to chief executive officers (CEOs) of every health region and hospital in Canada. The list was created from administrative information gathered from CIHI and ProMed Associates Ltd. and other sources, as well as research to identify all potential locations of medical imaging equipment. CEOs continued the process by distributing the information to the heads/managers of diagnostic imaging and nuclear medicine departments in their organizations. An enhanced Web site was developed that allowed participants to register online and complete the information from their respective sites. The package that the heads and managers of diagnostic imaging and nuclear medicine departments received included introductory and instructional information that was distributed by the consultants on CIHI letterhead (an overview of CIHI's mandate, a description of the project, the timetable, instructions for online registration and data entry or modification, verification and how to produce a hardcopy printout of their information for their records). Both public and private facilities were contacted, as per the agreed scope of work.

The secondary process included contacting diagnostic imaging–related organizations, such as the Canadian Association of Radiologists (CAR), l'Association des radiologistes du Québec (ARQ) and the Canadian Association of Nuclear Medicine (CANM), in order to secure their assistance, where possible, to identify potential locations of these technologies, regardless of whether they were identified previously or not. In addition, original equipment manufacturers were also contacted for the same purpose.

For those unable to access the Web site, alternative methods were offered in order to help facilitate participation. All participants were advised that their data would remain online in the database and that, with the proper authorization, staff from within their organization could access this information for various planning purposes.

Every question in the survey was identified as mandatory, except for the questions related to funding. These questions were answered globally for each organization, and were again asked for each piece of equipment. Participants had to provide a response to all questions before they were able to move ahead to the next piece of equipment. Clear and concise instructions in both official languages were provided to participants in written form and online (on the Web site) as part of the process to ensure the same level of understanding among respondents. The 2005 survey defaulted to the language that each participant's computer was set to. They also had the option to move freely between both official languages. Where necessary, support was provided to the respondents in real-time or online throughout the survey process.

Manual download of the online database was completed on a daily basis. Where required, participants were contacted for follow-up information and/or clarification on the data that they had provided. Where it was felt that the data were incomplete or possibly inaccurate, participants were contacted to verify their information.

When participants finished their data entry, they were taken to a main review page, where they could continue to enter new equipment or end the survey. Unlike in 2003, when each participant was asked (as part of the online survey process) to review the information they had provided, verify that it was complete and accurate, then to move on to the next equipment entry, this year the review process was continual and took place as each piece was entered.

The final step in the data collection process involved validation of machine counts by the federal, provincial/territorial Advisory Committee on Information and Emerging Technologies (ACIET). ACIET members were sent the finalized preliminary survey data for their respective province or territory that were submitted by ProMed Associates Ltd. to CIHI. Members were asked to forward the information to the appropriate individual in their government who could verify the counts of equipment to ensure that no equipment was missed, double counted or improperly classified. Feedback from this final verification aided in the final version of the survey data that was submitted to CIHI on October 31, 2005, and was used in the 2005 *Medical Imaging in Canada* report.

Coverage

CEOs for all health regions and hospitals were sent a copy of the cover letter and instructional information for distribution to medical heads and to managers of radiology and nuclear medicine departments. Identified key executives of private clinics were contacted directly. Within days of these mail-outs, each CEO's office was contacted to confirm receipt of the information and to encourage immediate distribution of the information to medical directors and managers of radiology and nuclear medicine who may have MRI, CT, PET, angiography, catheterization labs, nuclear medicine and lithotripter technology (which fell under the scope of this national survey). The corporate office was asked to identify a primary survey contact and an alternate contact (if there wasn't one already identified) to facilitate survey participation.

Using the 2001, 2003 and 2004 database as an initial list of reference sites with these technologies, data entries were monitored to ensure there was only one respondent for each health region, hospital or clinic. When duplication was suspected, based on registry information or if a significant change in technology numbers from the previous survey was detected, participants were contacted to verify their response. The 2005 survey results represent a response rate of 99.9% from all facilities/contacts from the 2005 list (plus new additions from the 2005 list of primary contacts).

The major concern for this survey is undercoverage or underreporting of these technologies, especially since no established list exists other than the 2001, 2003 and 2004 National Surveys. Provincial and territorial members of the Advisory Group for Information and Emerging Technologies assisted CIHI by coordinating the verification of the data in their respective province or territory.

Original equipment manufacturers were contacted to provide a confidential list of locations of their equipment as a reference only. In addition, published listings of Canadian Health care facilities were reviewed, and based on published programs and facility size, contacted and asked to participate, if applicable.

For 2005 there were several facilities and organizations that refused to respond to the survey. Three private facilities in Quebec did not respond to the survey, one private clinic, Ville Marie PET/CT has been included in the inventory count with one PET scanner, but no other characteristic or utilization data for that PET scanner is available. Medisys in Ontario and Quebec also did not provide complete information of all their modalities in operation in private clinics throughout Ontario and Quebec. Specifics for CT and MRI were provided, but not for their nuclear medicine cameras. The Medisys nuclear medicine cameras have been included in the inventory count, but no other characteristic or utilization data is available. A private clinic in Alberta, Calgary/Canmore MRI, also did not participate this year, or in previous years. As with the other equipment, the MRI is counted but no characteristic or utilization data is available.

Calculation Methods

Calculation of Population Rates

Equipment per million population was calculated using the number of units divided by the most recent (January 1) total population estimate in millions.

MRI and CT exams per 1,000 population were calculated using the number of units divided by the most recent (October 1) total population estimate in thousands.

Calculation of Hospital Operating Expenses

Hospital operating expense (MIS Financial Secondary Accounts 3*, 4*, 5*, 6*, 7*, 8*, 9*) is the sum of compensation, supplies, sundry, equipment, referred-out services and building and grounds.

Calculation of Hospital Diagnostic Imaging Exams

Hospital diagnostic imaging exams from the CMDB (MIS Primary Accounts 7*41525* and 7*41570* and MIS Statistical Secondary Accounts 457* and 458*) is the sum of in-house exams and in-house procedures for computed tomography and magnetic resonance imaging functional centres, respectively.

Calculation of Capital Expenditures

Capital expenditure for the private sector and for provincial and municipal government sectors is estimated from information obtained from the Investment and Capital Stock Division at Statistics Canada. Capital expenditure in the federal direct sector is obtained from the national public accounts and federal departments that provide health services. Public-sector capital expenditures include the provincial/territorial, municipal and federal governments' capital contributions. Capital expenditure in all sectors is based on full cost or cash basis accounting principles; capital is the only category of expenditure in which spending is categorized as private or public based on ownership of the facility in which the investment is made. This convention has been adopted due to data limitations.

Calculation of Utilization Index of MRI

Utilization index of MRI was calculated using age- and sex-specific inter-censal population estimates published by Statistics Canada as the denominator. Rates were adjusted to the 2001 Ontario Census population aged 20 or older using the method of direct standardization.

Treatment of Mobile MRI and CT Units

Mobile units are treated as one machine, whether or not they are shared by more than one organization or facility. Mobile units are associated with the site where, in the opinion of the survey respondent, the unit is located most of the time. When calculating the number of MRI or CT exams per 1,000 health region population, the shared mobile units are included in every region that uses them.

MAJOR CHANGES FROM PREVIOUS YEARS

Most notable changes in the quality of the information are noted as follows:

- Data were provided directly from primary sources (in all cases).
- Secondary sources, such as the Canadian Association of Radiologists (CAR), l'Association des radiologistes du Québec (ARQ), the Canadian Association of Nuclear Medicine (CANM), Toshiba, General Electric (GE) and Siemens helped to identify potential locations of existing technology.
- Increased emphasis on a more bilingual approach contributed to improved survey participation.

Revision History

Additional analysis and comparison of the 2003 and 2004 data to the 2005 survey results have led to new information about the number of machines in 2003 and 2004. Responses to the 2005 survey revealed that for several modalities, facilities did not respond in previous years. Through examination of the year of installation of these units and comparisons to the 2003 and 2004 results, several modalities in 2003 and 2004 have had their counts adjusted. The following is a list of equipment added to the inventory for 2003 and 2004:

Table B.1 Revisions to Medical Imaging Equipment Inventory, by Modality, 2003 and 2004

Modality	2003	2004
Angiography Suites	0	1
Catheterization Laboratories	1	1
Computed Tomography	6	8
Magnetic Resonance Imaging	2	6
Nuclear Medicine—Bone Densitometer	26	28
Nuclear Medicine—Gamma Camera	4	7
Nuclear Medicine—SPECT	3	6

In 2004, a facility in Quebec reported having only one MRI scanner. Results from the 2005 survey indicate that the facility actually had two MRI scanners in 2004. This information has been confirmed by the participant.

Two private clinics in British Columbia, each operating an MRI, were identified late in 2004 and were not included in the 2004 survey. They have been added to the MRI inventory in 2004.

The angiography unit in Prince Edward Island's Queen Elizabeth Hospital was removed from the inventory for 2004, as it was not in operation during the year.

The equipment counts for each of the above revisions for 2003 and 2004 have been adjusted accordingly in this report.

SOURCES OF DATA

- CIHI's **National Survey of Selected Medical Imaging Equipment** provides information on the number, distribution, and key characteristics of selected imaging technologies (angiography suites, catheterization labs, CT scanners, MRI scanners, nuclear medicine cameras, PET scanners and lithotripters) in Canadian hospitals and those in free-standing imaging facilities (sometimes also called "non-hospital," "community-based" and/or "private" facilities).
- CIHI's **Canadian MIS Database** (CMDB) provides financial and statistical information (for example, expenditures by functional area, workload measurement, outpatient visits) primarily on hospitals with some limited data on regional health authorities across Canada. Information is primarily obtained from provincial ministry of health databases. For the territories, however, data are collected from individual facilities/regional health authorities via the survey. For this report, we examined hospital operating expenses and diagnostic imaging exams for selected types of medical imaging equipment.
- Statistics Canada's **Health Services Access Survey** (HSAS) is a supplement to the Canadian Community Health Surveys (CCHS) of 2000–2001 and 2003. It captures national information on how Canadians 15 years of age and older use health care services and perceive barriers to care. The survey includes information on the use of three diagnostic services (MRI, CT and angiography) in non-emergency situations. All estimates from the HSAS reflect *self-reported* use and may be different from estimates of the number of medical imaging examinations performed derived from administrative data.
- CIHI's **National Ambulatory Care Reporting System** (NACRS) captures summary information on ambulatory care. The database primarily captured information on emergency department care in Ontario. For this report, we examined the use of CT scans in this environment. The CT scans were completed during the emergency department visit and could have been ordered for either the patient's main problem or other problems.
- CIHI's **National Physician Database** (NPDB) provides information about the socio-demographic characteristics of Canadian physicians and their fee-for-service activity levels. Since fee codes and payment methods for imaging services vary across the country, billing data on the use of medical imaging services are directly comparable only for selected jurisdictions. Imaging services paid for entirely through hospital global budgets or by individuals/third-party payers (for example, workers' compensation boards) are not captured.

www.cihi.ca *Taking health information further*
www.icis.ca *À l'avant-garde de l'information sur la santé*