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Medical Technology in Canada

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Executive summary

Medical technologies are an important component of medical care and can provide significant positive benefits to patients. Medical technologies can advance the identification and treatment of disease, can provide for more comfortable treatment regimes and reduce pain, offer new treatment options for ill individuals where none previously existed, and can provide a safer environment for both patients and providers fortunate enough to have access to them. In many cases, medical technologies can accomplish these improvements cost effectively, and in some cases can reduce costs while improving outcomes. So how good is Canada's health care system at ensuring that patients have high-tech health care available to them?

To answer that question, this study reviews various national and international studies to evaluate the availability of medical technologies in Canada relative to other countries, analyzes data produced by the Canadian Institute for Health Information (CIHI) to measure both the age and sophistication of medical technologies in Canada, and discusses a survey undertaken for this research paper that measures the stock of cutting-edge medical technologies in Canada's five largest cities.

The review of other studies examining the access Canadians have to modern and advanced medical technologies finds that people in this country generally receive poorer access to medical technologies than their counterparts in other nations. Canada, in fact, often ranks below the majority of developed nations in access to modern medical technologies. The other studies also reveal Canada to be a late adopter of advanced medical technologies; Canada also lags behind a number of other nations in the rate of expansion in the inventory or application of technologies after their introduction.

In order to determine the quality of the available services, it is important to examine both the age and sophistication of medical technologies, in addition to considering the size of inventories. Compared with their newer counterparts, older medical technologies are generally less reliable and need more maintenance, may provide a lower quality output or be less accurate, may be less safe for patients and operators, and may expose patients to greater risk. On the other hand, more sophisticated medical technologies can allow for shorter examination or operation times, offer higher quality services, and provide more services than the less sophisticated counterparts. Put simply, there is a qualitative difference between an inventory of older and relatively unsophisticated equipment versus an inventory of relatively new and highly sophisticated medical equipment.

A detailed analysis undertaken for this study of the Canadian Institute for Health Information's *National Survey of Selected Medical Imaging Equipment* (2006b) finds that Canada's health care system relies heavily on a sizable inventory of older and outdated medical technologies, according to guidelines produced by the Canadian Asso-

ciation of Radiologists and the European Coordination Committee of the Radiological and Electromedical Industries. Canada also often relies more on less sophisticated forms of technology than might be optimal.

For example, at the beginning of 2006, 14.8 percent of Canada's hospital-based CT scanners, 29.3 percent of hospital-based MRI units, 26.1 percent of hospital-based SPECT units, 35.7 percent of hospital-based gamma cameras, 56.3 percent of hospital-based lithotriptors, 47.4 percent of hospital-based angiography suites, and 40.2 percent of hospital-based cardiac catheterization labs were older than their respective lifecycle guidelines as recommended by the Canadian Association of Radiologists. While no free-standing facility-based CT scanner was older than its lifecycle guideline at the beginning of 2006, 22.6 percent of free-standing facility-based MRI scanners and 25.0 percent of free-standing facility-based gamma cameras were beyond their lifecycle guideline.[1]

Similarly, rules from the European Coordination Committee of the Radiological and Electromedical Industries recommend that no more than 10 percent of the installed base of medical technologies should be more than 10 years old. However, the CIHI data shows that 26.1 percent of hospital-based SPECT units, 35.7 percent of hospital-based gamma cameras, 50.0 percent of hospital-based lithotriptors, 24.6 percent of hospital-based angiography suites, 26.8 percent of hospital-based cardiac catheterization labs, and 25.0 percent of free-standing facility-based gamma cameras were more than 10 years old at the beginning of 2006.

This study also examines the availability in Canada of cutting-edge medical technologies, or technologies that have not been commonly available to health care providers for long. To empirically measure Canada's inventory of these medical technologies, the authors of this study conducted a survey in late 2006 to determine what access physicians had to 50 advanced medical technologies in Toronto, Montreal, Vancouver, Ottawa, and Calgary. The results reveal that while some cutting-edge medical technologies are commonly available to patients, many such technologies are relatively scarce in Canada, or are simply unavailable.

There are real and considerable costs associated with *not* investing in medical technologies, including long waits, less efficient use of medical resources, and poorer patient experiences. A health care system that offers patients and caregivers better access to advanced medical technologies is in the interests not just of patients, but of taxpayers who may one day become patients. Two questions arise, then: why is investment in medical technologies lacking in Canada, and why have governments not been

1 The analysis of the CIHI data in this study treats medical equipment located in hospitals separately from equipment contained in free-standing facilities. As CIHI's data makes the distinction, it is important to separate these two classifications in the analysis. Importantly, in-hospital technologies are generally available to patients through taxpayer-funded health care programs, while equipment in free-standing facilities may not always be available through taxpayer-funded channels.

purchasing modern medical technologies for implementation in their Medicare programs?

Canada's poor medical technology record cannot be explained by a lack of health care expenditures. In fact, Canada's universal access health insurance program is among the developed world's most expensive such programs. Further, the federal government has transferred $3 billion in targeted funding to the provinces since 2000 in an effort to improve the availability of medical technology in this country. Yet modern medical technologies remain notably rare in Canada's provincial Medicare programs.

Clearly, throwing more money at Medicare is not the solution to the lack of access to modern medical technologies. Rather, Canadians should be asking why they receive so little, despite spending so much on health care. The explanation for this disconnect between demand, spending, and the supply of medical technologies in Canada can be found in the incentive structure of the health care system. By employing private, competitive provision of health care services; using comprehensive, private insurance, both in parallel to and as a part of the universal system; and by strengthening the connection between the delivery of and payment for services, Canada's health care system would be better structured to deliver the world-class access to modern medical technologies that Canadians pay for.

Introduction

Medical technologies[2] are an important component of medical care and can provide significant benefits to patients. Medical technologies can advance the identification and treatment of disease, can provide for more comfortable treatment regimes and reduce pain, offer new treatment options for ill individuals where none previously existed, and can provide a safer environment for both patients and providers. Put simply, advanced and sophisticated medical technologies improve heath outcomes and quality of life for those patients fortunate enough to have access to them.

Providing Canadians with a high level of access to the latest medical technologies should be an objective of health policy in Canada; not doing so would surely be a failure of the health care system. This raises the question: how good is Canada's health care system at ensuring that patients have high-tech health care available to them? The answer is particularly relevant in light of the $3 billion the federal government has transferred to the provinces since 2000 in an effort to improve the availability of medical technology in Canada (Canada, Department of Finance, 2007a).

This study measures the quality and quantity of Canada's stock of advanced medical technologies relative to what is available and being delivered in other developed nations. The study begins with a discussion of the benefits and cost savings that can result from investments in medical technologies. Section 2 reviews various international and national studies to evaluate Canada's relative availability of medical technologies. Section 3 analyzes data produced by the Canadian Institute for Health Information (CIHI) to measure both the age and sophistication of this country's medical technologies. Section 4 discusses a survey undertaken for this research paper that measures the stock of cutting-edge medical technologies in Canada's five largest cities. The final section discusses the findings reported in the previous sections and offers policy recommendations that would improve access to advanced medical technologies for Canadians. A conclusion follows.

This study focuses principally on technologies in the diagnostic imaging, laboratory diagnostic, surgical, and patient services areas. The availability of pharmaceutical technologies in Canada has been studied extensively elsewhere (see, for example, Skinner, Rovere, and Glen, 2007). The purpose of this paper is to focus primarily on non-pharmaceutical medical technologies.

2 De Miranda et al. (2005) define medical technology as, "the application of procedures, information, and devices to develop highly sophisticated solutions to medical problems or issues such as the prevention of disease or the promotion and monitoring of good health."

1 The benefits of medical technologies

Advanced medical technologies can deliver numerous benefits to both patients and those funding the health care system. According to Australia's Productivity Commission (2005), medical technologies "…have reduced disease risk factors, long-term complications of related chronic diseases, and the need for drugs. They have also improved mobility and day-to-day functioning, and reduced hospital admissions, length of stay, and the indirect costs of caring for patients" (p. 118). Further, significant advances in the field of diagnostic equipment, surgical and laboratory procedures, and non-surgical equipment have increased hospital efficiency as well as patient comfort and safety. New medical devices and interventions are also able to offer patients treatments and diagnoses previously unavailable.

For example, newer advanced diagnostic equipment such as multi-slice Computed Tomography (CT) scanners, more powerful Magnetic Resonance Imaging (MRI) machines, and Positron Emission Tomography (PET) scanners (both stand-alone and combination PET/CT units) allow for greater accuracy, speed, and efficiency in diagnosing medical problems. They also provide less invasive procedures for the diagnosis of disease, which can facilitate earlier and more localized treatment. Doctors can use more sophisticated scanners to observe and learn more about the body's functions and location of disease without subjecting the patient to surgery for either diagnosis or needless interventions. For example, a PET scan can detect a lung cancer that has spread, and thus avoid a futile operation. It can also determine if liver tumours can be safely removed, and can help determine if chemotherapy treatment is working, or whether the drug cocktail being provided needs to be changed (Priest, 2006). PET scanners also allow some patients to avoid surgical biopsies for the diagnosis and identification of cancers.

Due to innovation in surgical technologies, surgeons are now able to use specialized instruments to reduce the impact of treatment on patients. For example, surgeons today might use a video camera to enter the body through small incisions, and then move the camera lens and their surgical tools through tissue and blood vessels to the affected area, rather than opening the entire body cavity as was once common. Thanks to minimally invasive surgical techniques, procedures that once required patients stay in hospital for days can now be performed on an outpatient basis. For example, surgical complications, time spent in hospital, and the amount of trauma to the patient have been significantly reduced by replacing conventional cholecystectomy (gall bladder removal) with minimally invasive laparoscopic cholecystectomy (Cain and Mittman, 2002).

New laboratory procedures have also played an important role in identifying certain medical conditions, or predispositions to them. Armed with increased knowledge about the potential risks for developing certain conditions or diseases, patients have

the impetus to be proactive about those diseases by altering their lifestyles and increasing their surveillance of the condition. For example, laboratory tests can determine mutations in the BRCA1 and BRCA2 genes, which can signal a higher risk of certain cancers like breast cancer or ovarian cancer (Stanford Cancer Center, 2006).

Advances in medical technology can also improve non-surgical hospital services. For example, electronic storage of diagnostic images can increase the efficiency of patient information transfer and ensure faster turnaround times. Electronically stored diagnostic images can also allow for long-distance contracting by reducing or eliminating the need to physically handle and transport images. As another example, automated medication dispensing systems can decrease the incidence of medical errors in drug distribution and can reduce the time pharmacists and nurses spend on drug dispensing.

New medical devices can also offer new treatment options to patients who were previously left untreated. Consider the Implantable Cardioverter Defibrillator (ICD), which works on the same principal as an external defibrillator, but is implanted in a patient's chest. The ICD sends an electrical current to the heart when it detects serious arrhythmia, or a stoppage, in order to restore normal rhythm. This device allows patients at risk of sudden cardiac arrest to live independently and not be under constant surveillance.

In countless ways, medical technologies can improve access to care, improve the effectiveness of care, decrease morbidity and mortality, speed up recovery, and increase patient comfort. These benefits are not just theoretical, but have been quantified in published studies.

Hunink et al. (1997) studied the decline in mortality rates due to coronary heart disease between 1980 and 1990. The authors estimated that 25 percent of the decline could be explained by primary prevention (reduction of coronary heart disease incidence), and 43 percent could be explained by improvements in the treatment of patients with coronary heart disease. That is, improvements in patient treatment between 1980 and 1990 explained almost half of the decline in mortality from coronary heart disease. Eugene Braunwald (1997), a renowned cardiologist and researcher, stated:

> Diagnostic imaging of the heart, great vessels, and coronary arteries… has greatly facilitated cardiac diagnosis. Notable therapeutic advances include the development of open-heart surgery for the treatment of many forms of congenital and acquired heart disease; catheter-based interventions, such as coronary angioplasty and stenting, for the nonsurgical treatment of coronary artery disease; and cardiac pacemakers and implanted cardiac defibrillators for a variety of life threatening cardiac arrhythmias. These procedures… have improved the quality and, increasingly, the duration of life. (p. 1362)

Braunwald goes on to say that advances in cardiac imaging "will facilitate the early identification of patients at high risk for serious coronary events." He adds that "newly

developing catheter-based techniques for coronary revascularization that incorporate new approaches to prevent restenosis [ie., the closing of an artery that was previously opened by a cardiac procedure] should help to reduce the incidence of acute coronary events." (p. 1366)

Wright and Weinstein (1998) tabulated the reported gains in life expectancy from a number of medical interventions from 83 published sources. Among other findings, the authors showed that various medical technologies can extend life expectancy for people with already established cardiovascular disease, cancer, and other conditions. The number of months gained from the treatments varied; however, there were gains of several years associated with a number of treatments. For example, implantable defibrillators for survivors of cardiac arrest were associated with gains of 36 to 46 months, and replacing standard chemotherapy with autologous bone marrow transplantation[3] for patients with relapsed non-Hodgkin's lymphoma was associated with a gain of 72 months (Wright and Weinstein, 1998).

Diamond et al. (2006) studied the benefits of percutaneous vertebroplasty, a treatment involving the injection of acrylic bone cement to relieve pain and/or stabilize fractured vertebrae, and in some cases to restore vertebral height, which has become an alternative to conservative treatment of acute osteoporotic vertebral fractures. The authors performed a 2-year prospective study comparing 88 patients with osteoporosis who received percutaneous vertebroplasty and 38 patients who declined the treatment and were managed using conservative methods. Diamond et al. found patients receiving vertebroplasty had better outcomes at 24 hours after the procedure than patients treated conservatively. Specifically, patients receiving vertebroplasty experienced a 60 percent reduction in pain scores and a 29 percent improvement in physical functioning, while no significant changes were recorded among those treated conservatively. Further, patients who received vertebroplasty reported persistently lower pain scores 6 weeks after treatment, though no significant differences between patient groups were found at 6 to 12 and 24 months. Those who received vertebroplasty also experienced a 43 percent reduction in the mean number of hospital bed-days occupied, and the rates of new vertebral fractures and death were not significantly different between the two groups.

Johnston et al. (2000) compared the outcomes of treating unruptured cerebral aneurysms[4] with the common procedure of surgical clipping (performed by neurosur-

3 Autologous bone marrow transplantation is a process where a patient's healthy bone marrow is removed and preserved while the patient undergoes high-dose radiation therapy. The patient's own marrow is then transplanted or injected back into the patient to replace marrow damaged by the radiation therapy.

4 Cerebral aneurysm (also known as an intracranial or intracerebral aneurysm) is a weak or thin spot on a blood vessel in the brain that balloons out and fills with blood (National Institute of Neurological Disorders and Stroke, 2007).

geons) and the newer, less invasive alternative of endovascular coil embolization[5] (performed by neurointerventional radiologists). The authors found that surgery was associated with greater rates of new disability, an increased likelihood of reporting new symptoms or disability after treatment, more complications, and longer recovery. Surgical patients also experienced longer hospital stays (7.7 days, on average, for surgery compared with 5.0 days for embolization) and higher hospital charges ($38,000, on average, for surgery compared with $33,400 for embolization).

Similarly, Molyneux et al. (2005) compared outcomes of treating ruptured intracranial aneurysms with neurosurgical clipping and endovascular coiling in 2,143 patients. The study found that 23.5 percent of patients treated with endovascular coiling were dead or dependent one year after treatment (8.0 percent dead, 2.6 percent fully dependent, 2.8 percent partially dependent, and 10.1 percent with significant restriction in lifestyle) compared to 30.9 percent of patients treated with neurosurgery (9.9 percent, 3.6 percent, 4.0 percent, and 13.4 percent respectively). This difference in survival was statistically significant and persisted for at least 7 years after treatment. The study also found that the risk of epilepsy was substantially lower in patients who received endovascular treatment. Conversely, though the risk of late rebleeding was still low, it was higher than for those treated with neurosurgery.

Frank R. Lichtenberg (2006) measured the effect of innovation in five areas of medical procedures and products: pathology and laboratory procedures, outpatient prescription drugs, inpatient prescription drugs, surgical procedures, and diagnostic radiology procedures, on the mortality and disability of Americans who were afflicted with a condition whose treatment was affected by innovation between 1990 and 2003. The study found positive and significant correlations between lab innovation and outpatient drug innovation, and mortality. The study also found that conditions with higher rates of laboratory and outpatient drug innovation exhibited greater increases in the mean age at death. Lichtenberg estimated the increase in the mean age at death resulting from the use of new laboratory procedures to be approximately 6 months, or 42 percent of the total increase (1.18 years), in the mean age at death observed over the period in the sample of diseases. He further estimated that new laboratory procedures introduced between 1990 and 1998 had saved 1.13 million life-years in 1998 (2.31 million people who died in 1998 multiplied by the extra 6 months they lived due to new laboratory procedures).[6]

5 Endovascular coil embolization entails depositing small, flexible platinum coils directly into the aneurysm sac to prevent it from further expansion. Surgical clipping involves placing a clip externally on the aneurysm sac to block blood from entering.

6 Lichtenberg (2006) also found that people with conditions for which there were higher rates of lab and outpatient drug innovation had greater declines in the probability of missing work between 1996 and 2003. However, when the initial disability was controlled for, this relationship between lab innovation and disability became statistically insignificant. Lichtenberg hypothesized that this was the result of the signifi-

A recent report by the Canadian Institute for Health Information (2007) looked at trends in hospital use. It suggested that "advances in medical technology [are] leading to more efficient ways of treating inpatients" (p. 15). The report also found that more operations are being performed as outpatient day surgeries across Canada; the number of hospital procedures performed as outpatient day surgeries increased by 30.6 percent over 10 years, while the number of inpatient surgeries decreased by 16.5 percent. The total number of surgeries increased by 17.3 percent. Further, the age-standardized hospitalization rate decreased by 25 percent over the 10 years, falling from roughly 11 out of 100 Canadians being hospitalized in 1995-1996, to roughly 8 out of every 100 Canadians in 2005-2006. The total number of days Canadians spent in acute care hospitals had also decreased, falling from approximately 23 million days in 1995-1996 to 20 million in 2006 (a 13.1 percent reduction). Moreover, even though the average length of hospital stay remained unchanged since 1995-1996 at 7.2 days, the age-adjusted national average length of hospital stay decreased from 7.5 days in 1995-1996 to 7 days in 2005-2006 (a 6.7 percent decrease). The report made no explicit link between the reduced length of hospital stay, the reduced likelihood of hospitalization, the increased reliance on outpatient day surgery, and advances in medical technology. However, the correlation between advances in medical technology (pharmaceutical, surgical, diagnostic, and otherwise) and shorter hospital stays is worth noting and has been confirmed by studies examining some forms of medical technologies (see, for example, Lichtenberg, 2003).[7]

Or, Wang, and Jamison (2005), in a study examining differences in mortality across OECD nations, found that the "availability of medical technology appears to play a significant role in improving the efficiency of health care provided by doctors (to reduce mortality) across countries" (p. 555). More specifically, they found after controlling for factors such as income and the number of physicians, that countries with a higher long-term availability of MRI and CT scanners (used as proxies for technology generally) produce better health outcomes in terms of life expectancy and potential years of life lost to heart disease. In other words, this study suggests that there is an important beneficial relationship between the supply of medical technologies and the impact of physician care.

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cant inverse relationship between initial health and the extent of laboratory innovation. As a result of errors in measuring initial health, controlling for this variable may have resulted in an underestimation of the impact of innovation on health.

Conversely, Lichtenberg (2006) found the relationship between surgical innovation and mortality to be not significant. However, the author discovered that some "new" procedures identified in his collected data may have simply been older procedures that were reclassified or relabeled, rather than actual innovations. This discovery led to the conclusion that the measure of surgical innovation used may have been problematic.

7 Note that the report also made no link between the amount of hospitalization (lengths of stay and admissions) and changes in health associated with care.

Table 1 Summary of research on the value of medical technology changes

Condition	Years	Change in treatment costs	Outcome		
			Change	Value	Net benefit
Heart attack	1984-98	$10,000	One-year increase in life expectancy	$70,000	$60,000
Low-birthweight infants	1950-90	$40,000	Twelve-year increase in life expectancy	$240,000	$200,000
Depression	1991-96	$0	Higher remission probability at some cost for those already treated		
		<$0	More people treated, with benefits exceeding costs.		
Cataracts	1969-98	$0	Substantial improvements in quality at no cost increase for those already treated		
		<$0	More people treated, with benefits exceeding costs		
Breast cancer	1985-96	$20,000	Four-month increase in life expectancy	$20,000	$0

Source: Cutler and McClellan, 2001: 19.

The studies examining the medical benefits of advances in technology discussed above show that advanced medical technologies can reduce mortality, increase longevity, and increase quality of life. However, these new technologies can be expensive and their costs are often cited as reasons for the lack of investment. A common concern is whether the benefits of medical technologies are worth their cost. Several studies address this issue directly.

In the paper measuring the effect of innovation in laboratory procedures discussed above, Frank R. Lichtenberg (2006) determined the cost per life-year gained from the new laboratory procedures was estimated to be $6,093. According to Lichtenberg, this value is generally considered to be "quite cost-effective" (p. 12). Similarly, Rublee (1989), in a review of access to medical technology, states that computerized diagnosis and lithotripsy can be both quality enhancing and cost saving (p. 178).

Cutler and McClellan (2001) reported on a series of studies showing the disease-level costs and benefits of medical advances in five conditions: heart attacks, low birth weight, depression, cataracts, and breast cancer. The study primarily measured increased longevity and increased productivity of patients as a result of the introduction of medical technology. Cutler and McClellan concluded that even though techno-

logical change has accounted for a significant portion of medical care cost increases over time, medical spending as a whole is worth the cost. Their findings are shown in table 1.

For example, according to the study, life expectancy for the average person following a heart attack was just short of 5 years in 1984, but by 1998 it had risen to 6 years. Assuming the additional year of life was valued at $100,000 and the annual cost of living was estimated to be $25,000 during that additional year of life, Cutler and McClellan (2001) estimated the benefit to society of an additional year of life for heart attack patients to be $75,000. Including an accounting for the time-value of money (a dollar given six years from now is worth less to an individual today than is a dollar given today), the present value of the benefits from technological change was found to be $70,000.[8] Since the treatment costs increased by $10,000 between 1984 and 1998 as a result of technological innovation that both replaced older forms of care and provided existing technologies to more patients, the net benefit from new technology was estimated to be approximately $60,000 (Cutler and McClellan, 2001).

Cutler and McClellan (2001) also reviewed studies examining the costs and benefits of technological change in the treatment of low birth weight infants, depression, cataracts, and breast cancer. They found that the estimated benefit of technological change in all but the latter was much greater than the cost. Though outcomes were improved by advances in the treatment of breast cancer, the increase in costs was roughly equal to the societal benefit, which led to the conclusion that, in this instance, "technological change was neither beneficial nor harmful on net" (p. 23).

The study concluded that the cost of technology for heart attacks, low birth weight, depression and cataracts is high, but it is outweighed by the value of health benefits that accrued from the introduction and use of these technologies. Although only 5 conditions were analyzed in the study, the results have implications for the health care system more broadly. The report states: "The benefits from lower infant mortality and better treatment of heart attacks have been sufficiently great that they alone are about equal to the entire cost increase for medical care over time. Thus, recognizing that there are other benefits to medical care, we conclude that medical spending as a whole is clearly worth the cost" (p. 12).[9]

A study by Cutler (2007) finds that revascularization, or re-establishing adequate blood supply, following a heart attack (including angioplasty and coronary artery bypass grafting) is also a cost-effective technological innovation. Specifically, the study examines the survival and care costs for US Medicare patients over a 17-year period

8 The authors used a 3 percent discount rate.

9 This conclusion should be applied with caution to the Canadian health care model in which the relationship between spending and access to health care has been shown to be tenuous at best (Esmail and Walker, 2007; Esmail and Walker with Bank, 2007; CIHI, 2006c; Esmail, Clemens, Veldhuis, and Palacios, 2007).

Table 2 Potential annual savings if existing surgical procedures for eight diseases were replaced with interventional radiology procedures, in appropriate circumstances

Disease	Treatment savings ($ millions)	Societal savings ($ millions)	No. of hospital bed-days saved	No. of patient lives saved
Peripheral Arterial Disease (iliac)	21.0	1.1	6,497	34
Peripheral Arterial Disease (lower extremity)	26.6	2.5	14,691	54
Abdominal Aortic Aneurysm	-5.0	8.5	6,559	43
Ischemic Stroke	-1.1	0.4	2,439	23
Cerebral Aneurysm	15.2	0.8	4,834	67
Uterine Fibroids	38.5	78.3	58,768	34
Vertebral Fracture (vertebroplasty)	59.7	ND	ND	0
Liver Cancer	25.4	0.7	4,222	147
Total	180.3	> 92.3[a]	98,010	402

ND = not determined.
[a]For most treatments, the societal savings associated with a potentially quicker recovery were not accounted for.
Source: Baerlocher, 2007: 616.

following their heart attacks. Cutler determines that revascularization results in a 1.1 year increase in life expectancy at a cost of approximately $38,000 ($33,246 per year of life gained) if the benefits of revascularization flow directly from the treatment, or a 0.08 year increase in life expectancy at a cost of approximately $1,389 ($17,022 per year of life gained) if admission to a hospital with revascularization capabilities is the source of benefits for patients. Either way, Cutler finds that the care provided is clearly worth the cost, whether the care provided is revascularization itself, or the quality of care provided by hospitals with revascularization capabilities Cutler (2007).

A study commissioned by the Canadian Association of Radiologists and the Canadian Interventional Radiology Association showed that significant savings could be realized if existing surgical procedures were replaced with interventional radiology (minimally invasive procedures performed using image guidance). Specifically, the study found that for 8 diseases, replacing existing surgical procedures with interventional radiology procedures in appropriate circumstances could potentially save 402 Canadian lives annually, as well as 98,010 hospital bed-days, $180.3 million in direct treatment costs, and more than $92.3 million in societal costs (see table 2).

(These costs include indirect health care savings associated with faster recovery and return to work, and less follow-up visits.) These savings calculations were not net-of-costs; the study estimated that an annual budget of $221.3 million would be required to realize the annual savings (Baerlocher, 2007; MRG, 2006).

Most research examining the benefits and cost effectiveness of advanced medical technologies tends to focus on pharmaceuticals rather than medical devices, partly as a result of the greater availability of data (Productivity Commission, 2005; Lichtenberg, 2003). However, given the parallels between new pharmaceuticals and new medical devices, pharmaceutical studies may be used to illustrate principles related to the analysis of the cost-effectiveness of new medical technologies.

According to a study by Frank R. Lichtenberg (2001), spending money on newer (and generally more expensive) drugs can actually reduce health care expenditures overall. Lichtenberg (2001) examined the relationship between the age of the pharmaceuticals that Americans were taking, and the numbers of non-drug medical events that these individuals experienced that were associated with the same condition. He found that individuals who were taking newer drugs had fewer and shorter hospital stays than those who were using older drugs. The group taking newer drugs also used fewer non-drug health care services overall (including physician visits, etc.). Lichtenberg estimated that going from a 15-year-old drug to a 5.5-year-old drug would increase the cost of a prescription by about $18, but would reduce the expected number of hospital stays (about 6 fewer stays per 1,000 prescriptions), the length of those stays, and the number of health services used overall, thus saving about $71.

Other studies have also shown that the benefits of pharmaceuticals can exceed their costs, or can increase longevity and quality of life at a reasonable cost. For example, Neumann et al. (2000) reviewed numerous cost-utility analyses and found that various drugs saved money or were cost-effective. Still other studies have shown that pharmaceuticals can provide numerous benefits to patients in the form of improved health outcomes, reduced disability, and increased life span (see, for example, Frech and Miller, 1999; Frech and Miller, 2004; Lichtenberg, 2002 and 2003; Han and Wang, 2005).

The evidence reviewed above finds that medical technologies can increase longevity, reduce mortality, and improve quality of life for those fortunate enough to have access to them. Medical technologies can often accomplish these improvements cost effectively, and in some cases can reduce costs while improving outcomes. Thus, a high quality health care program should provide individuals with a high level of access to medical technologies; not doing so would be to the detriment of patients. Does Canada's health care program live up to the claim that it is a high quality program?

2 Comparisons of the availability of medical technologies

A review of studies comparing general access to technology provides some insight into the availability of advanced medical technologies in Canada. The discussion below considers both the relative and absolute quality of health care in Canada as measured by access to medical technologies. It also provides some context for the subsequent sections that look at the age and sophistication of medical technology in Canada, as well as the availability of cutting-edge medical technology. This review is divided in two. The first part attempts to judge access to medical technologies for Canada as a whole by looking at cross-national comparisons of access. The second part tries to determine whether some provinces are performing better than others in this area by looking at comparisons of access to technology within Canada.

International comparisons

In 1999, Harriman et al. examined the availability of medical technologies internationally, by comparing Canada with other OECD countries, and regionally, by comparing British Columbia with two American states (Washington and Oregon). Harriman et al. found that internationally, Canada was generally in the bottom third of OECD countries, despite ranking among the OECD's highest spenders on health care (as a percent of GDP). For instance, Canada ranked twenty-first out of 28 OECD nations in the availability of computed tomography (CT) scanners, nineteenth out of 22 in the availability of lithotriptors (a machine that employs ultrasound to break up stones in the body), and nineteenth out of 27 in the availability of magnetic resonance imagers (MRIs). Canada compared favourably only in the availability of radiation equipment, where it ranked sixth out of 17. Overall, Harriman et al. showed that many OECD nations provided greater accessibility to a number of important technologies while spending less on health care than did Canada.

Harriman et al. (1999) also used OECD data to analyze the rate of diffusion of MRI technology over time (using MRI technology as a proxy for investment in technology generally). Technological diffusion can illustrate how committed a country is to bringing advanced medical technologies into its health care facilities. It also serves as an indicator of the restrictions regulatory bodies and funding agencies place on a technology, and can help determine whether a country is a leader, or a late adapter, in adopting advanced technologies. The researchers compared the availability of MRIs among OECD nations the first five years they became generally available, with their availability in the following five-year period. Harriman et al. (1999) found the diffusion of MRIs in other countries to be much more rapid than in Canada. This suggests that

Table 3 Leading-edge technologies available in Washington and Oregon but not available in British Columbia, as of March 31, 1998

Specialty	Technology
Anesthesia	Intraoperative transesophageal echocardiography
Cardiology	Echocardiography with harmonic imaging
	Radioactive Balloon Angioplasty
Emergency Medicine	Emergency room dedicated ultrasound
Gastroenterology	GI endoscopic ultrasound
	GI endoscopic laser
General Surgery	Minilaparoscopy (3mm)
Neurosurgery	Frameless stereotaxy
Opthamology	Foldable intraocular lens for cataract surgery
Obstetrics/Gynecology	Laparoscopic laser ablation of the endometrium
Otolaryngology	3D image guided sinus surgery
Radiology	Intraoperative CT scans
	Open type MRI
	MRI breast coil
	PET scan for clinical use
Vascular Surgery	Laser angioplasty
Urology	Brachytherapy
	Laser prostatectomy

Source: Harriman et al., 1999.

Canada is a late adopter of advanced medical technologies, and has not been strongly committed to investment in medical technology in the past or has restricted the introduction of new technology.

In their regional comparison, Harriman et al. (1999) found that hospitals at the University of British Columbia were technologically deficient when compared to university teaching hospitals in Oregon and Washington. Table 3 lists the technologies that the authors identified as entirely absent in British Columbia at the time of the survey, but which were present in the Washington and Oregon health systems.

In a comparison of community and regional hospitals, Harriman et al. found that hospitals in British Columbia, Washington, and Oregon were similarly equipped with CT scanners, ultrasound machines, and nuclear-medicine services, but that there was

Table 4 Percent of surveyed community and regional hospitals equipped with select medical services/technologies in Washington, Oregon, and British Columbia, 1997/1998[a]

	Diagnostic imaging				High-tech equipment			Cardiac and transplant procedures				Intensive care services			
	Ultra-sound	CT scanner	Nuclear medicine	MRI	Litho-tripsy	PET scanner	Spectro-scopy	Angio plasty	Cardiac catheterization lab	Coronary artery by-pass graft	Trans-plant	ICU	Cardiac ICU	Paed-iatric ICU	Neo-natal ICU
Washington	100%	100%	100%	100%	70%	10%	60%	80%	90%	60%	10%	100%	60%	10%	60%
Oregon	100%	100%	90%	80%	90%	0%	40%	80%	100%	80%	40%	90%	60%	30%	50%
British Columbia	100%	90%	80%	20%	0%	0%	60%	10%	20%	10%	0%	100%	20%	0%	10%

[a]The comparability of hospitals was ensured by matching facilities selected for surveying by the numbers of beds and admissions.
Source: Harriman et al., 1999.

a large deficit in the availability of MRIs and lithotripters in British Columbia. Moreover, hospitals in Oregon and Washington were also significantly more likely to provide specialized services, such as angioplasty, cardiac catheterization facilities, and specialized intensive care services[10] than were the equivalent facilities in British Columbia (table 4).

Recently released data from the OECD (2008) finds that while the availability of medical technology has improved in Canada, it remains below average. Specifically, the OECD reports that the number of MRI units in Canada (6.2 per million people in 2006) lags the OECD average (10.2 per million), and that the number of CT scanners (12.0 per million people in 2006) also lags the OECD average (19.2 per million). Conversely, the OECD reports that Canada's total expenditures on health care are above the OECD average both as a percent of GDP and per capita.

A 2006 Canadian Institute for Health Information [CIHI] report examined the OECD data on medical technology and also found access to services in Canada lagging that in many other countries. Specifically, Canada ranked below the OECD median in the availability of MRI machines, with 5.5 machines per million people on January 1, 2005, compared with a median of 6.6 for OECD countries with a population of one

10 While patients may be adequately treated in a general intensive-care unit, the services and technology provided in specialized centers are generally seen to be superior. For example, a specialized unit providing paediatric and cardiac care would have more specially trained personnel and a much wider spectrum of specialty equipment to monitor and manage these particular patient groups. Studies have also shown that specialized stroke care units can improve outcomes (Moon et al., 2003).

Table 5 Age-adjusted availability of medical technology in OECD nations that maintain universal access health insurance programs, 2004

Country	**MRIs/ million**	**Rank out of 24**	**CT Scanners/ million**	**Rank out of 24**	**Mammo-graphs/ million**	**Rank out of 17**	**Litho-tripters/ million**	**Rank out of 20**
Australia	4.1	17	50.1	2	—	—	1.4	13
Austria	15.4	4	28.3	6	—	—	1.7	11
Belgium	5.5	12	29.0	5	19.5	9	4.0[a]	6
Canada	**5.4**	**13**	**12.0**	**18**	**21.4[c]**	**7**	**0.6**	**17**
Czech Republic	2.9	21	13.2	14	14.4	12	3.3	7
Denmark	10.2	9	14.6	11	—	—	—	—
Finland	13.6	5	13.8	13	36.5	3	0.4	20
France	3.0	19	7.0	22	39.7[b]	2	0.6	17
Germany	5.6	11	13.0	15	—	—	3.0	9
Greece	2.1[b]	23	15.3[b]	10	24.9[b]	5	—	—
Hungary	2.5	22	6.6	24	12.3	13	1.1	15
Iceland	24.5	2	20.5	8	20.5	8	4.1	5
Ireland	—	—	—	—	—	—	—	—
Italy	12.0	7	22.4	7	—	—	—	—
Japan	29.6[b]	1	77.7[b]	1	—	—	5.4[b]	3
Korea	16.6	3	47.4	3	40.8	1	11.7	1
Luxembourg	11.4	8	29.8	4	23.0	6	2.3	10
Netherlands	—	—	—	—	—	—	—	—
New Zealand	4.3[a]	16	14.2	12	27.1	4	0.6[a]	17
Norway	—	—	—	—	—	—	—	—
Poland	2.1	23	7.6	20	16.9	10	3.2	8
Portugal	3.6[a]	18	11.8[a]	19	10.7[a]	14	1.3[a]	14
Slovak Republic	4.5	15	12.3	16	15.7	11	6.3	2
Spain	7.1	10	12.3	16	9.4	15	1.7	11
Sweden	—	—	—	—	—	—	—	—
Switzerland	13.6	5	17.0	9	—	—	4.5	4
Turkey	3.0	19	7.3[a]	21	6.5[a]	17	1.0[c]	16
United Kingdom	4.8	14	6.7	23	7.8	16	—	—
OECD average	**8.6**	**—**	**20.4**	**—**	**20.4**	**—**	**2.9**	**—**

[a]2003
[b]2002
[c]2001
— = not available
Note: Figures for Turkey were not age-adjusted due to a very low 65+ population not conducive to meaningful adjustment.
Source: Esmail and Walker, 2007.

Table 6 Comparative availability of selected medical technologies in Canada, Germany, and the United States, 1987-1989

	Canada (1989)			Germany (1987)			United States (1987)		
	No. of units	**Persons per unit (1,000)**	**Units per million persons**	**No. of units**	**Persons per unit (1,000)**	**Units per million persons**	**No. of units**	**Persons per unit (1,000)**	**Units per million persons**
Open-heart surgery	32	813	1.23	45[a]	1,355[a]	0.74[a]	793	307	3.26
Cardiac catheterization	39	667	1.50	161	379	2.64	1,234	198	5.06
Organ transplantation	28	929	1.08	28[a]	2,178[a]	0.46[a]	319	764	1.31
Radiation therapy	14	1,857	0.54	191	319	3.13	967	252	3.97
Extracorporeal shock wave lithotripsy	4[a]	6,500[a]	0.16[a]	21	2,904	0.34	228	1,069	0.94
MRI	12[a]	2,167[a]	0.46[a]	57	1,070	0.94	900	271	3.69

[a]1988.
Source: Rublee, 1989: 180.

million or more in 2004 (or in 2002 in Japan's case). The number of CT scanners in Canada was also below the OECD median: Canada had 11.3 scanners per million people compared to the OECD median of 13.8 per million (CIHI, 2006a).

The Fraser Institute's annual study, *How Good is Canadian Health Care?* also uses OECD data to compare access to technology among developed nations that maintain universal-access health insurance programs, but adjusts that data for the age of the population. This is done to account for the fact that Canada's relatively young population is likely to require fewer health care services than older populations, such as Japan's. The 2007 edition indicated that Canada continues to rank as one of the highest spenders on health care within the OECD while providing its citizens with relatively poor access to technologies (table 5). Specifically, the report finds that the age-adjusted number of machines available per million inhabitants in Canada is significantly lower than the average of OECD nations that maintain universal-access health insurance programs in three of the four categories where comparable data on technology is available for a significant number of countries: Canada has fewer MRI machines per million inhabitants, fewer CT scanners per million inhabitants, and fewer lithotripter machines per million inhabitants than the OECD average. As table 5 shows, the technology deficit relative to some countries, such as Japan and Switzer-

land, is even greater than Canada's technology deficit relative to the average of the developed nations compared (Esmail and Walker, 2007).

Two separate analyses by Rublee (1989 and 1994) examined the availability of open-heart surgery, cardiac catheterization, organ transplantation, radiation therapy, extracorporeal shock wave lithotripsy, and MRI, in Germany, Canada, and the United States. Rublee identified all of these medical technologies as having "wide medical applicability" and "high capital and operating costs" (1989: 179). Canada and Germany were used as comparators to the United States because of the similarities between the nations in terms of overall health care resources, though Rublee is careful to note that the resources were deployed somewhat differently in each nation. The author commented that "[b]y Western standards, Canada is an example of a country that has taken a tough stance on slowing the introduction of major technologies; Germany is one that has taken a few small steps in that direction; the United States has done practically nothing" (1989: 179).

In 1989, the poor availability of all technologies in Canada ranked it last in Rublee's study, with the exceptions of open-heart surgery and organ transplantation (per million people), where Canada outperformed Germany. Access to technology in the United States was found to be significantly better than in either Canada or Germany[11](see table 6). More specifically, Rublee states:

> The largest differences between the United States and the other two countries are in MRI, open-heart surgery, and cardiac catheterization. Germany has almost the same number of radiation therapy units per capita as the United States, and almost six times as many as Canada. Germany has more than twice the per capita availability of MRI and lithotripsy as Canada. Canada has more than twice the availability of organ transplantation as Germany. Key comparisons between Canada and the United States include: (1) nearly eight times more MRI and radiation therapy units per capita in the United States than in Canada; (2) over six times more lithotripsy centers per capita in the United States; (3) roughly three times more cardiac catheterization and open-heart surgery units per capita in the United States; and (4) slightly more availability of organ transplantation units per capita in the United States. (Rublee, 1989: 179-180)

11 Rublee (1989) noted that the differences between Canada, Germany, and the US could be interpreted as overprovision in the United States, as opposed to underprovision in Canada and Germany. Rublee stated that, "[i]ndeed, all levels could be optimal for the countries concerned, given different social values for technology in each of the countries concerned" (p. 181). He concluded that "the differences in levels of major technology, in themselves, indicate little about the overall effectiveness, achievements, and weakness of the health care systems of any of the three countries studied" (p. 181). However, as discussed in the earlier sections of this paper, a lack of, or low provision of, certain advanced technologies may have a significant adverse impact on patient care, and so it cannot be easily stated that lower access to medical technology in Canada is appropriate.

Table 7 Comparative availability of selected medical technologies in Canada, Germany, and the United States, 1992-1993

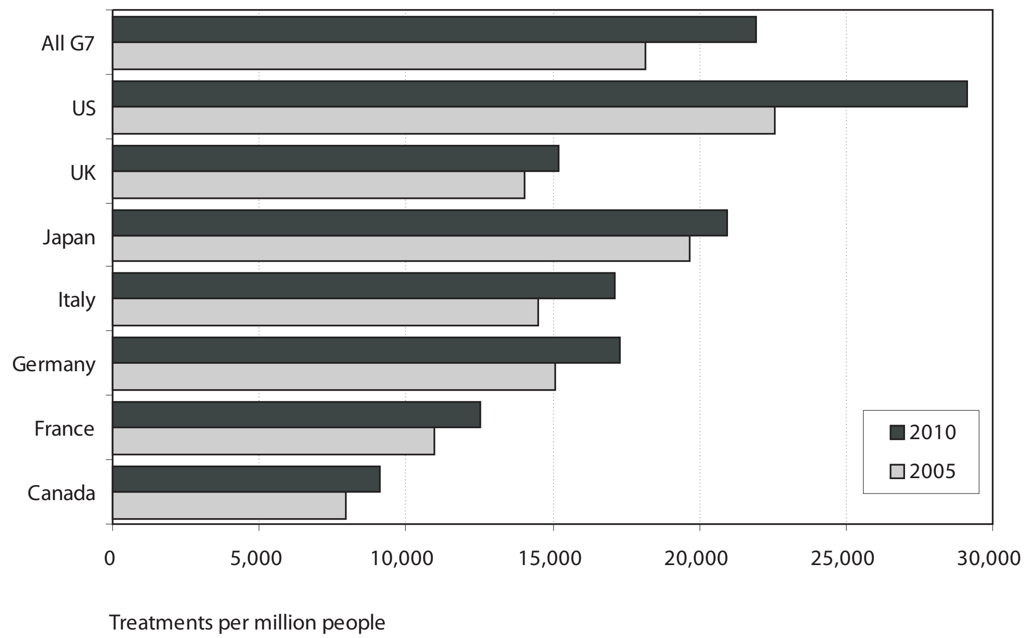
	Canada (1993)			Germany (1993)			United States (1992)		
	No. of units	Units per million persons[a]	Average annualized rate of change since 1989[b]	No. of units	Units per million persons	Average annualized rate of change since 1987[c]	No. of units	Units per million persons	Average annualized rate of change since 1987
Open-heart surgery	36	1.3	1.3%	61	0.8	0.4%[d]	945	3.7	2.6%
Cardiac catheterization	78	2.8	17.0%	277	3.4	4.5%	1,631	6.4	4.8%
Organ transplantation	34	1.2	3.2%	39	0.5	1.0%[d]	612	2.4	12.9%
Radiation therapy	32	4.8	11.0%	373	4.6	6.7%	2,637	10.3	2.3%
Lithotripsy	13	0.5	24.0%[d]	117	1.4	27.3%	480	1.9	14.9%
MRI	30	1.1	18.6%[d]	296	3.7	25.5%	2,900[e]	11.2[f]	20.4%

[a]Midyear population estimates as reported in US Bureau of the Census, *Statistical Abstract of the United States*, 1993 (113th ed.). Canadian figures based on 1992 population estimates.
[b]Based on figures from, and revisions to, D. Rublee, "Medical Technology in Canada, Germany, and the United States," *Health Affairs* (Fall 1989): 180.
[c]1987 and 1988 data do not include Germany's new states.
[d]1988.
[e]1993.
[f]Based on 1993 population estimate.
Source: Rublee, 1994: 115.

In his 1994 update, Rublee again found that the availability of all of the selected technologies was greater in the United States than the other two countries (see table 7). More relevant to this discussion, Canada's rate of units per million people remained well below that of the United States in all technologies studied. Similar to the 1989 findings, Canadians had better availability to open-heart surgery and organ transplantation than did Germans (units per million people). Additionally, the new data indicated that Canadians also had better access to radiation therapy than Germans. On the other hand, Germans had superior access to cardiac catheterization, lithotripsy, and MRI (Rublee, 1994).

A report by Millennium Research Group, commissioned by the Canadian Association of Radiologists and the Canadian Interventional Radiology Association, studied the availability of interventional radiology in G7 nations (Baerlocher, 2007). The study found that per million people, in 2005 Canada performed the fewest number of

Figure 1 Estimated numbers of interventional radiology treatments per million population in G7 nations in 2005 and predicted numbers for 2010



Source: Baerlocher, 2007: 616.

interventional radiology procedures among G7 nations. The study also reported that if current trends continued, Canada would remain behind all other G7 nations in 2010. Further, the forecasted number of procedures per million people performed in the US in 2010 would be 3.2 times greater than in Canada (figure 1).

In a study published in 2001, the Technological Change in Health Care (TECH) Research Network examined heart attack care in 17 countries, including Canada. The study looked at the adoption of new intensive technologies which were classified as "high-tech" because of the large quantity of expert input and resource cost required for each use (including cardiac catheterization within one year after heart attack, bypass surgery within one year after heart attack, and one-day or primary angioplasty in heart attack patients). The paper also examined access to "nonintensive" technologies, such as generic drug prescriptions, which incur a lower cost in terms of resources and expert input per use. The report indicated that technological change for heart attack care has differed in many ways across countries.[12] Canada, the study found, is considered a late adopter in the use of intensive procedures and was classified as one of the

12 The nature and magnitude of technological change were noted to be systematically related to the economic and regulatory incentives in a country's health care system.

Table 8 Distribution of PET scanners reported by INAHTA members, 2003 and 2004

Country/Region	Total no. of PET scanners (dedicated/PET-CT)[a]	PET scanners per 1 million people
Belgium	13 (9/4)	1.26
Denmark	6 (3/3)	1.2
Austria	9 (9/0)	1.13
Germany	80 (80/0)	1.0
France	50 (NR/NR)	0.83
United States (Veterans Health Administration)	6 (6/0)	0.83
Australia	13 (9/4)	0.65
Sweden	5 (5/0)	0.57
Israel	3 (1/2)	0.46
Canada	10 (10/0)	0.39
Finland	2 (2/0)	0.38
Spain	13 (13/0)	0.33
United Kingdom	16 (NR/NR)	0.28
The Netherlands	4 (NR/NR)	0.25
Average	—	0.65

NR = Breakdown not reported.
[a]Dedicated PET scanners perform PET scans only while PET-CT is a fusion technology that can also be used separately to perform only PET or CT scans.
Source: Hastings and Adams, 2006: 145.

slowest of the nations among those that rapidly expand access to care after adoption. For instance, Canada adopted intensive heart care procedures relatively late compared with early adopters like the United States, but the rate of their adoption then grew relatively quickly. However, that growth rate was somewhat slower than the other nations in the late adopter/rapid expansion group. (Those nations included Australia, Belgium, Canada,[13] France, Italy, Singapore, and Taiwan.) The overall use of high-tech treatments in Canada did not appear to catch up to that in the United States: Canada's growth rate for these treatments remained below that of the US, which was not the case for other nations, such as Australia. Conversely, the authors found no systematic differences in trends between nations for relatively inexpensive and "easy-to-use" drug

13 While this description applied to the trend in Canada generally, Ontario was specifically identified as a late adopter/slow growth jurisdiction for some measures.

therapies. The trends observed for expensive drugs were similar to those for "high-tech" interventions described above (TECH Research Network, 2001).

In 2006, the International Network of Agencies for Health Technology Assessment (INAHTA) published the results of a survey of the availability of PET scanners in its member countries. The survey was conducted between 2003 and 2004 and 27 INHATA agencies in 19 countries responded (a 69 percent response rate). The number of PET units per million people in Canada ranked this country near the bottom of the 14 nations for which data were available (see table 8). Specifically, Canada ranked tenth ahead only of Finland, Spain, the UK, and the Netherlands (Hastings and Adams, 2006).

Birnie et al. (2007) compared the use of implantable cardioverter defibrillators (a device that has been shown to reduce the death rate among survivors of cardiac arrest and among people at risk of arrhythmias) among those who survived out-of-hospital cardiac arrest in Canada and the United States from April 1, 1994 to March 31, 2003. They found that 16.6 percent of Canadians were implanted with the device prior to their discharge from hospital on average during the years studied, and that the rate of implantation had increased from 5.4 percent in 1994/95 to 26.7 percent in 2002/03. By comparison, 30.2 percent of Americans received such an implant prior to discharge over the years studied (rising from 9.7 percent in 1994/95 to 42.0 percent in 2002/03), and the rate of implantation in the United States exceeded the Canadian rate in every year studied (Birnie et al., 2007; Simpson, 2007). The study's results also support the finding that the rate of diffusion (in terms of geographic availability) of this technology may be lower in Canada than in the United States: Canadians were nearly three times as likely to receive the technology if admitted to a teaching hospital rather than a non-teaching hospital according to the study, while numerous medium and small community facilities in the United States provide such implants for patients (Birnie et al., 2007; Simpson, 2007).

Another way of looking at access to medical technology is to study the use of equipment already in place. Ontario's MRI and CT Expert Panel (Keller, 2005) looked at the number of scans being performed in Ontario in comparison to the number in the United States and Europe (see table 9). The Panel's report indicated that the actual population-based rates for MRI and CT scans per 1,000 residents in Ontario were well below those in the United States generally, and western New York specifically. Also, the number of scans reported in Ontario was below the benchmark number of scans proposed by the Alberta Imaging Advisory Committee and the Ontario Association of Radiologists.

CIHI's study *Medical Imaging in Canada, 2005* compared the rates of use of MRIs and CT scanners in Canada, the United States, and England (table 10). The report found that Canadians received more MRI and CT scans per 1,000 people than were provided by England's public system, but fewer than Americans received. Canadian MRI and CT scanners were also used fewer hours on average (slightly fewer for CT) than

Table 9 MRI and CT scans per thousand people, selected jurisdictions

Actual scans per 1,000 people	**CT**	**MRI**
United States	151	76.5 (50-115)
Western New York	—	79
European Association of Radiology	17-120	5-50
Ontario	80-97	30-34
Proposed scans per 1,000 people	**CT**	**MRI**
Imaging Advisory Committee (Alberta)	114	62
Ontario Association of Radiologists	110-130	60-69

Source: Keller, 2005: 19.

were scanners in the US. Conversely, Canada performed more exams per MRI scanner than either the US or England's public system and more exams per CT scanner than the US (data for exams per CT were not available for England), which would have made up for some of the deficit in Canada's technology inventory. This increased use was also measured when comparing the number of exams performed per full-time equivalent technologist (data which only Ontario and New Brunswick reported). Despite the higher number of scans performed per MRI and CT machine in Canada (at least in comparison with England's public system and the US), the CIHI report noted that their data suggest an underutilization of both types of technology (CIHI, 2005).[14]

Yet another way of measuring the availability of medical technology is to survey physicians for their opinions on the quality of health care systems and availability of

14 The Ontario MRI and CT Expert Panel's report's findings support CIHI's findings. According to the Panel's report, hospitals reported to the ministry that their MRI scanners operated 199,353 hours in 2003-04, while the Ministry funded 170,560 MRI hours. For CT scans, hospitals reported 288,100 operational hours for CT scanners per year. A comparison of the Panel's recommended standard (16 hours a day, 7 days a week) to actual operational hours found that on average, hospitals were operating their MRI scanners at 69 percent of recommended capacity, and their CT scanners at 53 percent of capacity. Excluding paediatric facilities, an additional 101,648 hours would be available to Ontarians if all MRI scanners operated for the recommended standard time, while an additional 243,108 hours would be available if MRI scanners were to operate 24 hours a day, 7 days a week. For CT scanners, an additional 233,700 hours were available at the recommended 16 hours a day, 7 days a week standard (Keller, 2005: 21). Importantly, the Panel's report noted that even if operational hours of current MRI machines were expanded to 24 hours a day, 7 days a week, many regions in Ontario would still have insufficient MRI capacity to meet the recommended benchmark of 62 scans per 1,000 people, as proposed by Alberta's Imaging Advisory Committee (Keller, 2005: 21).

Table 10 Average number of Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) exams per 1,000 people, per scanner, per full-time equivalent (FTE) technologist, and average number of hours of operation of scanners per week in the US, England, and Canada, 2004-2005 or latest year

Country	Exams per 1,000 people		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[b]	5,298[c]	1,195[b]	1,790	70.0	57.6
England[a]	19.0	43.0	3,513	—	517	1,173	—	—
Canada	25.5	87.3	4,666[f]	7,745[f]	1,341[d]/1,508[e]	4,058[d]/3,273[e]	66.0	57.0

[a]Includes exams in the public sector only
[b]Based on exams performed in hospital sites with fixed MRI scanners
[c]Based on the total number of CT exams and total number of fixed CT scanners. It is implicitly assumed that the 1.8 percent of sites (130 out of 7,355) using mobile scanners perform a negligible number of exams.
[d]Rate for New Brunswick in 2003-2004. New Brunswick and Ontario are the only two provinces that submit data to CIHI's *Canadian MIS Database* on earned hours of technologists.
[e]Rate for Ontario in 2003-2004. Ontario and New Brunswick are the only two provinces that submit data to CIHI's *Canadian MIS Database* on earned hours of technologists.
[f]For improved international comparability, average number of exams per scanner in Canada was calculated by dividing the total number of scanners installed, including scanners installed but not yet in operation.
— = not available.
Source: CIHI, 2005: 78.

medical technology. A recent survey by the Commonwealth Fund (Blendon et al., 2001) surveyed physicians in Australia, Canada, New Zealand, the United Kingdom, and the United States regarding quality of and access to health care. According to the survey, over half (59 percent) of the physicians surveyed in Canada believed that their ability to deliver high-quality care decreased over the 5 years prior to the survey, compared to 38 percent in Australia, 53 percent in New Zealand, 46 percent in the United Kingdom, and 57 percent in the United States. Moreover, 62 percent of the Canadian physicians surveyed indicated that they were very concerned that the quality of care would decline in the future compared to 44 percent in Australia, 52 percent in New Zealand, 39 percent in the United Kingdom and 53 percent in the United States (see table 11). While these concerns may not be directly related to access to medical technologies, a greater supply of, and access to, medical technologies would likely improve perceptions of quality and access among physicians.

With respect to the availability of medical resources and technologies specifically, 63 percent of Canadian physicians reported shortages of the latest medical and diagnostic equipment in their communities. This was by far the highest percentage of physicians in the countries surveyed. In Australia only 13 percent of physicians indicated that the supply of the latest medical and diagnostic equipment was inadequate;

in New Zealand it was 29 percent, in the United Kingdom it was 47 percent, and in the United States it was 8 percent. Moreover, Canada also had the highest percentage of doctors (37 percent) who considered limitations in ordering diagnostic tests or procedures a major problem for their practice, compared to 9 percent of doctors in Australia, 26 percent in New Zealand, 30 percent in the United Kingdom and 21 percent in the United States (table 11) (Blendon et al., 2001).

The survey also addressed physicians' perceptions of patients' problems. Although New Zealand had the highest percentage of doctors who reported that patients often lacked access to the newest drugs or medical technologies, Canada tied for second place

Box 1 The Debate over PET Scanning

Some analysts and government officials in Canada have argued that PET scanning is often overused in other countries, and that limiting access to it might be the right approach. For example, Ontario has been restricting access to PET scanning because it contends that it does not yet have proof that, as a diagnostic tool, PET scanners provide superior results to CT scanners (Eggertson, 2005). This raises the question of whether access to PET scanners is a valid comparison of the quality of care provided by health care systems. That said, while access to PET scanning does vary among the provinces and is more restricted in some provinces than others, most provinces do provide public funding for PET services. In 2006, patients in British Columbia, Alberta, Manitoba, Ontario, Quebec, and New Brunswick had access to publicly funded PET scans. In addition, Nova Scotia was planning to have a PET scanner available within a year (CADTH, 2005; Priest, 2006).

There are several reasons why access to PET should be considered a valid and useful measure of access to medical technology and the quality of care in a health care program. A number of experts see PET scans as an already proven tool for treating cancer cases and in other areas of care (see, for example, Eggertson, 2005). For example, PET scans can help physicians asses a tumour's response to treatment within 2 to 3 weeks, allowing physicians more opportunities to adjust and tailor treatment regimens for patients. PET scans can also be used in the detection, location, monitoring, staging, follow up, and recurrence assessment (particularly when there may be difficulty distinguishing between recurrence and scar tissue) of cancer. In addition to cancer diagnosis and care, PET scanners can also be used (and are used in various nations) for the diagnosis and determining the stage of Alzheimer's disease, the diagnosis of epilepsy, and in cardiology (e.g. myocardial viability) (Gonzalez et al., 2002; Priest, 2006; Pearcey and McEwan, 2006; Eggertson, 2005). Further, PET scanning can provide a less invasive option for patients than conventional procedures, a fact that is not often considered in assessments of PET (OECD, 2005). Indeed, clinical PET scanning is routine in the US, in many European countries, and in Japan (CADTH, 2005).

Various international technology assessment reports and studies have also shown the usefulness of PET scanning. For example, a 2003 Norwegian review (English-lan-

with the United Kingdom and the United States, where 26 percent of doctors held this view. In Australia only 15 percent of doctors believed this to be the case (table 11).

The evidence reviewed in this section demonstrates that Canada often lags most developed nations in access to modern medical technologies and is a late adopter of advanced medical technologies. The evidence also demonstrates that Canada lags a number of other nations in the rate of expansion in inventories or applications of technology, after they have been introduced. The considerable lack of access to modern technologies despite relatively high levels of expenditure is one reason the Canadian health care system should be considered a failure.

guage summary published by the International Network of Agencies for Health Technology Assessment) reported that PET should be employed in oncology as it is more accurate than other diagnostic procedures for several indications. The review specified that this finding applied mainly to "non-small cell lung cancer (NSCLC) and solitary pulmonary nodules, staging of Hodgkin's disease, identifying metastasis from malignant melanoma and colorectal cancer, and in finding tumours in the head/neck" (Mørland, 2004). Despite finding these important benefits, the report noted that PET is still in the development phase, and that "examinations should be performed within the framework of clinical trials" (Mørland, 2004).

Another example comes from a Scottish review of PET imaging in the measurement and treatment of cancer, which focused primarily on non-small cell lung cancer and lymphoma (Bradbury et al., 2002; Facey, 2003). The report found that PET was more cost-effective than CT in the restaging (i.e., the re-measurement of the stage) of Hodgkin's disease following induction chemotherapy. The review also found that PET has the potential to be cost-effective in the treatment of non-small cell lung cancer. The paper recommended further research on the effectiveness of PET in the restaging of all lymphoma patients and for patients with other cancers, particularly where the existing diagnostic/monitoring techniques provide poor accuracy (and thus where PET can substantially improve prognosis).

The Canadian Agency for Drugs and Technologies in Health has also examined the literature and evidence surrounding the application of PET (CADTH, 2005). In addition to discussing the two reviews above, CADTH notes that a study of PET from the Quebec health technology assessment agency AETMIS (which determined that the cost-effectiveness of PET in non-small cell lung cancer is acceptable), concluded that PET's main advantages are the "improvement in quality of life, the reduction in useless debilitating interventions, and faster access to effective therapy" (CADTH, 2005). Further, the CADTH summary discusses an Institute for Clinical and Evaluative Sciences report which found that PET is likely to be cost-effective for some cancers and intractable seizures (CADTH, 2005).

Given the evidence on the usefulness and benefits of PET scanning discussed above and in other reports (see, for example, CIHI, 2005; and OECD, 2005), the authors of this study have decided to include PET scanning in the evaluation of access to high-tech medicine.

Table 11 Generalist and medical specialist physicians' views on quality of care, in five countries, 2000

	Australia	Canada	New Zealand	United Kingdom	United States
Percent who said their ability to provide quality care has:					
Gotten worse in the past five years	38%[a]	59%	53%	46%	57%
Improved in the past five years	26%[a]	10%[a]	21%[a]	25%[a]	15%
Stayed about the same	33%[a]	28%	26%	29%	25%
Thinking about the future, percent who were:					
"Very concerned" that quality of care will decline	44%[a]	62%[a]	52%	39%[a]	53%
"Very concerned" that patients will wait longer than they should for medical treatment	53%[a]	75%[a]	67%[a]	68%[a]	41%
Percent who reported inadequate supply of the latest medical and diagnostic equipment	13%[a]	63%[a]	29%[a]	47%[a]	8%
Percent who reported limitations in ordering diagnostic tests or procedures as a "major problem" for their own medical practice	9%[a]	37%[a]	26%	30%[a]	21%
Percent who reported patients "often" lack access to newest drugs or medical technology	15%[a]	26%	51%[a]	26%	26%

[a]p<.05 (statistically significant) for differences with the United States.
Source: Blendon et al., 2001: 235, 236, and 238.

Provincial comparisons

The preceding section finds that Canadians in general endure relatively poor access to modern medical technologies, but is the access equally poor among the provinces? Do Canadians in some provinces receive better services than those in other provinces? Several studies provide helpful insight.

For instance, the Canadian Institute for Health Information [CIHI] (2006a) found notable provincial variations in the availability of a number of medical technologies; some provinces have no access at all to particular technologies. As table 12 shows, New Brunswick had the highest rate of nuclear medicine cameras (32.0 per million people), while Prince Edward Island had the lowest rate (14.5 per million). Newfoundland and Labrador had the highest rate of CT scanners (19.5 per million people), while Ontario had the lowest (9.4 per million). Angiography suites were most available in

Table 12 Number of machines (#) and number of machines per million people (rate) of selected imaging technologies, by province and for Canada, as of January 1, 2006

Jurisdiction	Nuclear medicine cameras		CT scanners		Angiography suites		MRI scanners		Catheterization labs		PET scanners		Fusion tech. PET/CT scanners		Fusion Tech. SPECT/PET scanners	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
NL	15	29.3	10	19.5	3	5.9	2	3.9	2	3.9	0	—	0	—	0	—
PEI	2	14.5	2	14.5	0	—	1	7.2	0	—	0	—	0	—	0	—
NS	26	27.8	15	16.0	6	6.4	5	5.3	5	5.3	0	—	0	—	0	—
NB	24	32.0	10	13.3	8	10.7	5	6.7	3	4.0	0	—	0	—	1	1.3
QC	163	21.4	107	14.0	41	5.4	56	7.3	26	3.4	4	0.5	3	0.4	0	—
ON	313	24.8	118	9.4	73	5.8	64	5.1	44	3.5	6	0.5	6	0.5	0	—
MB	19	16.2	18	15.3	5	4.3	8	6.8	4	3.4	1	0.9	0	—	0	—
SK	16	16.2	15	15.2	4	4.1	4	4.1	4	4.1	0	—	0	—	2	2.0
AB	69	20.7	34	10.2	14	4.2	26	7.8	12	3.6	2	0.6	2	0.6	0	—
BC	74	17.3	47	11.0	21	4.9	25	5.8	12	2.8	2	0.5	1	0.2	0	—
Canada	**721**	**22.2**	**378**	**11.6**	**175**	**5.4**	**196**	**6.0**	**112**	**3.5**	**15**	**0.5**	**12**	**0.4**	**3**	**0.1**

Note: The number of total CT scanners in Canada also includes the number of CT scanners in territories which were not included in this table. The data here includes medical imaging equipment in both hospitals and free-standing facilities.
— = not applicable.
Source: CIHI, 2006a: 8.

New Brunswick (10.7 per million people), least available among the provinces with this technology in Saskatchewan (4.1 per million), while PEI had none at all. Meanwhile, Alberta had the highest rate of MRI scanners (7.8 per million people), while Newfoundland and Labrador had the lowest rate (3.9 per million).[15] Access to catheterization labs also varied among the provinces. Nova Scotia had the highest rate (5.3 per million people) and British Columbia had the lowest rate among provinces with such labs (2.8 per million). PEI had no such labs. Technologies such as PET,

15 MRI scanners and CT scanners can serve as substitutes for each other to some extent, which suggests that if more of one type are highly available, there may be less need for the other form of scanner (CIHI, 2006a).

Table 13 Number of CT and MRI exams[a] per 1,000 people, 2005-06

Province	CT exams per 1,000 people	MRI exams per 1,000 people
Newfoundland & Labrador	115	12
Prince Edward Island	111	19
Nova Scotia	162	30
New Brunswick	138	35
Quebec[b]	100	30
Ontario	92	33
Manitoba	110	25
Saskatchewan	107	20
Alberta	100	40
British Columbia	86	20
Canada	98	30

[a]An exam is defined as a technical investigation using imaging technology to study one body structure, system, or anatomical area that yields one or more views for diagnostic and/or therapeutic purposes (one exam can include more than one scan). Exceptions include routinely ordered investigations of multiple body structures, which by common practice or protocol are counted as one exam.
[b]Exams were not reported in Quebec for some scanners in both hospitals and free-standing facilities. The number of exams for these scanners was estimated based on average exams per scanner in reporting hospitals and free-standing facilities in Quebec.
Source: CIHI, 2006a: 11.

PET/CT and SPECT/PET scanners were sparsely scattered throughout the country; many provinces had no such machines.

The CIHI report also describes the use of MRI and CT scanners among the provinces and reports significant differences in the number of exams per 1,000 people (table 13). For instance, Nova Scotians received the highest rate of CT scans (162 per 1,000 people), while residents of BC received the lowest rate (86 per 1,000). On the other hand, Albertans received the most MRI scans (40 per 1,000 people), while residents of Newfoundland and Labrador received the fewest (12 per 1,000).

A study by Technological Change in Health Care (TECH) Research Network (2001), which looked at international differences in heart attack care (discussed above), also looked at investment in intensive heart attack treatments in Ontario, Alberta, and Quebec. The study examined access to cardiac catheterization, bypass surgery, and angioplasty within certain time frames. The study found both Alberta and

Table 14 Availability of publicly funded clinical PET scanning in Canada, December 2006

Province	Scanning facilities	Number of scans funded per year	Funded scans per 100,000 people per year
British Columbia	1	2,000	47
Alberta	3	6,000	178
Saskatchewan	0	130	15
Manitoba	1	900	77
Ontario	5	750	6
Quebec	7	16,000[b]	209
New Brunswick	1[a]	300	40
Prince Edward Island	0	20	15
Nova Scotia	0[c]	60	6.5
Newfoundland & Labrador	0[d]	50	10

[a]One additional planned within two years with funding for a total of 400 scans per year.
[b]To be increased to 23,000 with additional scanners opening in 2007.
[c]Scanner opening in 2007 with funding for 1,500 patients annually.
[d]Scanner planned for 2009.
Source: Pearcey and McEwan, 2006: 16.

Quebec to be relatively late adopters of technology, and the use of technologies also grew relatively moderately following their adoption. The growth rates of the use of these technologies in the two jurisdictions were somewhat slower than in the US, or among several nations identified with Canada as "late start/fast growth" nations. Ontario, in at least some measures of technology, was identified as a "late start/slow growth" jurisdiction.

Pearcey and McEwan (2006) examined the availability of PET scanning in Canada's provinces. The authors reported significant differences in access to publicly funded PET scans (see table 14). Quebecers had the most access (approximately 209 publicly funded PET scans per 100,000 people) and Ontarians had the least access (6 scans per 100,000 people). The authors also pointed out that PET scanners were not available in all provinces at the time of their report, and that patients in Saskatchewan, Nova Scotia, PEI, and Newfoundland and Labrador needed to travel out of their provinces to have a scan, even if it were publicly funded. The authors found four private

PET scanning facilities in Canada: one in BC (Vancouver), one in Ontario (Mississauga), and two in Quebec.

The studies reviewed in this section indicate that the relative lack of advanced medical technology in Canada is not spread equally among the provinces. Indeed, generally speaking, the disparity among the provinces is marked. Internationally, the country provides poor overall access to medical technology, but for any given technology, patients in some provinces are clearly worse off than those in other provinces.

3 The age and sophistication of Canada's technology inventory

Apart from the size of inventories of medical technologies, it is important to understand the age and sophistication of those inventories to determine the quality of the available services. Relative to their newer counterparts, older medical technologies are generally less reliable and need more maintenance, may provide a lower quality output or be less accurate, may be less safe for patients and operators, and may expose patients to greater risk. Newer, more sophisticated medical technologies can allow for shorter examination or operation times, higher quality output, and additional services compared to their older, less sophisticated counterparts. Most relevant to this paper is that an inventory of outdated and unsophisticated equipment is qualitatively much different from an inventory of relatively new and highly sophisticated medical equipment.

The Canadian Institute for Health Information's [CIHI] *National Survey of Selected Medical Imaging Equipment* (2006b) allows for such an examination. The survey data, available on the CIHI's website at *www.cihi.ca*, provides the location, age, and select specifications of CT scanners, PET scanners, MRI machines, SPECT scanners, gamma cameras, lithotriptors, angiography suites, cardiac catheterization labs, and select fusion technologies (PET/CT and SPECT/CT) in hospitals and free-standing facilities across Canada on January 1, 2006.[16]

The authors of this paper have analyzed these data to judge both the sophistication and age of Canada's inventory of medical technologies. Specifically, Canada's inventory is compared to guidelines published by Ontario's MRI and CT Expert Panel, by the Canadian Association of Radiologists, and by the European Coordination Committee of the Radiological and Electromedical Industries. These comparisons enable the authors to determine whether or not Canada's current inventory of medical technologies is up-to-date and relatively sophisticated. The comparison gives some insight into the investment by Canada's health care system in new technology and the replacement of older, outdated equipment.

The analyses below treat medical equipment located in hospitals separately from equipment contained in free-standing facilities. CIHI data includes equipment in both

16 According to CIHI, hospitals are defined as "[a]n 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, psychiatric care" (CIHI, 2006b).

According to CIHI, free-standing facilities "[r]ange from specialized services run privately by physicians, radiologists, dentists, chiropractors, or mammography programs to broad-based imaging centres offering a wide range of tests" (CIHI, 2006b).

public and private settings; it is important to separate these two classifications in the analysis because in-hospital technologies will generally be available to patients through taxpayer-funded health care programs, while equipment in free-standing facilities may not always be available through these channels.

Age of equipment

The age of medical equipment matters for a number of reasons. Older and outdated equipment can have a higher risk of failing or breaking down, which may disrupt imaging services (CAR, 2000b). Further, it may be increasingly difficult to obtain spare parts for older equipment. Older machines can also produce poorer quality images (CAR, 2000b).

Various organizations have developed standards for evaluating the age of medical equipment. Guidelines from two such organizations are considered in the analysis of Canada's technology inventory below. The rules published by the European Coordination Committee of the Radiological and Electromedical Industries (ECCREI) for the evaluation of medical equipment can be found in a report by the Ontario MRI and CT Expert Panel (Keller, 2005). The guidelines divide the age of equipment into 3 categories (table 15). Equipment up to 5 years old is considered to reflect the current state of technology, and the rules state that at least 60 percent of the installed equipment should fall within this category. Equipment 6 to 10 years old is still fit for use, but

Table 15 European Coordination Committee of the Radiological and Electromedical Industries' rules for the evaluation of medical equipment

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
6-10 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 in Keller, 2005: 38.

Table 16 The 2001 Canadian Association of Radiologists' life cycle guidelines for selected technologies

Equipment	Years after which equipment is regarded as outdated
General Radiography Unit	5-10
General Radiography Mobile	5-10
General Radiography Tomography	5-10
Fluoroscopic R/F	5-10
Mobile Fluoroscopic C-Arms	5-10
Angiographic Suites	7
Cardiac Catheterization Labs	7
CT	8
MRI	6
Ultrasound	6
Nuclear Medicine (including SPECT and Gamma Cameras[a])	10
Bone Density	6
Urology	10
Mammography	5-7
Lithotriptor	7

[a]At the time these guidelines were published, Nuclear Medicine included SPECT and Gamma Cameras but not PET (Personal communication with CAR, June 2007).
Source: ProMed Associates Ltd., 2004: 72.

replacement strategies must be developed for it; the ECCREI rules state that not more than 30 percent of the installed equipment base should be in this category. Technologies older than 10 years are considered to be no longer "state-of-the art," and the ECCREI rules state that it is essential that this equipment be replaced. Not more than 10 percent of the installed equipment should be older than 10 years.

The *Province-wide Diagnostic Imaging Review and Framework for Strategic Planning* report for the Saskatchewan Department of Heath published equipment lifecycle guidelines recommended by the Canadian Association of Radiologists (CAR) (ProMed Associates Ltd., 2004). Table 16 shows these guidelines and provides a slightly different set of standards by defining the maximum life expectancy of machines. As the report notes, "When machines exceed their maximum life expectancy, concerns arise related to equipment age, availability of parts, utilization capabilities, upgrade ability, clinical relevance, operational reliability and performance,

Table 17a The age of Canada's hospital-based medical technology inventories, relative to European Coordination Committee of the Radiological and Electromedical Industries' rules, at January 1, 2006

	ECCREI rules	**Hospital-based inventories**										
		CT	**SPECT/ CT**	**PET/ CT**	**PET**	**All PET capa-ble**	**MRI**	**SPECT**	**Gam-ma cam-eras**	**Litho-trip-tors**	**Angio. suites**	**Car-diac cath. labs**
Number of Units	N/A	357	3	11	13	24	167	348	230	16	175	112
0-5 years old	At least 60% of the installed equipment base should be younger than 5 years	68.3%	100.0%	100.0%	61.5%	79.2%	64.7%	35.3%	36.5%	31.3%	41.1%	43.8%
6-10 years old	Not more than 30% of the installed equipment base should be between 6 and 10 years old	26.3%	0.0%	0.0%	23.1%	12.5%	28.1%	38.5%	27.8%	18.8%	34.3%	29.5%
> 10 years old	Not more than 10% of the installed base can be tolerated to be older than 10 years	5.3%	0.0%	0.0%	15.4%	8.3%	7.2%	26.1%	35.7%	50.0%	24.6%	26.8%
Age of oldest machine(s) (years)	N/A	16	1	4	15	15	21	24	29	20	44	18

Sources: Keller, 2005: 38; CIHI, 2006b; calculations by authors.

safety, redundancy, serviceability, and increased operational costs" (ProMed Associates Ltd., 2004: 72).

It is possible to evaluate the age profile of inventories of selected medical technologies in Canada according to the guidelines set by the European Coordination Committee of the Radiological and Electromedical Industries and the Canadian Association of Radiologists by categorizing the inventory of medical technologies provided by CIHI (2006b). The ages of Canada's medical technology inventories are summarized in tables 17 and 18 and described in detail below.

Table 17b The age of Canada's free-standing facility-based medical technology inventories, relative to European Coordination Committee of the Radiological and Electromedical Industries' rules, at January 1, 2006

	ECCREI rules	Free-standing facility-based inventories					
		CT	PET/CT	PET	MRI	SPECT	Gamma cameras
Number of Units	N/A	17	1	2	31	23	12
0-5 years old	At least 60% of the installed equipment base should be younger than 5 years	76.5%	100.0%	50.0%	54.8%	47.8%	75.0%
6-10 years old	Not more than 30% of the installed equipment base should be between 6 and 10 years old	23.5%	0.0%	50.0%	45.2%	47.8%	0.0%
> 10 years old	Not more than 10% of the installed base can be tolerated to be older than 10 years	0.0%	0.0%	0.0%	0.0%	4.3%	25.0%
Age of oldest machine(s) (years)	N/A	8	2	6	9	16	20

Source: Keller, 2005: 38; CIHI, 2006b; calculations by authors.

CT scanners

At the start of 2006,[17] Canada's stock of hospital-based CT scanners, as well as hospital-based PET/CT and SPECT/CT scanners, fell within the ECCREI guidelines on equipment life cycles. Of the 357 hospital-based CT scanners in Canada, 68.3 percent were between 0 and 5 years of age (compared to a rule of at least 60 percent), 26.3 percent were between 6 and 10 years of age (compared to a rule of no more than 30 percent), and 5.3 percent were over 10 years old (compared to a rule of no more than 10 percent). Further, all of Canada's hospital-based PET/CT and SPECT/CT scanners were less than 5 years old (table 17a).

On the other hand, according to the CAR guidelines, there are concerns regarding the age of hospital-based CT scanners in Canada. At the start of 2006, 14.8 percent of the hospital-based CT scanners were over 8 years old, which is the CAR lifecycle

17 All data from the CIHI survey are as of January 1, 2006.

Table 18a The age of Canada's hospital-based medical technology inventories, relative to CAR guidelines, at January 1, 2006

	Hospital-based inventories								
	CT	**SPECT/CT**	**PET/CT**	**MRI**	**SPECT**	**Gamma cameras**	**Litho-triptors**	**Angio. suites**	**Cardiac cath. labs**
Number of units	357	3	11	167	348	230	16	175	112
CAR lifecycle guideline	8 Years	8 Years (CT)	8 Years (CT)	6 Years	10 Years	10 Years	7 Years	7 Years	7 Years
Percent beyond guideline	14.8%	0.0%	0.0%	29.3%	26.1%	35.7%	56.3%	47.4%	40.2%
Age of oldest machine(s) (years)	16	1	4	21	24	29	20	44	18

Sources: ProMed Associates Ltd., 2004: 72; CIHI, 2006b; calculations by authors.

Table 18b The age of Canada's free-standing facility-based medical technology inventories, relative to CAR guidelines, at January 1, 2006

	Free-standing facility-based inventories				
	CT	**PET/CT**	**MRI**	**SPECT**	**Gamma cameras**
Number of units	17	1	31	23	12
CAR lifecycle guideline	8 Years	8 Years (CT)	6 Years	10 Years	10 Years
Percent beyond guideline	0.0%	0.0%	22.6%	4.3%	25.0%
Age of oldest machine(s) (years)	8	2	9	16	20

Sources: ProMed Associates Ltd., 2004: 72; CIHI, 2006b; calculations by authors.

guideline for this technology. In 2006, the oldest CT scanner in Canada was 16 years old (table 18a).

Canada's inventory of free-standing facility-based scanners fared much better, according to both sets of guidelines. Of the 17 free-standing facility-based CT scanners, 76.5 percent were between 0 and 5 years of age (compared to a rule of at least 60 percent), 23.5 percent were between 6 and 10 years of age (compared to a rule of no more than 30 percent), and none were over 10 years old (table 17b). Further, at the start of 2006, there were no machines over the CAR lifecycle threshold of 8 years of age, though 2 machines were 8 years old at that time (table 18b).Canada's sole free-standing facility-based PET/CT machine was 2 years old at the start of 2006.

MRI scanners

Canada's hospital-based inventory of MRI scanners also falls within the ECCREI guidelines. At the start of 2006, 64.7 percent of hospital-based MRI scanners were 5 years old or younger (compared to a rule of at least 60 percent), 28.1 percent were between 6 and 10 years old (compared to a rule of no more than 30 percent), and 7.2 percent were over 10 years of age (compared to a rule of no more than 10 percent) (table 17a). According to the CAR guidelines, however, there are serious concerns regarding the hospital-based MRI inventory: 29.3 percent of scanners in Canada were beyond CAR's 6-year lifecycle threshold, and the oldest scanner in Canada was 21 years old (table 18a).

The 31 MRI machines in free-standing facilities in Canada at the start of 2006 fared about the same as the hospital-based machines, according to both sets of guidelines. Specifically, 54.8 percent of the machines were between 0 and 5 years of age (compared to a rule of at least 60 percent) and 45.2 percent of the MRI machines were between 6 and 10 years old (compared to a rule of no more than 30 percent). None were over 10 years of age (table 17b). The data also suggest that according to CAR guidelines Canadians should be concerned about the free-standing facility-based MRI inventory as well: 22.6 percent of the machines were over 6 years old at the start of 2006, another 22.6 percent of machines were 6 years old at the start of 2006, and the oldest two machines were 9 years old (table 18b).

PET machines

Of the 13 hospital-based PET-only machines in Canada at the start of 2006, 8 (61.5 percent) were between 0 and 5 years old (compared to an ECCREI rule of at least 60 percent), 3 (23.1 percent) were between 6 and 10 years old (compared to a rule of no more than 30 percent), and 2 (15.4 percent) (compared to a rule of no more than 10 percent) were more than 10 years old. At the start of 2006, the oldest PET scanner in Canada was 15 years old. Conversely, as mentioned above, Canada's inventory of 11 hospital-based PET/CT scanners[18] fared markedly better (as might be expected given the recent development of this fusion technology); all machines are less than 5 years old. Combining the two inventories gives a look at the PET-capable inventory (24 machines). The combined hospital-based PET and PET/CT inventory came within the ECCREI guidelines; 19 machines (79.2 percent) were between 0 and 5 years old (compared to a rule of at least 60 percent), 3 machines (12.5 percent) were between 6 and 10 years old (compared to a rule of no more than 30 percent), and 2 machines (8.3 per-

18 PET/CT is a fusion technology that can be used in combination, or separately to perform only PET or CT scans. Approximately half of Canada's hospital-based PET capable scanners (11 of 24) are the newer, fusion PET/CT scanners.

cent) were over 10 years old (compared to a rule of no more than 10 percent) (Table 17a).

The published CAR guidelines did not include a lifecycle for PET machines.

At the start of 2006, Canada had 2 PET scanners in free-standing facilities, and 1 PET/CT in a free-standing facility. 1 PET scanner was 1 year old, 1 was 6 years old, and the PET/CT scanner was 2 years old (table 17b).

SPECT units

Canada's inventory of hospital-based SPECT units is generally old and outdated and falls well outside the ECCREI guidelines. At the beginning of 2006, 35.3 percent of the 348 hospital-based units were between 0 and 5 years of age (compared to a rule of at least 60 percent), 38.5 percent of machines were between 6 and 10 years of age (compared to a rule of no more than 30 percent), and 26.1 percent of machines were over 10 years old (compared to a rule of no more than 10 percent) (table 17a). Canada's hospital-based SPECT inventory is also old relative to CAR guidelines: 26.1 percent of the SPECT inventory was over the 10-year lifecycle guideline at the start of 2006. The oldest unit was 24 years old. In contrast, Canada's 3 hospital-based SPECT/CT units were 1 year old at the start of 2006 (table 18a).

The inventory of SPECT units in free-standing facilities also fell outside the ECCREI guidelines, but fared much better than the hospital-based inventory. At the start of 2006, 47.8 percent of the 23 units were between 0 and 5 years old (compared to a rule of at least 60 percent), 47.8 percent were 6 to 10 years old (compared to a rule of no more than 30 percent), and 4.3 percent were over 10 years of age (which is also the CAR lifecycle limit) (tables 17b and 18b). Clearly, the free-standing facility-based SPECT inventory is generally newer than the hospital-based inventory, though it is clear that both inventories are much older than the guidelines recommend.

Gamma cameras

When compared with both the ECCREI and CAR guidelines, Canada has a poor inventory of gamma cameras. Of the 230 hospital-based units, 36.5 percent were between 0 and 5 years of age at the start of 2006 (compared to a rule of at least 60 percent), 27.8 percent were between 6 and 10 years of age (compared to a rule of no more than 30 percent), and 35.7 percent were over 10 years old (compared to a rule of no more than 10 percent) (table 17a). CAR's recommended lifecycle for gamma cameras is also 10 years (table 18a). The two oldest hospital-based gamma cameras were 29 years old at the start of 2006.

Canada's free-standing facility-based gamma cameras were either relatively young, or relatively old. Specifically, 9 (75 percent) of the 12 were between 0 and 5

years of age, while the other 3 were over 10 years old. The oldest machine was 20 years old (tables 17b and 18b).

Lithotriptors

A significant number of Canada's hospital-based lithotriptors are, according to both the CAR and ECCREI guidelines, outdated and beyond their lifecycle. Of the 16 lithotriptors in the inventory at the start of 2006, 5 (31.3 percent) were between 0 and 5 years of age (compared to a rule of at least 60 percent), 3 (18.8 percent) were between 6 and 10 years of age (compared to a rule of no more than 30 percent), and 8 of them (50 percent) were more than 10 years old (compared to a rule of no more than 10 percent) (see table 17a). Equally troubling is that 9 of Canada's inventory of 16 units (56.3 percent) were older than the 7-year CAR guideline for these units (table 18a).

CIHI reported no lithotriptors in free-standing facilities at the start of 2006.

Angiography suites

Canada's angiography suite inventory also needs updating, according to both CAR and ECCREI guidelines. Of Canada's 175 hospital-based angiography suites, 41.1 percent were between 0 and 5 years old (compared to a rule of at least 60 percent), 34.3 percent of the suites were between 6 and 10 years old (compared to a rule of no more than 30 percent), and 24.6 percent of the suites were more than 10 years old (compared to a rule of no more than 10 percent) (table 17a). Of particular concern is that 47.4 percent of the hospital-based angiography suites in Canada were older than the CAR 7-year lifecycle guideline, while another 7.4 percent of the suites were 7 years old at the beginning of 2006 (table 18a). Notably, at that time, the oldest such suite in Canada was 44 years old.

Cardiac catheterization labs

According to both the ECCREI and CAR guidelines, Canada has too few new cardiac catheterization labs, and too many that are old and outdated. Of the 112 hospital-based cardiac catheterization labs, 43.8 percent were between 0 and 5 years old (compared to a rule of at least 60 percent), 29.5 percent were between 6 and 10 years old (compared to a rule of no more than 30 percent), and 26.8 percent were more than 10 years old (compared to a rule of no more than 10 percent) (table 17a). A full 40.2 percent of Canada's catheterization labs were beyond the 7-year lifecycle recommended by the CAR, while another 8.0 percent were 7 years old at the beginning of 2006 (table 18a). The three oldest cardiac catheterization labs were 18 years old.

Overall findings

An examination of the CIHI data on medical technology inventories above shows that Canada has far too many older, outdated, and possibly unreliable medical technologies currently in operation, and too few newer technologies. The situation is particularly alarming for angiography suites, lithotripsy units, and cardiac catheterization labs. The medical technology inventory in Canada's free-standing facilities is generally newer, suggesting that these facilities are better at updating their equipment. Nevertheless, Canada's hospitals and free-standing facilities could clearly be doing much more to replace older equipment, which would be to the benefit of patients and providers.

These findings also apply to medical technologies beyond the 8 considered here. For example, Pommerville et al. (2004), in a report discussing the findings of 2 nation-wide surveys conducted by the Canadian Urological Association in 2003, discovered that older urology equipment was prevalent in Canada's hospitals. According to their survey results, 26.2 percent of respondents[19] reported the cystoscopy tables at their centres were over 15 years old, and 22.8 percent of respondents reported their cystoscopes[20] were over 15 years old. Pomerville et al. (2004) concluded that these data "suggest an important deficit in the updating of some of the basic tools for urology practice" (p. 2295).

A survey conducted by the Canadian Association of Radiologists in early 2000 of the age of medical technologies found that 50.3 percent of Canada's diagnostic imaging units had exceeded their useful life (CAR, 2000b). Further, just one third of the equipment offered any potential for future upgrades. The report broke down its findings on the prevalence of outdated technology and reported that the following proportion of units were outdated: 63 percent of general X-ray equipment, 50 percent of mobile X-ray units, 63 percent of fluoroscopy x-ray equipment, 50 percent of angiography x-ray equipment, 53 percent of ultrasound equipment, 32 percent of mammography units, 34 percent of nuclear medicine equipment, 39 percent of CT scanners, and 30 percent of MRI units (CAR, 2000b).

A 2004 province-wide review of diagnostic imaging for the Saskatchewan Department of Health also reported a high prevalence of older and outdated diagnostic imaging technologies (ProMed Associates Ltd., 2004). The report found that 55 percent of the 380 imaging devices in public facilities were over 10 years old. The average age of imaging devices in Saskatchewan's public facilities was 12.0 years, though

19 Survey respondents were academic and hospital leaders who were also members of the Canadian Urological Association.

20 A cystoscope is a thin telescope that is passed into the bladder via the urethra. It allows a doctor to examine and perform procedures on the inside of the bladder. See, for example, http://www.qe2foundation.com/en/home/howyourgifthelps/currentneeds/default.aspx#CystoscopyTable)

Table 19 The age (in years) of diagnostic equipment in public facilities in Saskatchewan

Equipment	<5	5 to 10	11 to 15	16 to 20	>20	Total	Mean	Mode[a]	Max
General Radiography Unit	18	18	34	31	50	151	16.1	23	38
General Radiography, Mobile	7	12	11	2	6	38	11.6	11	30
General Radiography, Tomography	3	2	—	1	—	6	7.2	4	17
Fluoroscopic R/F	9	17	10	8	4	48	10.4	5	26
Mobile Fluoroscopic C-Arm	5	5	4	4	—	18	9.9	3	18
Angiographic Suite	3	1	1	—	—	5	6.0	3	13
Cardiac Catheterization Unit	1	1	1	1	—	4	9.3	—	16
CT Scanner	5	6	—	—	—	11	4.4	6	9
MRI Scanner	—	3	—	—	—	3	5.0	5	5
Ultrasound	23	17	15	8	1	64	8.2	3	25
Nuclear Medicine	4	5	2	2	1	14	8.8	3	22
Bone Density	2	1	1	—	—	4	5.8	—	13
Urology	—	1	2	1	—	4	12.5	11	18
Mammography	1	1	7	—	—	9	10.6	11	14
Lithotriptor	—	1	—	—	—	1	7.0	7	7
Total	81	91	88	58	62	380	12.0	—	—

[a]Mode is the most frequently occurring value in a data set.
— = Not available.
Source: ProMed Associates Ltd., 2004: 70.

some imaging units were well over 25 years old (ProMed Associates Ltd., 2004). Table 19 gives detailed findings from the report.

Sophistication of equipment

Newer, more sophisticated machines can produce faster, higher quality scans than older equipment. Newer machines can also provide more services than older, less sophisticated devices, which can improve the patient's experience and, potentially, improve the diagnosis and results.

CT scanners

The sophistication of CT scanners[21] is partly determined by whether the scanners are "spiral" or "non-spiral" in design. Older, non-spiral CT scanners require that patients be moved through the scanner incrementally (the scanner takes an image or "slice" of data, stops rotation/image acquisition, moves the patient forward a distance equal to a slice of data, and then restarts rotation to take the next slice of data). Newer, spiral CT scanners allow the patient to be moved continuously as the CT scanner rotates and captures data. The result is that images are acquired more rapidly, artefacts due to movement are reduced (and thus the scans are sharper and better quality), and image resolution is increased (CIHI, 2005). At the start of 2006, 18 percent of Canada's hospital-based inventory of CT scanners were older, non-spiral machines, and 9 percent of Canada's hospital-based PET/CT scanners were the older type. Clearly, the inventory of lower-quality CT scanners in Canada's hospitals was not insignificant.

Canada's free-standing facility-based scanners were similarly poor. At the start of 2006, 18 percent of these CT scanners were the older, non-spiral design, though the sole, free-standing facility-based PET/CT scanner was a spiral machine.

Within the class of spiral scanners (82 percent of hospital-based and free-standing facility-based CT scanners, and 91 percent of hospital-based PET/CT scanners), CT scanners can be further divided into "single-slice" or newer generation "multi-detector" or "multi-slice" units. The newer units allow multiple image slices to be taken simultaneously, making them faster (so more patients can be scanned in a given time frame), and allowing them greater detection capacity (CIHI, 2005; Keller, 2005). According to CIHI, the clinical advantages of multi-detector units include more efficient use of contrast media, replacement of more invasive procedures, and better spatial resolution. Multi-slice CT scanners can also be used for paediatrics, geriatrics, bariatrics,[22] and cardiology (CIHI, 2005: 20). One potential downside to the newer generation units is the higher doses of radiation to which patients are exposed during their scan, though manufacturers are making progress on this front (CIHI, 2005).

At the start of 2006, 89 percent of Canada's 293 hospital-based spiral CT scanners were multi-slice units, as were all of Canada's hospital-based spiral PET/CT machines. That said, a sizable portion of Canada's entire hospital-based inventory of CT scanners lacks sophistication: 27 percent of all CT scanners and 9 percent of all PET/CT scanners are single-slice units.

The inventory of CT equipment in Canada's free-standing facilities fares somewhat worse than the hospital-based inventory by this measure. Specifically, of the 14 spiral CT scanners in these facilities, only 9 of them (64 percent) were multi-slice

21 The discussion here looks only at CT and PET/CT scanners as CIHI did not publish comparable information on SPECT/CT machines.

22 A field of medicine dealing with obesity.

units.[23] Canada's sole free-standing facility-based PET/CT scanner was a multi-slice unit. Of the total inventory, only 53 percent of Canada's free-standing facility-based CT scanners were multi-slice units.

Within the class of multi-slice CT scanners, there are also newer, more advanced machines. Specifically, multi-slice CT machines can range from older, slower, dual-slice units to the latest and most advanced 64-slice units. Next-generation 256-slice units are already being tested and likely will be available soon. Importantly, innovative and non-invasive diagnostic procedures such as CT colonoscopy and CT coronary angiography can only by performed on the newer and quicker multi-slice scanners (Keller, 2005). For example, advanced, multi-slice CT scanners enable arteries to be imaged, allowing patients to avoid invasive catheter angiography, which in turn results in less blood contamination and fewer of the complications that can arise from the insertion of medical tools and implements into arteries. The newer, faster machines are also better for children (minimizing or eliminating sedation altogether), allow for quicker treatment due to reduced imaging time, and reduce the doses of x-rays patients face (Zeidenberg, 2005). Ontario's MRI and CT Expert Panel believes that all CT centers should at least be capable of performing angiographies and brain perfusion studies, both of which require more advanced multi-slice machines, and that 64-slice should be the minimum standard for CT scanners in Ontario (Keller, 2005: 36).

Unfortunately, CIHI's latest public data release does not reveal the number of slices that Canada's multi-slice CT scanners can perform. However, data from CIHI's report *Medical Imaging in Canada, 2005* gives some insight into this measure of CT sophistication, although unfortunately this older data does not include some of the more recent investments in advanced 64-slice CT scanners that have been reported across the county (see, for example, Zeidenberg, 2005). According to the CIHI report, of the 217 multi-detector CT scanners in inventory at the beginning of 2005, 17 (8%) were older and slower dual-slice scanners, 113 (52%) were 4-slice scanners, 18 (8%) were 8-slice scanners, and 69 (32%) were 16-slice scanners. At January 1, 2005, there were no 32- or 64-slice scanners reported in Canada's inventory.

MRI scanners

The sophistication of Canada's MRI inventory is initially determined according to whether the machines are of "open-bore" or "closed-bore" design. A conventional, or closed-bore MRI machine uses a cylindrical magnet in which a patient lies still while

23 One non-spiral CT scanner in a free-standing facility was reported to be a multi-slice unit in CIHI, 2006b. It is not included here in the discussion of spiral CT scanners. Were this scanner included, it would not materially affect the findings: the proportion of multi-detector units in the inventory of machines that might be so equipped would rise to 67 percent (10 of 15), while the proportion of multi-detector units in the total population of free-standing facility-based CT scanners would rise to 59 percent (10 of 17).

an image is taken. The tunnel that houses the patient can be uncomfortable, especially for those who are claustrophobic (CIHI, 2005). In fact, because of patient reactions to claustrophobia, up to 10 percent of MRI examinations are cut short (Harriman et al., 1999). Conversely, wider and shorter open-bore MRI units do not enclose the patient inside a tunnel or casing; some of the latest open-bore units are open on all sides around the patient (CIHI, 2005). Open-bore MRI units not only make it easier to examine claustrophobic patients, but also increase access to MRIs for children, who often cannot remain still in the closed units, and obese individuals, who may be too big or heavy to fit into the tunnel of a conventional MRI.

CIHI data suggest that Canadians do not have easy access to open-bore MRI units. At the beginning of 2006, only 5 (3 percent) of Canada's 167 hospital-based MRI scanners were open bore units. Canada's free-standing facility-based MRI units measured up a little better: 6 (19 percent) of the 31 units were open-bore machines.

Field strength is a second measure of the sophistication of Canada's MRI scanners. Generally, higher magnetic field strengths (measured in tesla), allow better quality images to be acquired faster (CIHI, 2005). Further, MRI machines with higher field strengths are capable of performing newer tasks, such as functional imaging, angiography, and molecular imaging, as well as spectroscopy (providing information on tissue biochemistry) (CIHI, 2005).

Over time, the field strength of MRI units has generally increased from 0.5 tesla and below in the 1980s, to 1.5 tesla in the mid- to late-1980s. To some extent, this trend was reversed internationally in the 1990s when a number of countries opted for machines with lower field strengths, even though MRI units of up to 2 tesla were available. In more recent years, field strengths of 3 tesla have been introduced in clinical applications. In the past, open-bore MRI units often had lower field strengths than conventional MRI units, but this discrepancy has diminished significantly as newer, high-field MRI units are available with field strengths of 1.5 tesla.

Ontario's MRI and CT Expert Panel recommends that MRI machines in Ontario should have at least a 1.5 tesla magnet and be capable of performing perfusion studies and angiography (Keller, 2005: 36). At the beginning of 2006, Canada's hospital-based MRI machines performed relatively well by this standard: 90 percent of the 162 closed-bore units had a field strength of 1.5 tesla or more, and 1 (20 percent) of the 5 open-bore units had a field strength of 1.5 tesla or more. Canada's free-standing facility-based MRI units fared worse than the hospital-based inventory on this measure: 75 percent (18) of the 24 MRI units for which data were available (field strength was not clearly reported for one unit) had a field strength of 1.5 tesla or higher, and none of Canada's 5 free-standing facility-based, open-bore MRI units for which data were available had a field strength of 1.5 tesla or higher (field strength was not clearly reported for one unit).

An MRI's performance may be determined by more than field strength. According to CIHI (2005), "current technology" (design adaptations) have reduced the performance differences in the lower versus the higher field strength machines in conventional applications. However, in Canada, the hospital-based, closed-bore MRI units with field strengths below 1.5 tesla are an average of 8 years old, while the free-standing facility-based units are an average of 6 years old, which suggests that the lower field-strength machines in Canada are not commonly benefiting from these advances in design.

PACS

The use of Picture Archiving and Communications Systems (PACS) can serve as another measure of the sophistication of diagnostic technologies. PACS enables the digital storage, management, and distribution of images, which reduces or eliminates the need to physically store films, and reduces the handling of the films that are stored. Another obvious benefit of PACS is that images can be viewed on demand from anywhere in the facility, or even in the world, once access to the image server is secure.

CIHI (2005) lists a number of efficiency gains that are possible when an institution implements PACS. According to the report, facilities that have switched to viewing images digitally have reduced their diagnostic turnaround times markedly, increased the use of their diagnostic equipment, simplified the processes by which images are handled and assessed, and reduced the number of staff associated with a given exam (CIHI, 2005). When the processes are simpler and exam staff are reduced, fewer errors, fewer lost films, and fewer exams are the likely result. Indeed, CIHI confirms that a reduction in the number of lost films is one potential benefit of PACS (2005: 35).

With PACS, teleradiology (the viewing of images outside of the location or area where the image was taken) is greatly simplified and is available at reduced cost as a result of on-demand digital access. Remote digital access allows radiologists in other time zones to provide interpretations of scans taken at odd hours, which allows local physicians to rest and work a more regular schedule (Wachter, 2006a). For example, thanks to time-zone differences, a CT scan taken in the middle of the night in Toronto or Vancouver can be read by a radiologist in Europe or Asia (during their day) while the radiologists in Toronto or Vancouver are asleep.[24] Patients benefit from a quicker turnaround time for their diagnostics (Wachter, 2006b). An additional benefit for providers and payers is a potential reduction in costs resulting from broader competition in interpretation services and a potential reduction in labour costs, transportation costs, and late-night/on-call/overtime costs. Similarly, if the scan is to be interpreted

24 This example is based on the one employed by Wachter (2006b) in a presentation discussing patients in Bangor, Maine, receiving CT scans that are interpreted by radiologists in Bangalore, India.

or reinterpreted in Canada, it can be done from the radiologist's home or office, thereby saving a trip to the hospital or facility, or the cost of having the physical images rushed to the interpreting physician. PACS can also reduce duplication of scans, consolidate the expertise of radiologists, and facilitate the transfer of patients from one institution to another by potentially simplifying and speeding up the transfer of diagnostic images (Keller, 2005). In addition, PACS can help accelerate the delivery of diagnoses and services to patients in remote communities by electronically connecting with a radiologist or other physician with the required knowledge or expertise in another community, province, or even country.

Ontario's MRI and CT Expert Panel has recommended that all hospitals providing MRI and/or CT scans have a PACS that is capable of sharing information across a standard platform (Keller, 2005: iii). According to CIHI, however, while much of Canada's inventory of medical technologies is operating with a PACS in place, some is also operating without. Specifically, among hospital-based technologies, 34 percent of angiography suites (60 of 175), 60 percent of cardiac catheterization labs (67 of 112), 28 percent of CT scanners (101 of 357), 18 percent of PET/CT scanners (2 of 11), 67 percent of SPECT/CT scanners (2 of 3), 23 percent of MRI scanners (38 of 167), 35 percent of gamma cameras (81 of 230), 62 percent of PET scanners (8 of 13), and 46 percent of SPECT units (160 of 348) were operating without PACS. Among free-standing facility-based technologies, 41 percent of CT scanners (7 of 17), 45 percent of MRI machines (14 of 31), 33 percent of gamma cameras (4 of 12), 50 percent of PET scanners (1 of 2), and 83 percent of SPECT units (19 of 23) were operating without PACS. Canada's sole clinic-based PET/CT scanner was operating with PACS.

To summarize, Canada's health care system relies too heavily on older, possibly outdated, and unreliable medical technologies, and on less sophisticated forms of technology than might be considered optimal.

4 Availability of specialized, leading-edge medical technologies

Most of the technologies discussed in both the literature review and in the examination of CIHI data above are commonly-known medical devices. It is also worth asking about the availability of cutting-edge medical technologies, or technologies that have not been available for long. Comprehensive data on the availability of these technologies are limited, but a review of the health technology approvals by national regulatory agencies and media or expert panel reports suggest that Canada trails other developed nations in this area, too.

Many recent advances in medical technology have been in the area of minimally-invasive surgical procedures. The new technologies have either improved upon older methods by reducing patient discomfort, or have opened new avenues of treatment to patients who previously had very limited treatment options. For example, Magnetic Resonance-guided Laser-induced Interstitial Thermotherapy (MR-guided LITT) has brought new treatment possibilities to some of the 70 to 90 percent of individuals with metastatic liver cancer who are ineligible for a resection of the liver due to the number, size, or position of their tumours. MR-guided LITT, which uses laser energy delivered directly through optical fibres to destroy tumours, offers an additional option for these patients. Various studies have also found that it offers safer care (in terms of complications and mortality rates) and can lead to greater longevity than a conventional liver resection (CADTH, 2006a). MR-guided LITT may also be more comfortable for patients as it can be performed in an outpatient setting with only local anaesthesia. According to a 2006 update from the Canadian Agency for Drugs and Technologies in Health (CADTH) this technology is yet to be licensed in Canada. The US Food and Drug Administration, on the other hand, granted approval for the technology over a decade ago, in 1997 (CADTH, 2006a).

Another example of an advanced surgical technology that is relatively scarce in Canada is the Gamma Knife. Developed several decades ago, the Gamma Knife offers patients a minimally-invasive alternative to open-skull surgery for brain tumours and other lesions in the brain by using highly focused radiation beams (no incision is required) that spare surrounding tissue during treatment. According to the Gamma Knife manufacturer's website, there are only three Gamma Knife units in all of Canada compared to more than 100 units in the United States, many of which are accessible to US residents covered by government health programs (CADTH, 2006b; Elekta, 2007; WVHCS-GKC, 2007).

Yet another example of a cutting-edge technology that is available in many nations, but not commonly available in Canada, is radiofrequency ablation for totally occluded coronary arteries. This technology offers patients with totally occluded

(blocked) arteries—which are difficult to treat with traditional balloon catheter angioplasty because of the difficulties in passing the guide wire through the blockage, and thus are often treated with pharmaceuticals or coronary artery bypass surgery instead—a minimally-invasive treatment option. The technology delivers an electric current through a catheter guide wire and burns through blockages in coronary arteries, which then can be treated with conventional angioplasty and stent devices. The Canadian Agency for Drugs and Technologies in Health (CADTH) reports that the technology has been available in Europe for several years, and in the US since early 2004, but had not been used in Canada as of September 2006 despite being licensed by Health Canada in August 2003 (CADTH, 2006c).

A search of the Internet and the CADTH web site reveals a number of other very progressive, beneficial surgical and diagnostic technologies that are rare or unavailable to Canadians. In order to empirically examine Canada's inventory of cutting-edge or near cutting-edge medical technologies, the authors of this study conducted a survey in late 2006 to examine physicians' access to 50 advanced medical technologies[25] (listed in table 20) in hospitals in Toronto, Montreal, Vancouver, Ottawa, and Calgary.[26] (The survey methodology is described in greater detail in Appendix A and the survey form is republished in Appendix B.) As advanced health care services and costly medical technologies are more likely to be found in major population centres, surveying hospitals in Canada's most populous metropolises should capture access to medical technologies in Canada's most advanced institutions.[27]

Overall, responses to the survey were recorded for 49 of 88 (56%) Canadian facilities: 5 of 6 facilities in Calgary (83%), 4 of 22 in Montreal (18%), 5 of 9 in Ottawa (56%), 20 of 34 in Toronto (59%), and 15 of 17 in Vancouver (88%). Surveys were sent to acute care and ambulatory hospitals and cancer centres in all five cities, as well as central laboratory service providers in Calgary and Toronto.

There did not appear to be a bias based on the size of the institution among respondents in Calgary, Toronto, or Vancouver, while the apparent size biases in Ottawa and Montreal do not appear likely to affect the findings of this survey. All of Calgary's large facilities responded to the survey. Both larger and smaller facilities

25 The original survey contained a list of 51 technologies, including PET scanning. Only the fusion technology PET/CT is discussed here, as all facilities but one that reported the presence or absence of PET scanners also reported the presence or absence of PET/CT scanners. One facility reported that it only had a PET/CT scanner, not a PET scanner.

26 The definition of "city" used in this survey is Statistics Canada's "Census Metropolitan Area." This means that, for example, Toronto is not just the city of Toronto, but also includes the municipalities of Ajax, Aurora, Bradford West Gwillimbury, Brampton, Caledon, East Gwillimbury, Georgina, Halton Hills, King, Markham, Milton, Mississauga, Mono, New Tecumseth, Newmarket, Oakville, Orangeville, Pickering, Richmond Hill, Uxbridge, Vaughan, and Whitchurch-Stouffville.

27 Nearly 42 percent of Canada's total population resides in Canada's five largest Census Metropolitan Areas (Statistics Canada 2007a, and 2007b; calculations by authors).

Table 20 List and description of technologies included in the Fraser Institute's Medical Technology Survey

Area of Care	Technology	Description
Anaesthesia/ Cardiovascular	Intraoperative Transesophageal Echocardiography	Obtains images of the heart from inside the esophagus.
Cancer	Brachytherapy (including the use of balloon catheter)	Delivers radiation within the body by the implantation of radioactive devices or temporary radioactive seeds.
	Cryotherapy	Cryoprobes are inserted into the area to be treated and argon gas is then circulated through them to freeze and destroy the affected tissue.
	Intraperitoneal Therapy For The Delivery Of Chemotherapy	Administration of chemotherapy drugs directly to the affected site through a surgically implanted catheter.
	Radiofrequency Ablation Systems	Delivers electric current from a radiofrequency generator into a tumour.
	Magnetic Resonance-guided Laser-induced Interstitial Thermotherapy (MR-guided LITT)	Delivers laser energy directly to a tumour through optical fibres.
Cardiovascular	Implantable Cardioverter Defibrillator (ICD)	This device is implanted either under the collarbone in the patient's chest or in the abdomen with wires inserted into the pumping chambers of the heart. When ICD detects serious arrhythmia or a stoppage of the heart it passes an electric current to the heart to restore normal rhythm.
	External Counterpulsation	Physical procedure that involves the use of compressive cuffs, wrapped around the patient's legs, which undergo sequential diastolic inflation and prostostolic deflation according to patient's cardiac cycle.
	Catheter Guided Retriever For Manual Removal Of Blood Clots	The retriever is inserted through a catheter through the femoral artery, manually captures the blood clot, and removes it from the body through the catheter.
	Coronary Brachytherapy	The use of a catheter to emit radioactive energy in the artery following balloon angioplasty or coronary stenting to reduce recurrence of artery narrowing.
	Drug-eluting Stents	A wire mesh "scaffold" that remains in the artery to keep it propped open and releases drugs over time to reduce the probability of restenosis.
	Endovascular Stent Graft Repair	A tube supported by a stent is inserted to reinforce a weak spot in the artery.
	Radiofrequency Ablation System for Clearing Coronary Arteries	The system combines a visual display and guidance technology with radiofrequency energy delivered though a catheter guide wire to burn through blockages in coronary arteries.
Diagnostics	Positron Emission Tomography with Computer Tomography (PET/CT)	PET is an imaging procedure used to assess physiological and biochemical bodily processes. PET/CT fuses the anatomic (CT) and functional and metabolic (PET) images together.
	Open MRI	An alternative to conventional tube-shaped MRI machines.

Table 20 List and description of technologies included in the Fraser Institute's Medical Technology Survey

Area of Care	Technology	Description
Diagnostics	MRI Breast, Knee, and Hand and Forearm Coils	MRI Coils provide very high resolution images of particular body parts.
	Dynamic Contrast Enhanced MRI	The acquisition of serial MRI images before, during, and after the administration of an MR contrast agent. DCE MRI relies on a special algorithm to examine blood flow, which enables the physician to see changes in tumour vascularity.
	Magnetic Resonance Spectroscopy	MRS is used with commercially available MRI systems. MRI mainly provides anatomical information, whereas MRS provides data on tissue biochemistry.
	Echocardiography with Harmonic Imaging	Echocardiography is a diagnostic test that uses ultrasound waves to make images of the heart chambers, valves and surrounding structures. Harmonic imaging is an advanced ultrasound imaging modality which enhances ultrasound echoes and can specifically detect the characteristic signature of microspheres in contrast agents.
	Computed Tomography (CT) Laser Mammography	Breast imaging system that uses laser beams to create 3D cross sectional images of the breast.
	Ultrasound Transient Elastography System for Diagnosing Liver Fibrosis	Measures the speed of propagation of a mechanical wave through the liver parenchyma to provide an estimate of the liver's elasticity which is used to estimate the state of fibrosis.
	CT Virtual Colonoscopy	Computed tomographic (CT) colonography is used to examine the colon and rectum to detect abnormalities.
	CT Virtual Angiography	Virtual angiography uses X-rays to visualize arterial blood flow.
	Intraoperative CT	Mobile CT that can be used during surgery.
	Intraoperative MRI	Mobile MRI that can be used during surgery.
	Intraoperative Ultrasound	Intraoperative ultrasound is used during surgery to detect tissue movement.
	Intraoperative Fluoroscope	Provides an x-ray "movie" of organs and their motions during surgery.
	Computer-Aided Detection Systems for Diagnostic Scans and Images	Computer analysis systems to aid or assist in detection of potential abnormalities and reduction of errors in assessments.
Diagnostics—Genetic Testing	Genetic Testing (Adult, Children, Prenatal)	To assess the likelihood of developing certain conditions.
	Pharmacogenomic Therapy	The use of genetic information to predict the safety, toxicity, and/or efficacy of drugs in individual patients or groups of patients.
Gastroenterology	Wireless Capsule Endoscopy	Biocompatible plastic capsule is swallowed and moves through the gastrointestinal tract recording images to detect any abnormalities.
	GI Endoscopic Ultrasound	Endoscopic ultrasound uses a high frequency ultrasound located on the tip of a flexible endoscope.

Table 20 List and description of technologies included in the Fraser Institute's Medical Technology Survey

Area of Care	Technology	Description
Gastroenterology	GI Endoscopic Ultrasound Guided Fine Needle Aspiration	Fine needle aspiration (FNA) is used in combination with endoscopic ultrasound for disease staging, diagnosis and pain management.
General	Surgical Robots	Computer-assisted surgery systems, such as telesurgical systems, positioning sytems, and navigational aids.
	Antibiotic-Coated Central Venous Catheters	A catheter which uses an antibiotic coating to reduce the likelihood of bloodstream infections.
	Minilaparoscopy 3 mm or less	Minilaparoscopy is a surgical procedure with the assistance of a narrow, telescope-like instrument called a laparoscope inserted through a small incision to view or operate on the tissue from inside the body.
Neurology	Gamma Knife	Uses multiple beams of radiation to treat lesions inside the skull without requiring an open-skull surgery.
	Frameless Stereotaxy	A way to navigate three dimensionally during cranial and spinal neurosurgical procedures without having to mount a frame to the patient's head.
Neurology (Intracranial Aneurysms)	Coil Embolization for Aneurysms	Small flexible platinum coils are deposited directly into the aneurysm sac to prevent it from further expansion.
Ophthalmology	Optical Coherence Tomography	Imaging tool that produces high resolution cross sectional images of optical reflectivity.
	3-D Corneal Tomography	Imaging tool that provides a three-dimensional image of the eye.
	Multifocal Electroretinography	mfERG involves stimulating areas of the retina using an electrical signal and mapping the response.
	Retinal Nerve Fiber Analysis	Retinal nerve fiber analysis uses a scanning laser to diagnose glaucoma by measuring the optic nerve and the thickness of the retinal nerve fiber layer.
Otolaryngology	3D Image Guided Sinus Surgery	IGS surgery is facilitated by 3D, real-time correlation of the operative field to a monitor, which shows the precise location of a selected surgical instrument to the surrounding structures.
Osteoporosis	Percutaneous Vertebroplasty	The injection of bone cement into the vertebral body to provide pain relief for people with severe osteoporosis or tumor-related vertebral fractures.
Pharmacy	Automated Medication Dispensing Systems	Computer-controlled dispensing systems which may reduce the rate of prescription errors.
Urology	High Intensity Focused Ultrasound Machines	Ultrasound energy is delivered by a probe to increase the temperature in the area, destroying the tissue targeted.
	Holmium Lasers	Laser energy precisely vaporizes obstructing tissue. Mostly used to treat enlarged prostate symptoms.

Table 21 Select medical technologies available in 50 percent or more of facilities surveyed

Technology	Number of facilities responding (% of Total)[a]	Percentage of responding facilities[a] reporting having the technology
Intraoperative Fluroscope	44 (50%)	80%
MRI Breast, Knee, and Hand and Forearm Coils	44 (50%)	75%
Dynamic Contrast Enhanced MRI	43 (49%)	70%
Implantable Cardioverter Defibrillator	32 (36%)	63%
Echocardiography with Harmonic Imaging	32 (36%)	63%
Intraoperative Ultrasound	45 (51%)	62%
Holmium Lasers	21 (24%)	62%
CT Virtual Angiography	43 (49%)	60%
Intraoperative Transesophageal Echocardiography	38 (43%)	55%
External Counterpulsation	26 (30%)	50%

[a]The number of responding facilities counts only those facilities that reported a Yes or No for a given technology. Facilities not reporting a response for a given technology, or reporting "N/A or Don't Know" are not counted. A total of 88 facilities in Canada's five largest Census Metropolitan Areas were surveyed.
Source: The Fraser Institute's Medical Technology Survey, 2006.

were well represented among respondents in Toronto. While one of Vancouver's large teaching facilities did not respond to the survey, both larger and smaller facilities were well represented among respondents. In Montreal, 3 of the 4 respondents were larger hospitals. Finally, though smaller Ottawa hospitals were more likely to respond than larger hospitals, large, specialized, and teaching hospitals were well represented among respondents.

Despite its limitations, this survey is the most representative measure available of the state of Canada's inventory of cutting-edge medical technologies at the end of 2006 and beginning of 2007.[28]

Of the 50 technologies included in the survey, only 10 were reported to be "available for diagnosis or treatment of patients" in half or more of the facilities that

28 Caution is warranted in the interpretation of these results. Though 49 of 88 Canadian facilities surveyed responded (and several individuals at each facility were surveyed), not all responses from all facilities were complete, and some facilities that have these cutting-edge technologies may not have responded.

Table 22 Select medical technologies available in between 25 and 50 percent of facilities surveyed

Technology	Number of facilities responding (% of total)[a]	Percentage of responding facilities[a] reporting having the technology
Magnetic Resonance Spectroscopy	45 (51%)	49%
Automated Medication Dispensing Systems	25 (28%)	48%
Genetic Testing—Prenatal	31 (35%)	48%
Catheter Guided Retriever for Manual Removal of Blood Clots	34 (39%)	47%
Endovascular Stent Graft Repair	38 (43%)	47%
Genetic Testing—Adults	34 (39%)	47%
Genetic Testing—Children	35 (40%)	46%
CT Virtual Colonoscopy	42 (48%)	45%
Drug Eluting Stents	35 (40%)	40%
Open MRI	44 (50%)	36%
Radiofrequency Ablation Systems for Clearing Coronary Arteries	36 (41%)	33%
Minilaparoscopy (3mm or less)	24 (27%)	33%
Computer Aided Detection Systems for Diagnostic Scans and Images	41 (47%)	32%
GI Endoscopic Ultrasound Guided Fine Needle Aspiration[b]	34 (39%)	32%
Percutaneous Vertebroplasty	31 (35%)	32%
Coil Embolization for Anyeurisms	35 (40%)	31%
Intraperitoneal Therapy for Chemotherapy	31 (35%)	29%
GI Endoscopic Ultrasound[b]	34 (39%)	29%
Antibiotic-Coated Central Venous Catheters	28 (32%)	29%
3D Image Guided Sinus Surgery	25 (28%)	28%
Cryotherapy	32 (36%)	25%

[a]The number of responding facilities counts only those facilities that reported a Yes or No for a given technology. Facilities not reporting a response for a given technology or reporting "N/A or Don't Know" are not counted. A total of 88 facilities in Canada's five largest Census Metropolitan Areas were surveyed.

[b]Note that two facilities reported the presence of GI Endoscopic Ultrasound Guided Fine Needle Aspiration (FNA) but not GI Endoscopic Ultrasound, while one facility reported the availability of GI Endoscopic Ultrasound but not FNA. The remaining 9 facilities reported the availability of both.

Source: The Fraser Institute's Medical Technology Survey, 2006.

Table 23 Select medical technologies available in less than 25 percent of facilities surveyed

Technology	Number of facilities responding (% of total)[a]	Percentage of responding facilities[a] reporting having the technology
Wireless Capsule Endoscopy	30 (34%)	23%
Frameless Stereotaxy	30 (34%)	23%
Pharmacogenomic Therapy/Pharmacogenomics	30 (34%)	20%
Surgical Robots	35 (40%)	20%
Brachytherapy (including the use of balloon catheter)	36 (41%)	19%
High Intensity Focused Ultrasound	23 (26%)	17%
Multifocal Electroretinography	20 (23%)	15%
Coronary Brachytherapy	29 (33%)	14%
Retinal Nerve Fiber Analysis	17 (19%)	12%
Ultrasound Transient Elastography for Diagnosing Liver Fibrosis	37 (42%)	11%
3D Corneal Tomography	21 (24%)	10%
PET/CT	44 (50%)	9%
Gamma Knife	34 (39%)	9%
MR-guided LITT	38 (43%)	8%
CT Laser Mammography	40 (45%)	8%
Intraoperative MRI	44 (50%)	7%
Radiofrequency Ablation Systems	34 (39%)	6%
Intraoperative CT	43 (49%)	5%
Optical Coherence Tomography	21 (24%)	0%

[a]The number of responding facilities counts only those facilities that reported a Yes or No for a given technology. Facilities not reporting a response for a given technology or reporting “N/A or Don’t Know” are not counted. A total of 88 facilities in Canada’s five largest Census Metropolitan Areas were surveyed.
Source: The Fraser Institute’s Medical Technology Survey, 2006.

responded to the survey (table 21). Of the remaining 40 technologies, 21 were present in between 25 and 50 percent of responding facilities (table 22),[29] and 19 were present in less than one-quarter of responding facilities (table 23). While clearly there are

29 Some readers may be concerned about the inclusion of drug eluting stents in the survey, given the recent controversy regarding this technology. However, a recent study published in the *New England Journal of Medicine* (Tu et al., 2007) supports their inclusion, finding that drug eluting stents are both safe (there is no significantly increased rate of death or heart attack) and effective (they reduce the need for revascularization in patients at high risk of restenosis).

Table 24 Availability of select medical technologies in teaching and non-teaching (self reported) facilities

Technology	Percentage of responding teaching facilities reporting having the technology[a]	Percentage of responding non-teaching facilities reporting having the technology[a]
Implantable Cardioverter Defibrillator	88%	38%
Dynamic Contrast Enhanced MRI	86%	55%
MRI Breast, Knee, and Hand and Forearm Coils	81%	70%
Intraoperative Fluoroscope	80%	79%
External Counterpulsation	77%	23%
Echocardiography with Harmonic Imaging	77%	53%
Intraoperative Transesophageal Echocardiography	71%	43%
Intraoperative Ultrasound	70%	56%
Catheter Guided Retriever for Manual Removal of Blood Clots	67%	25%
Endovascular Stent Graft Repair	67%	30%
Magnetic Resonance Spectroscopy	65%	36%
Drug-eluting Stents	65%	17%
Holmium Lasers	63%	62%
Genetic Testing—Prenatal	62%	39%
Genetic Testing—Adults	60%	37%
CT Virtual Angiography	60%	61%
Automated Medication Dispensing Systems	54%	42%
Genetic Testing—Children	53%	40%
GI Endoscopic Ultrasound Guided Fine Needle Aspiration[b]	50%	17%
CT Virtual Colonoscopy	50%	41%
Radiofrequency Ablation Systems	47%	18%
Computer-Aided Detection Systems for Diagnostic Scans and Images	47%	18%
GI Endoscopic Ultrasound[b]	44%	17%
Antibiotic-Coated Central Venous Catheters	43%	14%
Minilaparoscopy 3 mm or less	42%	25%
Open MRI	42%	32%
Coil Embolization for Aneurysms	41%	22%
Percutaneous Vertebroplasty	40%	25%

Table 24 Availability of select medical technologies in teaching and non-teaching (self reported) facilities

Technology	Percentage of responding teaching facilities reporting having the technology[a]	Percentage of responding non-teaching facilities reporting having the technology[a]
Frameless Stereotaxy	38%	12%
Pharmacogenomic Therapy	36%	11%
Brachytherapy (including the use of balloon catheter)	35%	5%
High Intensity Focused Ultrasound Machines	33%	0%
Wireless Capsule Endoscopy	31%	18%
Intraperitoneal Therapy for the Delivery of Chemotherapy	31%	27%
Cryotherapy	31%	19%
Multifocal Electroretinography	30%	0%
Coronary Brachytherapy	25%	0%
Surgical Robots	24%	17%
Retinal Nerve Fiber Analysis	22%	0%
PET/CT	21%	0%
3D Corneal Tomography	20%	0%
Gamma Knife	19%	0%
3D Image Guided Sinus Surgery	18%	36%
Ultrasound Transient Elastography System for Diagnosing Liver Fibrosis	18%	5%
Magnetic Resonance-guided Laser-induced Interstitial Thermotherapy (MR-guided LITT)	17%	0%
Intraoperative MRI	16%	0%
Radiofrequency Ablation System for Clearing Coronary Arteries	14%	0%
CT Laser Mammography	11%	5%
Intraoperative CT	11%	0%
Optical Coherence Tomography	0%	0%

[a]The number of responding facilities counts only those facilities that reported a Yes or No for a given technology. Facilities not reporting a response for a given technology or reporting “N/A or Don’t Know” are not counted. A total of 88 facilities in Canada’s five largest Census Metropolitan Areas were surveyed.
[b]Note that one teaching facility and one non-teaching facility (self reported) reported the presence of GI Endoscopic Ultrasound Guided Fine Needle Aspiration (FNA) but not GI Endoscopic Ultrasound, while one non-teaching facility (self reported) reported the availability of GI Endoscopic Ultrasound but not FNA. The remaining 7 teaching and 2 non-teaching facilities reported the availability of both.
Source: The Fraser Institute’s Medical Technology Survey, 2006.

Table 25 Availability of select medical technologies in any facility by Census Metropolitan Area

Technology	Census Metropolitan Area				
	Calgary	Montreal	Ottawa-Hull	Toronto	Van-couver
Intraoperative Transesophageal Echocardiography	Y	Y	Y	Y	Y
Brachytherapy (including the use of balloon catheter)	N	N	Y	Y	Y
Cryotherapy	Y	Y	Y	Y	Y
Intraperitoneal Therapy for the Delivery of Chemotherapy	N	N	Y	Y	Y
Radiofrequency Ablation Systems	Y	Y	N	Y	Y
Magnetic Resonance-guided Laser-induced Interstitial Thermotherapy	N	Y	Y	N	N
Implantable Cardioverter Defibrillator	N/A	Y	Y	Y	Y
External Counterpulsation	N/A	Y	Y	Y	Y
Catheter Guided Retriever for Manual Removal of Blood Clots.	Y	Y	Y	Y	Y
Coronary Brachytherapy	N	Y	Y	Y	N
Drug-eluting Stents	Y	Y	Y	Y	Y
Endovascular Stent Graft Repair	Y	Y	Y	Y	Y
Radiofrequency Ablation System for Clearing Coronary Arteries	N	N	Y	N	N
PET/CT	Y	N[a]	Y	Y	Y
Open MRI	Y	Y	Y	Y	Y
MRI Breast, Knee, and Hand and Forearm Coils	Y	Y	Y	Y	Y
Dynamic Contrast Enhanced MRI	Y	Y	Y	Y	Y
Magnetic Resonance Spectroscopy	Y	Y	Y	Y	Y
Echocardiography with Harmonic Imaging	Y	Y	Y	Y	Y
CT Laser Mammography	N	N	N	Y	N
Ultrasound Transient Elastography System for Diagnosing Liver Fibrosis	Y	Y	Y	Y	N
CT Virtual Colonoscopy	Y	Y	Y	Y	Y
CT Virtual Angiography	Y	Y	N	Y	Y
Intraoperative CT	N	Y	N	Y	N
Intraoperative MRI	Y	Y	N	Y	N
Intraoperative Ultrasound	Y	Y	Y	Y	Y

Table 25 Availability of select medical technologies in any facility by Census Metropolitan Area

Technology	Census Metropolitan Area				
	Calgary	Montreal	Ottawa-Hull	Toronto	Van-couver
Intraoperative Fluoroscope	Y	Y	Y	Y	Y
Computer-Aided Detection Systems for Diagnostic Scans and Images	Y	Y	N	Y	Y
Genetic Testing—Adults	Y	Y	Y	Y	Y
Genetic Testing—Children	Y	Y	Y	Y	Y
Genetic Testing—Prenatal	N	Y	Y	Y	Y
Pharmacogenomic Therapy/Pharmacogenomics	N	Y	N	Y	Y
Wireless Capsule Endoscopy	N/A	Y	N	Y	Y
GI Endoscopic Ultrasound/GI Endoscopic Ultrasound Guided Fine Needle Aspiration[b]	Y	Y	Y	Y	Y
Surgical Robots	N/A	Y	N	Y	Y
Antibiotic-Coated Central Venous Catheters	Y	Y	Y	Y	N
Minilaparoscopy 3 mm or less	N	Y	Y	Y	N
Gamma Knife	N	Y	N	Y	N
Frameless Stereotaxy	N	Y	Y	Y	Y
Coil Embolization for Aneurysms	Y	Y	Y	Y	Y
Optical Coherence Tomography	N	N	N	N	N
3D Corneal Tomography	N	Y	N	Y	N
Multifocal Electroretinography	N	Y	Y	N	Y
Retinal Nerve Fiber Analysis	N/A	Y	Y	N	N
3D Image Guided Sinus Surgery	N/A	N	N	Y	Y
Percutaneous Vertebroplasty	Y	N	N	Y	Y
Automated Medication Dispensing Systems	Y	Y	N	Y	Y
High Intensity Focused Ultrasound Machines	N	Y	Y	Y	Y
Holmium Lasers	N/A	Y	Y	Y	Y

Y = Yes; N = No; N/A = data not available.
[a]CIHI 2006b reports two hospital-based PET/CT scanners in the city of Montreal at January 1, 2006.
[b]The responses for GI Endoscopic Ultrasound and GI Endoscopic Ultrasound Guided Fine Needle Aspiration have been merged here. Note that facilities in Calgary reported the availability of the latter but not the former, while facilities in all other cities reported the availability of both.
Source: The Fraser Institute's Medical Technology Survey, 2006.

Table 26 Availability of select medical technologies in British Columbia in 1998 and in Vancouver in 2006

Technology[a]	BC in 1998	Vancouver in 2006
Intraoperative Transesophageal Echocardiography	N	Y
Brachytherapy/Brachytherapy (including the use of balloon catheter)	N	Y
PET scan for clinical use/PET/CT	N	Y
Open type MRI/Open MRI	N	Y
MRI breast coil/MRI Breast, Knee, and Hand and Forearm Coils	N	Y
Echocardiography with Harmonic Imaging	N	Y
Intraoperative CT scans/Intraoperative CT	N	N
GI Endoscopic Ultrasound	N	Y
Minilaparoscopy (3mm)/Minilaparoscopy 3 mm or less	N	N
Frameless Stereotaxy	N	Y
3D Image Guided Sinus Surgery	N	Y

[a]In some instances there was not a perfect match between the description provided by Harriman et al., 1999 and that used in the 2006 survey. In those cases, the language used by Harriman et al. appears before the language used in the 2006 survey.
Sources: The Fraser Institute's Medical Technology Survey, 2006; Harriman et al., 1999.

some cutting-edge technologies commonly available to Canadians in the country's five largest cities, many cutting-edge technologies are relatively scarce in Canada, or are unavailable.

As might be expected, more cutting-edge technologies appear to be available in teaching hospitals (self reported) than in non-teaching hospitals (self reported). As table 24 shows, this was the case for most technologies with the notable exceptions of 3D image-guided sinus surgery and CT virtual angiography. That said, teaching hospitals were only slightly more likely to have intraoperative fluoroscope and holmium lasers than were non-teaching hospitals. The comparison reveals a troubling paucity of cutting-edge technologies in Canada's hospitals: an average of 24 percent of non-teaching hospitals across Canada reported that these services were available, compared with an average of just 44 percent for teaching hospitals. This comparison also shows that Canada is poor at diffusing cutting-edge technologies from teaching to general hospitals. Of course, it may not be sensible for all hospitals to provide all technologies for all patients; it may make sense for only one or two hospitals in an area to have certain high-cost technologies (depending on the number of patients needing

care). However, the data suggest that Canada's investment in medical technologies is short, even by this standard.

There are differences in access to technologies among Canada's five largest cities. Table 25 shows the availability of the 50 technologies anywhere in the given cities (i.e., if a single facility reported having this technology, the city received a positive grade). Toronto ranks first among the cities: 90 percent of the technologies for which data were gathered were available in at least one facility. Montreal (84 percent)[30] was second, followed by Vancouver (74 percent), and Ottawa-Hull (70 percent). Calgary has the worst access among the five cities: just 63 percent of the technologies for which data were reported were available in at least one facility.[31]

Access to new technologies in Canada appears to have improved slightly in the past nine years. A comparison of this survey's results for the city of Vancouver (from 2006) with the list of technologies unavailable in BC on March 31, 1998 (Harriman et al., 1999) indicates that British Columbia has invested in some cutting-edge, or near cutting-edge, technologies over the past 9 years (table 26). Specifically, 9 of the 11 technologies listed as unavailable in 1998 were available in at least one facility in Vancouver in 2006. However, two technologies (minilaparoscopy 3mm or less, and intraoperative CT) were still not available in Vancouver in 2006 according to respondents, despite being present in other large Canadian cities (see table 25).

30 This figure becomes 86 percent if the PET/CT scanners reported in CIHI, 2006b are used to supplement the information from the survey.

31 This finding may be related to the size of the cities; larger cities may be more likely to adopt expensive new technologies than smaller ones.

5 Discussion

Canadians face negative consequences from this country's lack of availability of medical technologies and from the age and lack of sophistication of the current limited inventory of technologies. Most obvious is that diagnosis of disease is later and less sophisticated than it could be (which can sometimes affect a patient's chance of survival or return to full health). Also, treatments are more invasive than they need to be, which leads to increased risk, requires longer recovery times, and may adversely affect a patient's lifestyle. Furthermore, some patients might not be able to receive the treatments that make the difference between life and death, or between a healthy, comfortable life, and one marred by disability. Another consequence is that patients might be forced to travel abroad to receive the life saving and life improving care they need, in some cases without taxpayer funding.

Delays in diagnosis and treatment can be devastating for individuals, their families, their employers, and others who rely on them. Diseases might advance during the delay, thus potentially affecting the treatment and outcomes, while complications can also arise as a result of this deterioration. Delays also lead to additional and often significant personal costs. Any wait time, even a short one, entails some amount of pain and suffering, mental anguish, lost productivity at work and leisure, and strained personal relationships. Wait times also take a toll on the family and friends of those waiting, and may even affect an individual's ability to provide for him or herself and loved ones.

Importantly, wait times for access to diagnostic services in Canada can be remarkably long. The Fraser Institute's annual *Waiting Your Turn* survey calculates wait times for various diagnostic technologies across Canada. According the latest edition of the report, the median wait times in 2007 for Canada as a whole (shown in table 27) were 4.8 weeks for a CT scan, 10.1 weeks for an MRI, and 3.9 weeks for an ultrasound (Esmail and Walker with Bank, 2007). Provincial wait time tracking programs reported similarly lengthy wait times for diagnostic services (table 28).

A recently published study gives some insight into the non-medical consequences of a long delay in getting access to one particular technology. In a study commissioned by the Canadian Medical Association, the Centre for Spatial Economics (C_4SE) estimated the cost of wait times for MRI scans in excess of the 30-day Maximum Recommended Wait Time proposed by the Wait Time Alliance. The estimate measured the impact of waiting from an economic perspective, including lost economic activity or production, and the "broader reduction in economic activity resulting from reduced incomes and lower spending" (C_4SE, 2008: 23). The authors estimated that the cost to the economy of all the people waiting more than 30 days for

Table 27 Weeks waited to receive selected diagnostic tests in 2007, 2006, and 2005

Province	CT-scan			MRI			Ultrasound		
	2007	2006	2005	2007	2006	2005	2007	2006	2005
British Columbia	4.0	5.0	5.0	12.0	12.0	12.0	3.5	3.0	3.0
Alberta	4.0	4.0	5.5	10.0	9.0	10.0	2.0	2.5	2.0
Saskatchewan	5.5	5.0	8.0	12.0	12.0	24.0	4.0	3.5	2.3
Manitoba	8.0	6.0	6.0	8.0	10.0	10.0	10.0	8.0	6.0
Ontario	4.0	4.0	6.0	7.8	8.0	11.5	2.0	2.0	2.0
Quebec	6.0	4.0	5.0	12.0	12.0	12.0	6.0	6.0	5.0
New Brunswick	4.0	5.0	4.0	8.0	9.0	10.0	4.0	4.5	4.0
Nova Scotia	4.0	4.0	4.0	10.0	8.0	9.0	5.0	6.0	4.0
Prince Edward Island	6.5	9.0	4.0	12.0	13.0	5.0	10.0	8.0	5.0
Newfoundland & Labrador	5.8	5.0	5.5	20.0	28.0	36.0	6.0	4.8	9.0
Canada	4.8	4.3	5.5	10.1	10.3	12.3	3.9	3.8	3.4

Source: Esmail and Walker with Bank, 2007.

an MRI scan was approximately $13.8 billion or roughly $20,000 per Canadian in the queue longer than 30 days (C$_4$SE, 2008).[32]

The poor access to medical technologies in Canada can have consequences over and above those borne directly by patients. For example, this country's lack of cutting-edge technologies can affect physician training. Students in Ontario, for instance, have been sent abroad for PET instruction due to the lack of available training equipment in Canada (Priest, 2007a). Apart from training considerations, the poor access to medical technologies will result in an on-going, inefficient use of medical professionals and other medical labour who must now rely too heavily on older equipment, and older and more labour-intensive processes.[33]

Why is investment in medical technology lacking in Canada, given the real and considerable costs that both patients and taxpayers carry when health care is delivered less efficiently than it might be? Intuitively, it would seem that a health care system that offers patients and caregivers better access to advanced medical technologies would be in the interests of both patients and taxpayers. If that is true, then Canadians

32 According to the report, the median wait time for an MRI is in excess of the recommended target in all provinces, and the average wait for an MRI for people waiting longer than the 30-day target is 85 days (12.1 weeks) (C$_4$SE, 2008: 20).

33 For example, physicians using more clinical time to treat people means that Canadians will require more doctors to provide a given level of care.

Table 28 Provincial wait times for diagnostic services according to provincial wait times databases

	Wait time measurement	Dates covered	Procedure	Wait time
Alberta	Median Wait Time	90 days preceding November 30, 2007	MRI Scans	7.4 weeks
			CT Scans	1.3 weeks
Manitoba[a]	Provincial Average Estimated Maximum Wait Time	November, 2007	MRI Scans	6 weeks
			CT Scans	7 weeks
			Ultrasound	12 weeks
Ontario	90th Percentile Wait Time	September-November 2007	MRI Scans	128 days (18.3 weeks)
			CT Scans	71 days (10.1 weeks)
Nova Scotia[a]	Expected Wait Time, by Facility	December, 2007	MRI Scans	14 to 203 days (2 to 29 weeks)
			CT Scans	0 to 65 days (0 to 9.3 weeks)
			Ultrasound	14 to 125 days (2 to 17.9 weeks)
Prince Edward Island	Median Wait Time	2006	MRI Scans	< 1 week urgent; 12 weeks routine
			CT Scans	<1 week urgent; 8 weeks routine

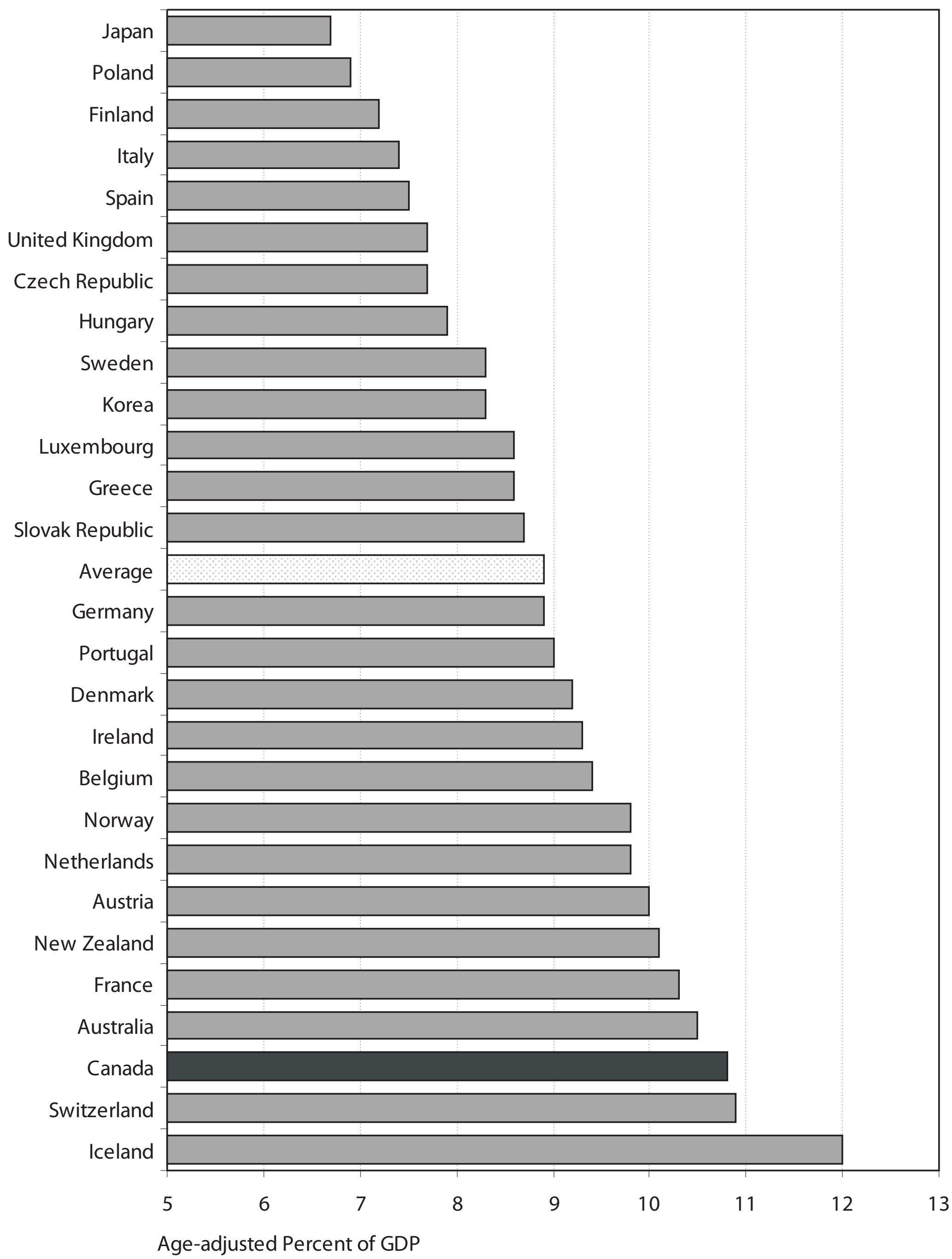
[a]Both Manitoba and Nova Scotia report wait times information for a number of diagnostic services in addition to MRI, CT, and Ultrasound.
Sources: Provincial Ministry of Health web sites, last accessed January 11, 2008.

may be left wondering why governments have not been purchasing modern medical technologies for use in their Medicare programs.

The explanation does not lie in a lack of health expenditures. According to the latest available figures, Canada's universal-access health insurance program is among the developed world's most expensive such programs (figure 2) (Esmail and Walker, 2007). Indeed, Canadian expenditures on health (as an age-adjusted share of GDP) have been shown to be 21 percent higher than in the average nation that has a universal-access health insurance program, and 61 percent higher than in Japan, which has the developed world's least expensive (on an age-adjusted basis) universal-access insurance program (Esmail and Walker, 2007; calculations by authors). It seems sufficient funds are available to purchase the latest medical technologies for Canadians.

Canada's federal government has also provided the provinces with additional financial resources, with the express intent of funding better access to medical technologies for Canadians. Specifically, between 2000 and 2004, three separate funds

Figure 2 Age-adjusted health spending in universal access OECD countries (% GDP), 2004



Source: Esmail and Walker, 2007.

Table 29 Federal transfers for diagnostic and medical equipment, 2000-2004

Year and fund name	Amount	Details
2000—Medical Equipment Fund	$1 billion	Funds available over 2 years (2000-01 and 2001-02)
2003—Diagnostic and Medical Equipment Fund	$1.5 billion	Funds accounted for in 2002-03, and available to provinces through 2005-06 Investment permitted in defined categories: acquisition of new equipment with established safety, efficacy, and effectiveness; replacement/updating of existing equipment; and direct installation costs of equipment
2004—10-Year Plan to Strengthen Health Care	$500 million	Included as part of the $41.3 billion 10-Year Plan to Strengthen Health Care Funds available in 2004-05

Sources: Canada, Department of Finance, 2007a and 2007b.

totalling $3 billion were created to provide provinces with the funding necessary to improve access to medical technologies in their health care programs (see table 29) (Canada, Department of Finance, 2007a & 2007b). Yet, despite these additional funds, modern medical technologies remain notably rare in Canada's provincial Medicare programs.[34]

Could a potential explanation for the rarity of modern medical technologies in Canada be a lack of patient demand? Could Canadians have signalled to governments and those in charge of the Medicare programs that they prefer the current method of health care delivery over one that relies more heavily on medical equipment and machinery? The available evidence appears to largely refute these claims.[35]

34 According to the OECD (2005), a survey of decision makers and those familiar with the decision making process in health care suggests that additional resources for the implementation of new technologies are seen as important for encouraging investment. This was reported to be particularly true for those technologies (no matter how effective) which are not cost saving, but which do improve quality of life and survival for patients. Clearly this desire has been met to some extent in Canada, and yet there remains a lack of access to medical technology.

35 A report by the Auditor General of Canada (2004) notes that Health Canada's license approval process has, on average, taken longer than the performance targets Health Canada has negotiated with industry for at least two classes of medical devices. Specifically, in a random sample of applications, the Auditor General found an average authorization time that was 15 days longer than the 75-day performance target for class III devices, and 50 days longer than the 90-day performance target for class IV devices (Auditor General of Canada, 2004). While these delays will affect Canadians' timely access to medical devices, they are not sufficient to explain the considerable lack of medical technologies in Canada and so are not discussed here.

Table 30 International comparison of public interest in news about scientific issues, 1992-2000

	Percent saying they are "very interested" in ...			
	New medical discoveries	**New inventions and technology**	**New scientific discoveries**	**Number of respondents**
United States[a]	66%	37%	36%	2,001
Europe average[a]	44%	34%	36%	12,170
Belgium	37%	27%	30%	951
Denmark	39%	36%	39%	967
France	59%	42%	47%	969
Germany	36%	25%	27%	1,910
Greece	55%	43%	45%	959
Ireland	38%	30%	28%	921
Italy	46%	39%	45%	924
Luxembourg	47%	35%	37%	474
Netherlands	58%	44%	41%	966
Portugal	28%	21%	22%	960
Spain	38%	31%	36%	942
United Kingdom	51%	39%	41%	1,226
US average[b]	67%	45%	47%	5,013
Canada[c]	64%	46%	47%	1,500

[a]1992
[b]Average of 1995, 1997, and 2000.
[c]2000
Source: Kim et al., 2001: 196.

In fact, surveys suggest that Canadians are interested in medical advances and believe that having access to advanced medical technology is very important and perhaps even essential. According to a review of surveys published Kim et al. (2001) in the journal *Health Affairs*, Canadians have a relatively higher interest in new medical discoveries, new inventions and technology, and new scientific discoveries, than their counterparts in Europe and are similar to Americans in this regard (table 30). Canadians are also similar to Americans in that they view access to the most advanced medical technology as essential: 33 percent of Canadians felt this way compared to 35 percent of Americans and just 21 percent of Germans (table 31). Further, more than 40 percent of Canadians disagreed that "it is impossible for any government or public or private health insurance to pay for all new medical treatments and technologies," (Kim

Table 31 Three-country comparison of views on medicine and medical technology, 1994

	United States		Canada		Germany	
	All	**Over 65**	**All**	**Over 65**	**All**	**Over 65**
Believe that modern medicine can cure almost any illness for people who have access to the most advanced technology and treatment	34%	27%	27%	25%	11%	11%
Being able to get the most advanced tests, drugs, and medical procedures and equipment is…						
Absolutely essential	35%	24%	33%	28%	21%	15%
Very important	51%	56%	48%	42%	55%	54%
Somewhat important	13%	17%	16%	18%	18%	17%
Not important at all	1%	3%	2%	4%	3%	6%
Base	1,214	162	1,472	192	1,210	246

Source: Kim et al., 2001: 198.

et al., 2001: 199) putting Canadians among the most likely to disagree among nations surveyed (table 32).

The available evidence suggests that Canadians would likely prefer to see better access to advanced medical technologies than is available in Canada today, and that they are already paying for that superior access. Given that, why is spending on new medical technologies constrained in Canada to the extent that it is, and why are Canada's relatively high levels of expenditure not purchasing the sort of access to medical technology that one might expect?

Policy recommendations

The cause of much of Canada's medical technology deficit lies in Canada's health policy choices. Specifically, the incentives resulting from the way hospital care is funded and delivered in Canada, the monopolization of health care financing and insurance, and government management of public health insurance have a marked impact on access to advanced medical technologies. An examination of each of these areas of Canada's approach to health care policy follows, including recommendations for improving the incentives to provide a higher level of access to advanced medical technologies.

Part of the explanation for the disconnect between demand, spending, and the supply of technologies discussed in the preceding sections can be found in the ownership structure of Canada's hospitals. Although legally incorporated as private, non-profit institutions (The Standing Senate Committee on Social Affairs, Science, and

Table 32 International comparison of public's view of cost constraints on medical technology, 1996 and 2000

	Disagree that it is impossible for any government or public or private health insurance to pay for all new medical treatments or technologies		
	All	**Over age 65**	**Under age 65**
United States[a]	47%	42%	48%
Europe average[b]	36%	32%	37%
Austria	29%	24%	29%
Belgium	36%	34%	36%
Denmark	24%	18%	25%
Finland	25%	22%	25%
France	51%	50%	50%
Germany	37%	34%	42%
Greece	61%	52%	63%
Ireland	23%	24%	22%
Italy	37%	36%	36%
Luxembourg	34%	30%	33%
Netherlands	32%	36%	31%
Portugal	36%	29%	36%
Spain	45%	35%	45%
Sweden	29%	26%	29%
United Kingdom	38%	28%	39%
Canada[a]	42%	45%	43%

[a]2000
[b]1996
Source: Kim et al., 2001: 199.

Technology, 2002), hospitals in Canada are best considered government business enterprises (GBEs).[36] The vast literature and evidence on the differences between government and private service providers clearly explains why government ownership of facilities has limited the availability of medical technologies more than would have been the case otherwise. Kornai (1992) identified budget constraints as one major,

36 Canadian hospitals are in effect and in practice public entities: they are governed largely by a political process, given wage schedules for staff, are told when investment can be undertaken, denied the ability to borrow privately for investment, told which investments will be funded for operation, and forcibly merged or closed by provincial governments.

unchangeable difference between private-sector and government businesses. Because government budget constraints are "soft," it is effectively impossible for government to be de-capitalized. Private-sector businesses, on the other hand, face "hard" budget constraints: if they incur sustained losses, or even a few large losses, the decline of capital can push them into bankruptcy. Kornai argued that this basic and unwavering difference between the two types of entities results in extraordinary differences in operations. Private-sector businesses must provide consumers with the goods and services they demand in a timely manner and at affordable prices that are consistent with their quality. GBEs do not face the same constraints. They can consistently lose money by offering goods and services whose prices do not reflect their timeliness or, critical to this discussion, quality.

Another pivotal difference between the two types of business enterprise that is central to this discussion relates to capitalization. Megginson and Netter (2001) found in a review of the literature on privatization that GBEs tend to develop with less capital and thus are more labour-intensive than their private-sector counterparts. Similarly, Eamonn Butler found that privatization of state-owned enterprises often results in re-capitalization of the entity because governments tend to view capital spending in their businesses to be less important than distributing money to the very visible areas demanded by the public (Butler, 1992). Clearly, private sector companies face very different incentives and risks than their public sector counterparts, and one result of Canada's almost exclusive reliance on public hospitals is that Canadians receive less access to advanced medical technologies and have a greater supply of older and outdated technologies than they might otherwise.[37] Allowing private health care providers to have a greater role in the delivery of health care services would have the effect of improving access to advanced medical technologies for Canadians.

The lack of competition in Canada's hospital sector that has resulted from the way care is funded has further removed, or even eliminated, incentives to focus on patient demands. Hospital care in Canada is largely funded through a block-funding or budgetary model where hospitals are given a periodic budget to provide care to patients. The effect of this is to disconnect funding from the provision of services to patients. As a result, incentives to provide a higher or superior quality of care to patients are virtually absent in Canada's health care programs (Esmail, 2007b).[38]

37 This finding is also borne out in practice. Specifically, in France, the per capita increase in MRI equipment occurred more rapidly in private hospitals than in public hospitals (US Congress Office of Technology Assessment, 1995), while private clinics in Greece were the first purchasers of, and continued to be the principle providers of access to high-tech diagnostic machines (European Observatory on Health Care Systems, 1996).

38 Hospitals in Canada do not normally receive higher revenues by improving quality or speed of service. On the contrary, Canadian hospitals are more likely to go over their budgets if they spend money on modern technologies in an effort to provide better care.

An alternative way to pay for hospital services, variously known as a Diagnosis Related Group (or DRG) funding model, prospective fee-for-service funding, or activity-based financing, provides hospitals with funding only for services that are delivered, based on the expected costs of treating a patient with a given health condition. If a hospital fails to meet patient expectations under such a regime, their departure to another hospital immediately results in lower revenues. Conversely, increasing the number of patients treated (or attracting more patients) results in increased financial resources for the hospital. This is the opposite effect that treating more patients (or having patients depart to other facilities) has under a global budget model such as is used across Canada.

Moving from the current budgetary model for hospital care financing in Canada to an output- or activity-based funding model would have a marked impact on Canadians' access to advanced medical technologies. For example, Goodman (2004) notes that "provider competition to offer state-of-the-art technology," and "public demand"[39] are important factors that reinforce the market for health technology (Goodman, 2004: 9). The OECD (2005) also notes that budgetary limits tend to dampen the overall rate of technology diffusion. TECH (2001) finds that relatively strict supply-side policy restrictions, including central planning of the availability of intensive services and global budget financing for hospital care, are related to markedly slower rates of growth in the provision of intensive or "high-tech" treatments. Further, studies examining the result of moving to DRG-type or activity-based financing schemes have found that technical efficiency (unit of output per unit of inputs), throughput, and cost efficiency are all improved under an activity-based financing regime as compared to a block funding model (Esmail, 2007b). Put simply, activity-based funding creates incentives for hospitals to treat more patients, to provide care with greater efficiency and productivity, and to provide the types of services (such as better access to high tech care and newer and more advanced equipment as well as shorter wait times) that patients want.[40]

39 Goodman (2004) lists "consumer awareness, direct-to-consumer advertising, and mass media reports" as drivers of such demand (p. 9).

40 Both Moise and Jacobzone (2003) and OECD (2005) note that the actual rate of reimbursement under a DRG-type financing system, relative to the cost of delivering the technology, plays an important role in the diffusion rate of technology.

Romeo et al. (1984) (cited in OECD, 2005) found no clear pattern regarding technology diffusion and either public or private ownership or competition among providers. However, Hirth et al. (2000) (also cited in OECD, 2005) found that less competitive markets were associated with lower use of new technologies, while Bryce and Cline (1998) found a positive association between competition for physicians and their patients and the supply of technologies in Pennsylvania. (It should be noted that Bryce and Cline also determined that this competition resulted in excess supply of the technologies studied based on measures of actual use in comparison with measures of capacity and minimum volume standard set by the state and select medical organizations.)

Canada's various prohibitions on privately financed health care have also resulted in poorer access to advanced medical technologies than might have been available otherwise. The technological advances that we all enjoy in our lives have been financed, at some point, by the wealthy. Today, we can all drive cars and visit websites on the Internet using our personal computers. There was a time when both forms of technology were prohibitively expensive and available only to those with sufficient financial means, who then purchased these goods and helped finance their advancement and the construction of a knowledge base around them to a point where they became available to everyone (Esmail and Walker, 2007). Disallowing or discouraging the existence of such a market has the effect of discouraging investment in new technologies by making their introduction more costly. For instance, the knowledge base created by these speculative purchasers is absent in Canada and must be imported from abroad, which also delays the introduction of new technologies. Further, these new technologies are being introduced in a program that is intended to deliver equal access to services for all individuals without any financial responsibility for patients. This makes it difficult to restrict access to these often costly new technologies in order to contain expenditures and minimize unnecessary or ineffective application. This also makes it difficult to develop proficiency, knowledge, and expertise before allowing treatment of large numbers of patients (or while denying access to patients who may benefit from the new innovation).[41]

Put simply, competition among private insurance companies and privately funded providers would likely improve access to medical technologies for Canadians. That is because in the search for a larger market share and more subscribers, insurance companies and providers would try to offer those services and products (such as high-tech medicine) that individuals want.[42] As noted above, the presence of these technologies in Canada would have the effect of reducing the cost of their introduction into the public health insurance scheme.

Finally, bureaucratic and governmental control over what health care is delivered, where, and how (as opposed to allowing the private market and individual patients to control health care delivery), has also resulted in poorer access to medical technology than might have been the case otherwise. Specifically, Canadians receive only the level of health care that their provincial governments and regional authorities deem appropriate. This means that decisions regarding health care management and

41 Indeed, the OECD notes that "… new technologies, when first introduced into practice, are often relatively unfamiliar. Much improvement occurs as a result of downstream learning, which may lead to subsequent modifications in the technology itself or its application. Secondly, technological change can simultaneously reduce cost per patient, enhance quality, and reduce risk to patients, thereby expanding the target population of use and/or demand" (OECD, 2005: 31).

42 For instance, the OECD notes, citing Wild (2000), that the private sector in Austria promoted high-tech medicine, and that technologies were in some cases purchased both "for reasons of competition and prestige" (OECD, 2005: 35).

delivery are controlled through both political and bureaucratic processes, which can be strongly influenced by special interests and other organized groups. This structure has important implications for the medical technologies that are purchased. Importantly, patient preferences for new, less invasive, and more comfortable services made possible by technological advances, but which produce a similar ultimate result as the current or older method, may not always be taken into account in governmental or bureaucratic decision making (OECD, 2005). Further, special interest groups can have a strong influence on the allocation of health care resources by governments, and their interests may not align with those of patients. Examples of the influence special interest groups have in the health care sector in Canada can be found in significant pay premiums (relative to comparators in the public sector, the private sector, and in other health sectors) for (primarily non-medical) workers in the hospital sector (see for example Esmail, 2002; Mullins, 2004 and 2005; McMahon and Zelder, 2002), and unacceptably long actual and target wait times for access to medically necessary health care (Esmail and Walker with Bank, 2007; Esmail, 2007c). Of course, voters can influence government decisions, but sick Canadians who might benefit from costly medical technologies often make up a small proportion of the population, so transferring funds from the majority of the population to them is not always politically expedient (see for example: Skinner, 2005; and Skinner, forthcoming).

A superior alternative to government management and control of the public health insurance scheme would be to allow patients greater control over their health care dollars (both for services covered by Medicare, and for services currently not covered by Medicare, such as outpatient pharmaceuticals). The result would be a system more focused on the desires and requirements of patients and health care funders, rather than those of administrators and providers. This could be accomplished through some form of medical savings account (see for example Ramsay, 1998; McMahon and Zelder, 2002). Alternatively, it could be accomplished using a competitive, social insurance-based approach in which comprehensive universal health insurance would be provided in a competitive marketplace involving private insurers, as is done in Germany, Switzerland, and the Netherlands, among others (Esmail and Walker, 2007; Esmail, 2006).[43]

Moving towards a greater role for private financing and privately managed comprehensive insurance delivered in a competitive marketplace, and away from the internally-focused, government run system in place today would lead to a health care system that delivered to patients and payers the health care goods and services they

43 Rydén et al. (2004) found in a survey of European Cardiology Societies that the "relative usage of coronary stents" and the "usage of implantable cardioverter defibrillators" was greater in "countries with a social health insurance-based funding system" (p. 614).

demand in a timely manner[44] and at affordable prices that are consistent with their quality.[45] Such a shift in the financing and management of health care would also mean a significant change in the relationship between the budgetary cycle of government and access to health care and medical technologies.[46] Further, by incorporating a comprehensive range of health care services under the oversight and management of a single organization (the insurer), such a reform has the potential to increase access to technologies that may increase costs in one area of care, but will likely decrease costs in another.[47] Pharmaceuticals provide a good example of such a technology, as their use can have a significant impact on pharmaceutical budgets/spending, but can also have the effect of reducing spending in other areas of the health care system by a sizable amount (see for example, Lichtenberg, 2001) .[48]

44 Notably, countries that have opted for a social insurance-based approach appear to have fewer problems with the promptness of care than those who have chosen a tax-financed system (Altenstetter and Björkman, 1997).

45 In considering who should operate the companies providing universally accessible comprehensive insurance in such a scheme, readers should note the important distinctions between government business enterprises (in this case as insurance providers) and private sector providers highlighted above in the discussion of private versus government provision of care. See also Kornai, 1992; Megginson and Netter, 2001; Clemens, 2004; and Clemens and Veldhuis, 2004.

46 Both OECD, 2005, and Moise and Jacobzone, 2003, note that budgetary limits tend to dampen the overall rate of technology diffusion.

47 The phenomenon discussed here is commonly known as silo funding.

48 For discussions of silo funding and budgetary limits in government-managed health care programs, see OECD, 2005; and Moise and Jacobzone, 2003.

6 Conclusion

Medical technologies are an important component of medical care. A review of the literature examining their value shows that medical technologies can increase longevity, reduce mortality, and improve quality of life for those fortunate enough to have access to them. The evidence also shows that in many cases, medical technologies can accomplish these improvements cost effectively, even in some cases, reducing costs while improving health outcomes. Because of these benefits, it should be an objective of health policy in this country to provide Canadians with a high level of access to the latest medical technologies. Put simply, Canada's health care system is failing if it does not provide a high level of access.

Unfortunately, Canada's medical technology record is relatively poor compared with that of other nations. The evidence shows that Canada is a late adopter of advanced medical technologies; but even after these technologies have been introduced, Canada is slow to expand the inventories or applications of these technologies. In total, Canadians have poorer access to medical technologies than their counterparts in a number of other developed nations.

A closer examination of Canada's limited existing inventory of medical technologies finds that this country relies too heavily on older and outdated medical equipment. In many cases, it has too few newer technologies and equipment. Canada is also overly reliant on less sophisticated forms of technology than might be considered optimal. This is important because older machines, relative to their newer counterparts, are often less reliable and need more maintenance, may provide a lower quality output or be less accurate, may be less safe for patients and operators, and sometimes expose patients to greater risk. Conversely, newer and more sophisticated pieces of equipment can allow for shorter examination or operation times, provide higher quality output, and offer additional services than their less sophisticated counterparts. An inventory of outdated and unsophisticated equipment is qualitatively much different from an inventory of relatively new and highly sophisticated medical equipment. Canada could be doing a much better job of replacing older and less sophisticated equipment.

A survey of the availability of cutting-edge technologies in Canada's five largest cities also finds room for improvement. The survey found that while some cutting-edge technologies are commonly available to patients, many such technologies are relatively scarce and are sometimes unavailable in this country.

The lack of access to modern and advanced medical technologies has important consequences. Most obvious is that the diagnosis of disease is later and less sophisticated (which can sometimes affect a patient's chance of survival or return to full health), and treatments are more invasive (which increases risk, requires longer recovery times, and may affect a patient's lifestyle). The state of access to and quality of med-

ical technology in Canada might also mean that some patients cannot receive life-saving treatments, or must eventually live with a disability, rather than enjoy a healthy, comfortable life.

Why is investment in medical technology lacking in Canada? Why have governments not been purchasing modern medical technologies for implementation in their Medicare programs? Canada's record of poor investment in medical technology cannot be explained by a lack of money. In fact, Canada's health insurance program ranks among the developed world's most expensive universal access, health insurance programs. Further, the federal government has transferred $3 billion in targeted funding to the provinces since 2000 in an effort to improve the availability of medical technology in Canada. Yet modern medical technologies remain rare in Canada's provincial Medicare programs.

Clearly, throwing more money at Medicare is not the solution. Rather, Canadians should be looking at why they receive so little from Medicare despite spending so much on health care. The explanation for the disconnect between demand, spending, and the supply of technologies in Canada can be found in the incentive structure of the health care system. By employing private competitive provision of health care services, employing comprehensive private insurance (both in parallel to and as a part of the universal system), and by strengthening the connection between the delivery of and payment for services, the Canadian health care system will be better structured to deliver the world-class access to modern medical technologies that Canadians have long been paying for.

Appendix A: The survey of the availability of advanced medical technologies in Canadian hospitals

The authors designed the medical technology survey to obtain a more complete set of data on the employment of advanced, cutting-edge, and near cutting-edge medical technologies in Canada. The survey was sent to hospitals in Canada's five largest Census Metropolitan Areas and was conducted in October and November of 2006. It was composed of a list of 51 advanced medical technologies and asked respondents to identify whether those technologies were available for the diagnosis or treatment of patients being treated in their facility.

The list included technologies in various areas and specialties including cancer care, diagnostic services, cardiovascular care, neurology, urology, genetics, and general hospital and surgical services.

The list was compiled by reviewing technologies discussed in Harriman et al. (1999) and by reviewing technologies discussed on the website of the Canadian Agency for Drugs and Technologies in Health and its counterparts in the Unites States and Europe including:

- SBU—the Swedish Technology Assessment Organization
- CEDIT—the French Technology Institute
- NHS/NICE—the National Institute for Clinical Excellence in the UK
- University of Birmingham, UK—the National Horizon Scanning Centre—the New and Emerging Technology Briefings
- BlueCross BlueShield Association—the Technology Evaluation Centre
- Health Canada
- Federal Drug Administration (US)

A search of medical journals, health-related organizations' websites (such as various cancer agencies and cardiac agencies), and manufacturer websites was also conducted.

The final list of advanced medical technologies and the survey were subjected to both internal and external peer review for completeness and validity as well as to ensure that the technologies for which information was requested in the survey were useful technologies that could be and have been applied successfully in clinical practice.

In order to maximize the likelihood of response for any given facility, the survey was faxed to a number of department heads at all facilities including chiefs of surgery, heads of imaging, laboratory directors, and heads of oncology. All hospitals except psychiatric, rehabilitation, and military facilities in Canada's 5 largest Census Metro-

politan Areas (Statistics Canada, 2005)—Toronto, Montreal, Vancouver, Ottawa-Hull, and Calgary—were contacted. The contact list for hospitals in Canada was purchased from the Canadian Medical Association. Separate sites of the same organization (e.g. Milton and Oakville sites of Halton Healthcare Services) were treated as separate facilities in the survey.

In a number of cases, more than one department head from a given facility responded to the survey. The following process was used to aggregate multiple responses into a single survey for a given facility: any "Yes" responses for a given technology took precedence over "No" or "N/A or don't know" responses,[49], while "No" responses took precedence over "N/A or don't know" responses.[50]

The response rate for Canada at the individual survey level was 24 percent overall, while 49 of 88 facilities (the level of data aggregation employed in this report) responded in total.

The survey was also run simultaneously in the 15 largest Metropolitan Statistical Areas (US Census Bureau Population Division, 2006) in the United States[51] using lists purchased from the American Hospital Association and Medical Marketing Services. Very low response rates (about 2 percent overall) and an incomplete dataset precluded meaningful analysis of this data. Only the Canadian component of the survey is discussed in the report.

49 For example, if a given facility had multiple respondents and only one respondent reported "Yes" for a given technology, the facility was reported as having responded "Yes" to having that technology.

50 For example, if a given facility had multiple respondents and all but one reported "N/A or don't know" for a given technology, and the one respondent reported "No," the facility was reported as having responded "No" to having that technology.

51 The 15 largest MSAs were: New York-Northern New Jersey-Long Island; Los Angeles-Long Beach-Santa Ana; Chicago-Naperville-Joliet; Philadelphia-Camden-Wilmington; Dallas-Fort Worth-Arlington; Miami-Fort Lauderdale-Miami Beach; Houston-Sugar Land-Baytown; Washington-Arlington-Alexandria; Atlanta-Sandy Springs-Marietta; Detroit-Warren-Livonia; Boston-Cambridge-Quincy; San Francisco-Oakland-Fremont; Riverside-San Bernardino-Ontario; Phoenix-Mesa-Scottsdale; and Seattle-Tacoma-Bellevue.

Table A1 List of technologies included in the survey

Specialty	Technology
Anaesthesia/Cardiovascular	Intraoperative Transesophageal Echocardiography*
Cancer	Brachytherapy (Including the Use of Balloon Catheter)*
	Cryotherapy
	Intraperitoneal Therapy for the Delivery of Chemotherapy
	Radiofrequency Ablation Systems
	Magnetic Resonance-guided Laser-induced Interstitial Thermotherapy
Cardiovascular	Implantable Cardioverter Defibrillator
	External Counterpulsation
	Catheter Guided Retriever for Manual Removal of Blood Clots
	Coronary Brachytherapy
	Drug-eluting Stents
	Endovascular Stent Graft Repair
	Radiofrequency Ablation System for Clearing Coronary Arteries
Diagnostics	Positron Emission Tomography (PET)*
	Positron Emission Tomography with Computed Tomography (PET-CT)
	Open MRI*
	MRI Breast, Knee, and Hand and Forearm Coils*
	Dynamic Contrast Enhanced MRI
	Magnetic Resonance Spectroscopy
	Echocardiography with Harmonic Imaging*
	Computed Tomography Laser Mammography (CT Laser Mammography)
	Ultrasound Transient Elastography for Diagnosing Liver Fibrosis
	Virtual Colonoscopy CT
	Virtual Angiography CT
	Intraoperative CT*
	Intraoperative MRI
	Intraoperative Ultrasound
	Intraoperative Fluroscope
	Computer-Aided Detection Systems for Diagnostic Scans and Images

Table A1 List of technologies included in the survey

Specialty	Technology
Diagnostics (Genetic Testing)	Genetic Testing for Adults
	Genetic Testing for Children
	Prenatal Genetic Testing
	Pharmacogenomics to Predict Safety, Toxicity and/or Efficacy of Drugs in Patients
Gastroenterology	Wireless Capsule Endoscopy
	GI Endoscopic Ultrasound*
	GI Endoscopic Ultrasound Guided Fine Needle Aspiration
General	Surgical Robots (e.g., Telesurgical Systems, Positioning Systems, Navigational Aids)
	Antibiotic-coated Central Venous Catheters
	Minilaparoscopy 3 mm or less*
Neurology	Gamma Knife
	Coil Embolization for Aneurysms
	Frameless Stereotaxy*
Ophthalmology	Optical Coherence Tomography
	3-D Corneal Tomography
	Multifocal Electroretinography
	Retinal Nerve Fiber Layer Analysis
Otolaryngology	3-D Image Guided Sinus Surgery*
Osteoporosis	Percutaneous Vertebroplasty
Pharmacy	Automated Medication Dispensing Systems
Urology	High Intensity Focused Ultrasound Machines (HIFU)
	Holmium Lasers

*Included in the list of technologies examined by Harriman et al., 1999.

Appendix B: Fraser Institute Medical Technology Survey, 2006

1. Hospital Information

Your Department: ______________________________

Hospital Type. Please check one of the following boxes:

☐ Teaching ☐ General Medical and Surgical

☐ Children's ☐ Other; Please specify ______________________________

Hospital Ownership. Please check one of the following boxes:

☐ Private Not-for-Profit ☐ Private For Profit ☐ Public

2. Is the following technology available for diagnosis or treatment of patients in your facility? Please check the appropriate box.

Specialty	Technology	Yes	No	N/A or Don't Know
Anaesthesia/ Cardiovascular	Intraoperative Transesophageal Echocardiography	☐	☐	☐
Cancer	Brachytherapy (Including the Use of Balloon Catheter)	☐	☐	☐
Cancer	Cryotherapy	☐	☐	☐
Cancer	Intraperitoneal Therapy for the Delivery of Chemotherapy	☐	☐	☐
Cancer	Radiofrequency Ablation Systems	☐	☐	☐
Cancer	Magnetic Resonance-guided Laser-induced Interstitial Thermotherapy	☐	☐	☐
Cardiovascular	Implantable Cardioverter Defibrillator	☐	☐	☐
Cardiovascular	External Counterpulsation	☐	☐	☐
Cardiovascular	Catheter Guided Retriever for Manual Removal of Blood Clots	☐	☐	☐
Cardiovascular	Coronary Brachytherapy	☐	☐	☐
Cardiovascular	Drug-eluting Stents	☐	☐	☐
Cardiovascular	Endovascular Stent Graft Repair	☐	☐	☐
Cardiovascular	Radiofrequency Ablation System for Clearing Coronary Arteries	☐	☐	☐
Diagnostics	Positron Emission Tomography (PET)	☐	☐	☐
Diagnostics	Positron Emission Tomography with Computed Tomography (PET-CT)	☐	☐	☐
Diagnostics	Open MRI	☐	☐	☐
Diagnostics	MRI Breast, Knee, and Hand and Forearm Coils	☐	☐	☐
Diagnostics	Dynamic Contrast Enhanced MRI	☐	☐	☐
Diagnostics	Magnetic Resonance Spectroscopy	☐	☐	☐
Diagnostics	Echocardiography with Harmonic Imaging	☐	☐	☐
Diagnostics	Computed Tomography Laser Mammography (CT Laser Mammography)	☐	☐	☐
Diagnostics	Ultrasound Transient Elastography for Diagnosing Liver Fibrosis	☐	☐	☐

Appendix B: Fraser Institute Medical Technology Survey, 2006

Specialty	Technology	Yes	No	N/A or Don't Know
Diagnostics	Virtual Colonoscopy CT	☐	☐	☐
Diagnostics	Virtual Angiography CT	☐	☐	☐
Diagnostics	Intraoperative CT	☐	☐	☐
Diagnostics	Intraoperative MRI	☐	☐	☐
Diagnostics	Intraoperative Ultrasound	☐	☐	☐
Diagnostics	Intraoperative Fluroscope	☐	☐	☐
Diagnostics	Computer-Aided Detection Systems for Diagnostic Scans and Images	☐	☐	☐
Diagnostics – Genetic Testing	Genetic Testing for Adults	☐	☐	☐
Diagnostics – Genetic Testing	Genetic Testing for Children	☐	☐	☐
Diagnostics – Genetic Testing	Prenatal Genetic Testing	☐	☐	☐
Diagnostics – Genetic Testing	Pharmacogenomics to Predict Safety, Toxicity and/or Efficacy of Drugs in Patients	☐	☐	☐
Gastroenterology	Wireless Capsule Endoscopy	☐	☐	☐
Gastroenterology	GI Endoscopic Ultrasound	☐	☐	☐
Gastroenterology	GI Endoscopic Ultrasound Guided Fine Needle Aspiration	☐	☐	☐
General	Surgical Robots (e.g. Telesurgical Systems, Positioning Systems, Navigational Aids)	☐	☐	☐
General	Antibiotic-coated Central Venous Catheters	☐	☐	☐
General	Minilaparoscopy 3 mm or less	☐	☐	☐
Neurology	Gamma Knife	☐	☐	☐
Neurology	Coil Embolization for Aneurysms	☐	☐	☐
Neurology	Frameless Stereotaxy	☐	☐	☐
Ophthalmology	Optical Coherence Tomography	☐	☐	☐
Ophthalmology	3-D Corneal Tomography	☐	☐	☐
Ophthalmology	Multifocal Electroretinography	☐	☐	☐
Ophthalmology	Retinal Nerve Fiber Layer Analysis	☐	☐	☐
Otolaryngology	3-D Image Guided Sinus Surgery	☐	☐	☐
Osteoporosis	Percutaneous Vertebroplasty	☐	☐	☐
Pharmacy	Automated Medication Dispensing Systems	☐	☐	☐
Urology	High Intensity Focused Ultrasound Machines (HIFU)	☐	☐	☐
Urology	Holmium Lasers	☐	☐	☐

☐ Yes, I would like to receive a free digital copy of the published study.

Email address: ____

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