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The Value of Radiology in Canada.

At a Glance

- Radiology is an integral component of the health care system, which continues to evolve significantly in the era of technological advances and changing population needs.
- This report presents a preliminary framework to better establish the value of radiology from a population health and systems perspective. Segmented research must take into account the benefits to patients, other health care providers, the health care system, and society.
- While evidence of system-wide efficiency is sparse, teleradiology, interventional radiology, and clinical decision support systems are three innovation examples that show great promise.

BRIEFING JANUARY 2017

Executive Summary

The system-wide sustainability of health care in Canada is at a tipping point. There are a multitude of strains and pressures on the system, especially in a time of uncertain funding, demands for efficiency, and an abiding desire to improve quality of care for all patients.[1] Health care spending is increasing, and the benefits from those expenditures are not always tangible in the eyes of the public and policy-makers.[2,3]

Appropriate use of medical imaging and the expertise provided by radiology can help health policy-makers, patients, and providers respond to these challenges. Across Canada, radiologists work at the centre of innumerable patient care pathways—at the intersection of primary and tertiary care. Medical imaging is essential to the diagnosis and treatment of many conditions. Patients from every demographic group rely on radiologists to provide insight into their health and optimal care.

Growing demands for medical imaging to diagnose and treat disease and injuries[4] have resulted in increased strain on the health care system, as best evidenced by the continuing wait time issues in many jurisdictions.[5] This micro-level pressure is exacerbated because of the value that radiology adds to the system. Most general practitioners believe that advances in medical imaging have boosted their confidence in treatment for their patients by providing information that would otherwise not be available—potentially allowing for better clinical decision-making and faster times to definitive diagnoses.[6] This demand is reflected in wait times for specialized diagnostic imaging tests. For example, in 2015, Canadian general practitioners reported that two-fifths of their patients

1 Advisory Panel on Healthcare Innovation, *Unleashing Innovation: Excellent Healthcare for Canada*.
2 Robson, *Healthcare Spending Decelerating? Not So Fast!*
3 Barua, Palacios, and Emes, *The Sustainability of Health Care Spending in Canada*.
4 Organisation for Economic Co-operation and Development, *Health Care Utilisation*.
5 Canadian Institute for Health Information, *Wait Times for Priority Procedures in Canada*.
6 Hughes and others, "Perspectives on the Value of Advanced Medical Imaging."

The value of radiology extends beyond the economic benefits.

often had difficulty receiving specialized diagnostic imaging tests (including CT imaging, mammograms, and MRIs)—substantially higher than the international average of one-fifth.[7] Wait times for MRI and CT scans increased between 2011 and 2015, and they continue to vary widely among the provinces.[8] Diagnostic imaging has been unable to consistently reach national benchmarks, despite continuous efforts at improvement.[9]

How Radiology Adds Value to a Pressured Health System

The value of radiology extends beyond the economic benefits. Radiologists are involved in all aspects of the patient clinical journey, and the benefits include and extend beyond the patient's health status. In determining the value of radiology, it is easier to segment the benefits into manageable pieces when establishing and articulating value from different perspectives. The framework presented in this report provides an overview of some of the metrics that could be applied to articulate the value of radiology from the perspective of the patient, other health care providers, the health care system, and society in general. Some of these metrics include the impact on extended life and quality of life in a population or an individual patient. Other metrics that are less commonly used include productivity gains, decreased patient anxiety, reduced caregiver burden, and system efficiency.

After contextualizing the place of radiology and the importance of medical imaging to the health system, this report looks at three key examples of how radiology and medical imaging have added value—first, through breast cancer screening (mammography); second, via teleradiology programs that bring radiologists' expertise to remote and rural communities that would not otherwise have access to these essential diagnostic services; third, through interventional radiology procedures that enable technologically advanced, life-saving options for patients without the need for invasive surgery. The report highlights and begins to quantify the value of the examples above.

7 Canadian Institute for Health Information, *How Canada Compares*.

8 Canadian Institute for Health Information, *Wait Times for Priority Procedures*.

9 Canadian Association of Radiologists. *National Maximum Wait Time Access Targets*.

The Value of Breast Cancer Screening

Clear evidence supports both the population health and economic benefits of breast cancer screening, as exemplified through mammography. In terms of economic burden, the direct and indirect costs of breast cancer are about $512 million in current dollars.[10] Radiology's value is demonstrated through stage-shifting (i.e., the detection of disease at an earlier stage), which results in less invasive and less costly treatment. In the absence of screening, expected costs are much higher, particularly in terms of costs related to treatment and productivity losses, as the economic burden of disease is greater in the later stages. The lifetime cost burden of breast cancer is higher when the disease is diagnosed at a later stage, which is more likely in the absence of screening.[11] These costs include treatment, follow-up care, metastases diagnosis, continuing care, and end-of-life care. Treatment cost estimates range from $34,214 at stage I to $53,429 at stage IV—an average increase of about 16 per cent from one stage to the next. Radiology can help to reduce these costs.

The Value of Teleradiology

Teleradiology—the transmission of images from one place to another—allows radiologists to provide interpretation and consultation to patients in rural and remote areas (and to remain available for patient care) without being physically present in the imaging facility. The practical need for this process has not changed, but teleradiology has evolved greatly since the advent of radiology as a diagnostic tool. In the early days, plain films were couriered from a general practitioner's office to a radiologist for expert interpretation; today, digital images are transmitted via the Internet.[12] Teleradiology improves access to radiological services in rural and remote communities. For example, a teleradiology program links a hospital in Iqaluit, Nunavut, to radiologists at The Ottawa Hospital. In 2010, prior to the arrival of a CT scanner in Iqaluit, over 400 patients had to be transported south to Ottawa to receive their diagnoses. The average duration of the stay for these patients was 13 days, which

10 Public Health Agency of Canada, *Economic Burden of Illness in Canada*.

11 Will and others, "Estimates of the Lifetime Costs of Breast Cancer Treatment in Canada."

12 Bradley, "Teleradiology."

Teleradiology has decreased the cost and the need to be physically relocated to receive treatment.

translated into $2,600 per patient to cover accommodation and other expenses. For emergency cases, which may include physicians and nurses as escorts, the average round-trip cost for the flight and crew was approximately $25,000. Additionally, wait times were long (three to four months) and extended stays in Ottawa caused anxiety for some patients.[13] Teleradiology has added value by decreasing the cost and the more intangible human burden of needing to be physically relocated to receive treatment.

The Value of Interventional Radiology

Interventional radiology (IR) has allowed complicated surgical procedures (such as cancer biopsies and stroke treatments) to become less invasive and more effective through guided imaging. Over the past two decades, this subspecialty has vastly expanded to treat a variety of diseases affecting every organ in the body. For example, IR has been used to treat acute ischemic stroke, playing an important role in ensuring treatment efficiency by restoring blood flow quickly and safely.[14] IR has contributed to significant efficiency gains in health care. For example, endovascular therapy for the treatment of lower extremity (peripheral artery disease, or "PAD") has been shown to cost, on average, $6,000 less per patient compared with traditional surgical bypass; endovascular aortic repair (EVAR) has been found to save an average of $9,900 per ruptured aneurysm and $11,600 per unruptured aneurysm compared with traditional open repair.[15] The value of radiology in these instances is derived from the avoidance of invasive surgery, reduced morbidity and mortality, and the associated acute care costs, including potentially costly post-operative care and bed usage.

The Way Forward: A Model for Further Study

Ultimately, this briefing is a primer. Additional research and studies are necessary to fully evaluate the ways in which radiology adds value, in a quantifiable and more qualitative way, across the health system. While radiology is by no means the sole solution to the challenges facing the

13 Sharpe, "Implementation of the First CT Scanner in the Eastern Arctic."

14 Ischemic stroke can be defined as a sudden lack of blood flow to the brain due to a blocked artery.

15 Millennium Research Group, *Interventional Radiology*.

Canadian health care system, it is essential to recognize its value at the hub of patient care through the capacity of medical imaging to improve patient outcomes via increased efficiency and quality of care.

Introduction

Governments, taxpayers, and other health care system stakeholders are concerned with the sustainability of the public health care system, the share of overall costs financed by out-of-pocket spending, and how to rein in costs without compromising the delivery of appropriate, timely, and quality care. The Conference Board of Canada estimates that overall, health care spending has grown at an average pace of 6.1 per cent per year over the last 13 years.[16] Since 2000, excluding inflation and population growth, health care spending has averaged 2.6 per cent per year. In a scenario in which the provincial and territorial governments are able to deliver more efficient health care (constant real per capita spending on health care leading to lower health care expenditures compared with the status quo), it is expected that, in 2034–35, total spending on health care will be at most $345 billion, compared with $397 billion in a status quo scenario.[17]

The top three cost drivers in health care spending are hospitals, drugs, and physicians. Together, they account for 60.7 per cent of all expenditures (hospitals, 29.5 per cent; drugs, 15.7 per cent; physicians, 15.5 per cent).[18] In 2015, public health care spending ate up an estimated average of 38 per cent of the provincial/territorial budgets. This share varies across jurisdictions, from a low of 18 per cent in the Northwest Territories to a high of 46 per cent in Manitoba and Nova Scotia.[19] Reducing health care spending will be particularly difficult, given the rising demand for health care as a result of population aging.

Rather than seeing radiology as only a cost driver, this briefing aims to start an informed discussion on the value of radiology, from the broader Canadian health and health care system perspective, through a review

16 Beckman, *A Difficult Road Ahead*.

17 Ibid.

18 Canadian Institute for Health Information, *National Health Expenditure Trends, 1975 to 2015*.

19 Ibid.

Innovation in radiology has improved access, quality of patient care, and appropriate referrals.

of the published literature and consultations with Canadian radiologists and the addition of case examples. The added economic value of radiologists—not just as image interpreters but as contributors to a more efficient health care system—is discussed.

Expenditures in diagnostic imaging may create savings and benefits in other health care and societal cost centres, resulting in long-term and system-wide returns on investment that are not typically captured in cost-effectiveness analyses. Cost savings can be derived through accurate diagnosis and earlier and more successful treatments. The benefits include reduced morbidity and mortality as well as associated personal costs to patients and their families.

This introductory report begins with a brief historical background of radiology and provides a profile of diagnostic radiologists in Canada. It also discusses some of the challenges regarding the demand and supply for radiology by showing wait times for magnetic resonance imaging (MRI) and computed tomography (CT) scans, strains on medical imaging capacity, and the increasing number of imaging exams in Canada and other similar countries. The report also delves deeper into the radiology value-added services and discusses how value in radiology is dependent on referral practices from both general and specialty medicine and on access to advanced imaging technology. To illustrate the different ways in which radiology provides value to patients, the health care system, and society, the report discusses the established value of radiology in breast cancer screening from both a health and economic lens, and how innovation in radiology—teleradiology, interventional radiology, and clinical decision support systems—has improved access, quality of patient care, and appropriate referrals. Finally, this report concludes by establishing a measurement framework for evaluating the value of radiology that can be applied to future research and policy analysis from the perspective of patients, the health care system, and society as a whole.

What Is Radiology?

An Important Branch of Medicine

Radiology, defined as "a branch of medicine that uses some forms of radiation (such as x-rays) to diagnose and treat diseases,"[20] has long been established as an essential component of the health care system. In January 1896, a Viennese newspaper reported on the discovery of energy x-rays by Wilhelm Conrad Roentgen at a laboratory in Germany.[21] Within a few days of that publication, physicians began speculating that x-rays could show changes in human bodies, such as "bullets, bones and kidney stones."[22] Scientists and the medical profession of that time were excited by the discovery's ability to enhance understanding of the human body, its potential for saving lives, and the value it would have on social progress.

Over time, radiology has evolved significantly. The electric currents in Roentgen's glass tubes have evolved into x-ray machines, CT and computerized axial tomography (CAT) scans, fluoroscopy, MRI, mammography, nuclear medicine (including bone scans and molecular imaging), positron emission tomography (PET), and ultrasound.[23] Although radiology is a large branch of medicine, this report focuses on "diagnostic imaging" and the role of radiologists in the areas of screening, diagnosis, treatment, telemedicine, and clinical decision support.

Radiologists are specialist physicians who complete at least five years of residency training after finishing medical school[24] and are experts in using diagnostic imaging technologies for both the diagnosis and minimally invasive treatment of human diseases. Their role goes beyond solely generating and interpreting diagnostic images.[25] Their mandate

20 Merriam-Webster, "Radiology."

21 Linton, "History of Radiology."

22 Linton, "Moments in Radiology History."

23 CT and PET are referenced in several places in this report. It is important to note that in the context of the Canadian scope of medical practice, these imaging modalities are not fully recognized as part of the radiology discipline. Although CT is part of the discipline, positron admission tomography and hybrid imaging PET/CT are not. Rather PET/CT falls under the specialty of Nuclear Medicine, which is a separate Royal College specialty. Oversight of the procedures and reporting is performed by physicians who hold a Nuclear Medicine certification from the Royal College.

24 Canadian Medical Association, *Diagnostic Radiology Profile*.

25 Dhanoa and others, "The Evolving Role of the Radiologist."

Radiology in Canada is a dynamic specialty.

is to advise other physicians on what diagnostic imaging studies should be done in a clinical workup, interpret these studies to identify or rule out a disease, and advise on any subsequent imaging study where appropriate.[26] Radiology is used to diagnose the sources or causes of ill health, monitor how well an individual may be responding to a treatment, and screen for different conditions such as cancer or heart disease. Innovation in radiology has also expanded its use in therapy through image-guiding biopsy and interventional radiology—where imaging is used to help guide surgical procedures, allowing for smaller incisions, rendering them less invasive and enabling shorter hospital stays or outpatient surgeries. Other innovations in the field of radiology include new ways of leveraging technology to improve access for patients living in remote communities through teleradiology, as well as approaches to improving appropriate referral practices.

A Brief Profile of Radiologists in Canada

Radiology in Canada is a dynamic specialty, and radiologists are continuing to evaluate their practices to keep up with the needs and demands of both the Canadian population and their medical colleagues.

By the Numbers

There are 2,351 diagnostic radiologists currently practising in Canada.[27,28] The majority of diagnostic radiologists are male (69 per cent), and approximately three-quarters of diagnostic radiologists are aged 35 to 64, with only 6 per cent younger than 34 years.[29] Chart 1 illustrates the age and sex breakdown of diagnostic radiologists in Canada. This breakdown includes interventional radiologists, as they are trained in diagnostic radiology but have undergone further training to become experts in image-guided therapies.[30] As visualized, there are substantially more males than females in every age category, but the disparity is less in the younger age

26 Dr. Greg Butler (Assistant Professor, Department of Diagnostic Radiology, Dalhousie University), e-mail interview by Dr. Thy Dinh, August 1, 2016.

27 Canadian Medical Association, *Diagnostic Radiology Profile*.

28 Diagnostic radiologists need to be distinguished from radiation oncologists, who are experts in diagnosing and caring for patients with malignant disease.

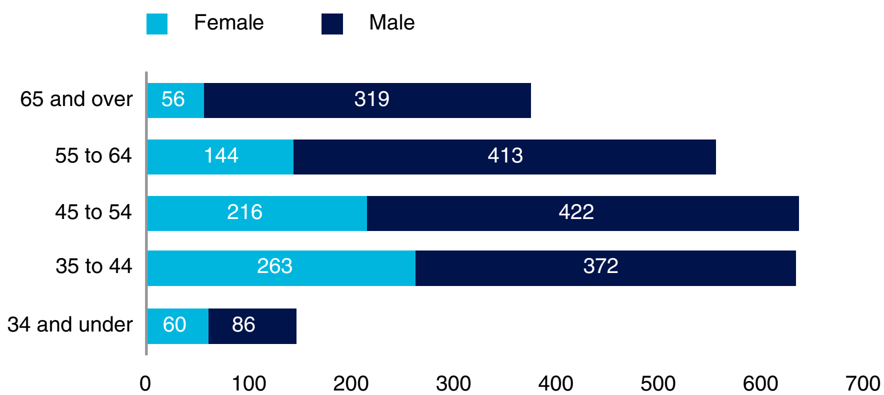
29 Canadian Medical Association, *Diagnostic Radiology Profile*.

30 Millennium Research Group, *Interventional Radiology*.

Chart 1

Number of Diagnostic Radiologists in Canada, by Age and Sex, 2016

(total)



Source: Canadian Medical Association.

categories, which suggests that radiology is becoming a more gender-balanced profession.

Where and How Do Radiologists Work?

Most radiologists in Canada work in community hospitals (34 per cent) or academic health sciences centres (28 per cent), while fewer work in community clinics (13 per cent), research units (11 per cent), non-academic teaching hospitals (8 per cent), community clinics (2 per cent), and nursing homes. Despite these varied settings, more than two-thirds (71 per cent) work in a hospital-based practice organization.[31]

Not including on-call duty, radiologists in Canada work approximately 46 hours per week. This time is predominantly occupied by directly caring for patients, which does not involve a teaching component (25.8 hours per week), with less than 1 hour per week spent on research. Chart 2 shows a breakdown of hours worked per week (excluding on-call) by diagnostic radiologists in Canada. The majority (92 per cent) of radiologists spend up to 120 hours per month on call, and a substantial proportion (13 per cent) spend more than 120—and up to 180—hours per month on call.[32]

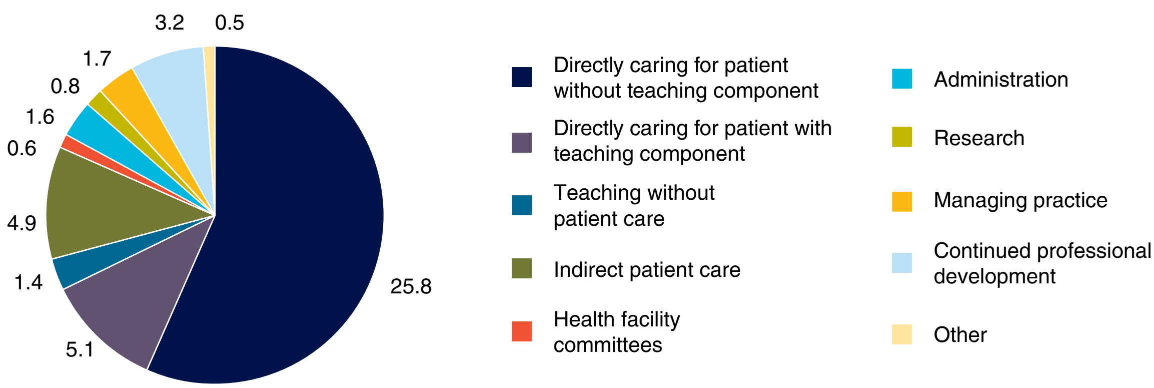
31 Ibid.

32 Ibid.

Chart 2

Hours Worked by Diagnostic Radiologists in Canada, 2014

(hours per week, per cent)*



* Excluding on-call
Source: Canadian Medical Association.

How radiologists are remunerated has important implications for the Canadian health care system. More than three-quarters of Canadian radiologists (82 per cent) are primarily paid through a fee-for-service algorithm, with a minor proportion (2 per cent) primarily paid through salary. In 2013–14, the average gross salary for radiologists (among those earning a minimum of $60,000 per year) was $339,566.[33] As mentioned earlier, rather than seeing remuneration for radiologists solely as a cost driver for the health care system, this report aims to start an informed dialogue on the value of radiology for Canada's health care system for the health of its citizens.

Demand and Supply Challenges

Over the past decade, the field of radiology has seen rapid technological process. Radiologists play an increasingly important role in both the detection of disease and injury and in health management. This demand for medical imaging places a strain on the health care system, as well as on radiologists and technologists alike. A recent study showed that while the number of radiology residency positions has increased in Canada over the past two decades, this demand has not been matched by the

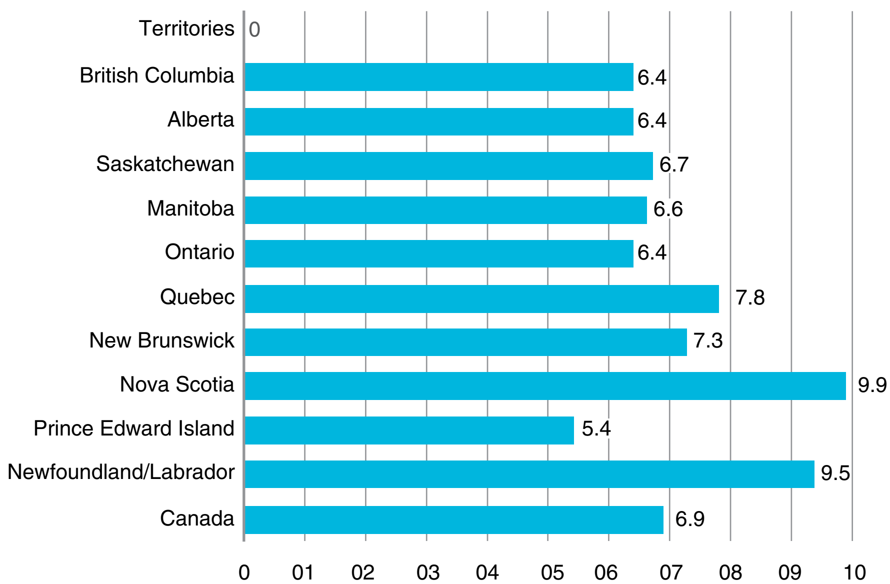
33 Ibid.

number of applicants.[34] There is also a shortage of radiologists in rural and remote areas (e.g., no radiologists work in the territories). In the provinces, the figures range from 5.4 to 9.5 diagnostic radiologists per 100,000 people, and, on average, there are 6.9 diagnostic radiologists per 100,000 people. (See Chart 3).[35]

Chart 3

Number of Diagnostic Radiologists, by Province, 2016

(per 100,000 people)



Source: Canadian Medical Association.

To provide a general understanding of the per capita ratio of radiologists versus other physician specialties, Chart 4 compares the number of diagnostic radiologists with the number of professionals in other specialties in Canada.[36] There are substantially more anesthesiologists and psychiatrists than diagnostic radiologists, and similar numbers of obstetricians/gynecologists and pediatricians in Canada.

34 Kenny and others, "How Competitive Is the Canadian Diagnostic Radiology Residency Match?"

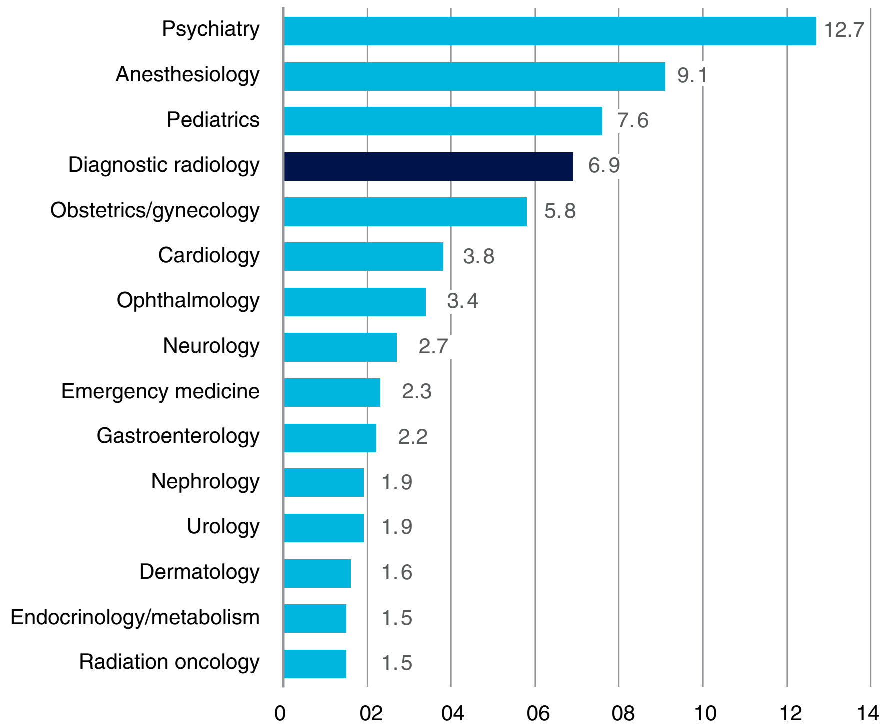
35 Canadian Medical Association, *Diagnostic Radiology Profile*.

36 Canadian Medical Association, *Canadian Specialty Profiles*.

Chart 4

Number of Physicians, by Specialty in Canada, 2016

(per 100,000 people)



Source: Canadian Medical Association.

The demand for health care resources has also been increasing in Canada. Most general practitioners believe that advances in medical imaging have boosted their confidence in treatment for their patients by providing information that would otherwise not be available—potentially allowing for better clinical decision-making and faster time to definitive diagnosis.[37] This demand is reflected in wait times for specialized diagnostic imaging tests. For example, in 2015, Canadian general practitioners reported that two-fifths of their patients often had difficulty receiving specialized diagnostic imaging tests (including CT imaging, mammograms, and MRIs)—substantially higher than the international average of one-fifth.[38] The median wait times for MRI and CT scans

37 Hughes and others, “Perspectives on the Value of Advanced Medical Imaging.”

38 Canadian Institute for Health Information, *How Canada Compares*.

Wait times for a CT or MRI scan continue to be an issue.

have also increased in most reporting provinces. There continues to be variability in the wait times for these two modalities by province.[39] (See Table 1.) The 90th percentile wait time for a CT scan ranged from 28 days in Manitoba to 74 days in Nova Scotia; for an MRI scan, the 90th percentile wait time ranged from 91 days in Ontario to 202 days in Nova Scotia. According to the Canadian Institute for Health Information, benchmarks have not been established for diagnostic imaging because there is not enough clinical evidence, and these tests can be used for a variety of indications.[40] However, the Canadian Association of Radiologists (CAR) recommends maximum MRI and CT wait time targets of 24 hours for emergency/life-threatening conditions, 7 days for urgent conditions, 30 days for semi-urgent conditions, and 60 days for non-urgent conditions.[41] Although the available data do not distinguish between type of priority, wait times for a CT or MRI scan continue to be an issue.

Even if everyone waiting for CT and MRI scans were suffering from non-urgent conditions, there are patients in many provinces for whom the CAR benchmark wait times are not being met. (See Table 1.) In those provinces for which we had data on wait times, wait times in Prince Edward Island and Nova Scotia appeared to exceed the 60-day maximum benchmark for CT scans in 2015. For MRI scans, patients in Prince Edward Island, Nova Scotia, Ontario, Manitoba, Saskatchewan, and Alberta were waiting between 1.5 and 3.4 times longer (or even more) than the 60-day maximum benchmark wait time in 2015. Since neither the median or average wait-times for CT or MRI scans nor the number of patients waiting more than the CAR benchmark wait times were available, we were not able to determine the number or the share of patients in each province who were unable to access these scans in a timely manner.

39 Canadian Institute for Health Information, *Wait Times for Priority Procedures*.

40 Ibid.

41 Canadian Association of Radiologists, *National Maximum Wait Time Access Targets*.

Table 1

Wait Times for CT and MRI Scans, 50th and 90th Percentiles, by Province,* April to September 2015

(number of days)

	CT		MRI	
Province	**50th percentile**	**90th percentile**	**50th percentile**	**90th percentile**
Prince Edward Island	30	61	56	167
Nova Scotia	21	74	55	202
Ontario	7	37	36	91
Manitoba	18	28	99	189
Saskatchewan	20	50	30	149
Alberta	17	56	90	172

* Data missing for Newfoundland and Labrador, New Brunswick, Quebec, and British Columbia.
Source: Canadian Institute for Health Information, 2016.

In addition to the ongoing wait time issues in Canada, there are major strains on medical imaging capacity. For example, Canada is in the lower 50 per cent of CT and MRI units per million people, compared with other reporting Organisation for Economic Co-operation and Development (OECD) countries.[42] As of 2015, Canada had 15.01 CT units, 9.48 MRI units, and 1.31 PET or PET-CT units per million people. This translates to a total of 538 CT units, 340 MRI units, and 47 PET or hybrid PET-CT units for all of Canada.[43]

There has also been a steady increase in the number of CT, MRI, and PET exams per 1,000 people in Canada each year, and in other similar countries. (See charts 5, 6, and 7.) Among these OECD countries, Canada has more exams per 1,000 people than Australia but fewer than France and the United States. The charts also show that there are substantially more exams per 1,000 people in the U.S., and that this figure has remained relatively stable over the past five years.

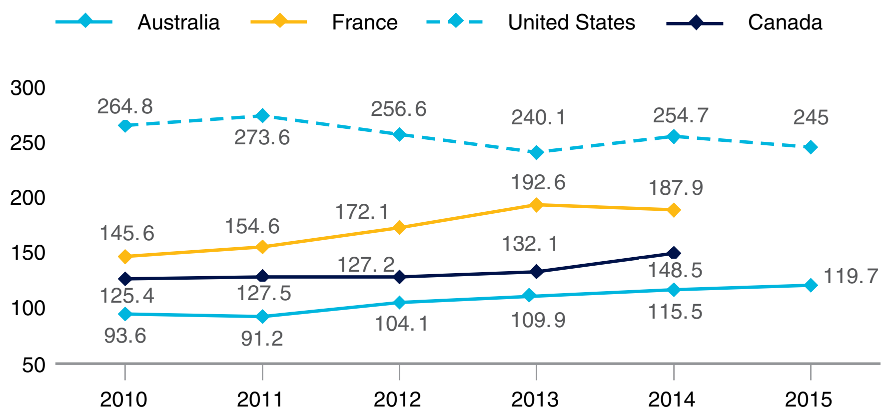
42 Canadian Agency for Drugs and Technologies in Health, *The Canadian Medical Imaging Inventory*.

43 Ibid.

Chart 5

Number of CT Exams, by Country and Year

(per 1,000 people)

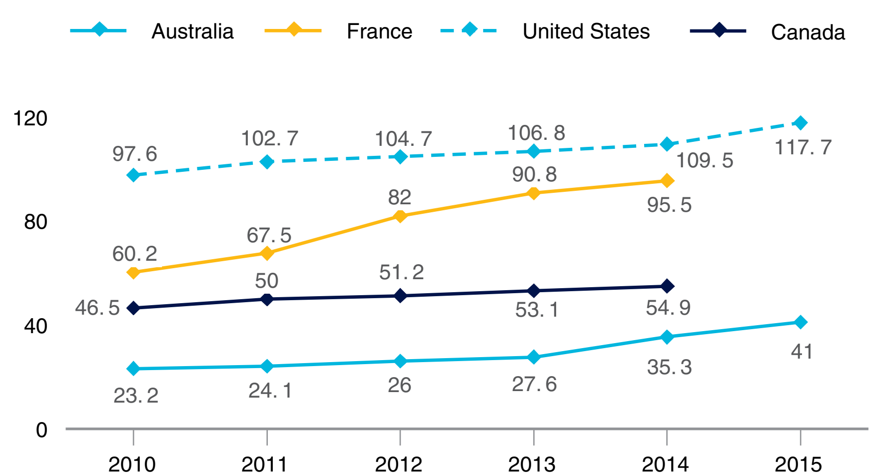


Note: No 2015 data available for Canada and France.
Source: Organisation for Economic Co-operation and Development.

Chart 6

Number of MRI Exams, by Country and Year

(per 1,000 people)

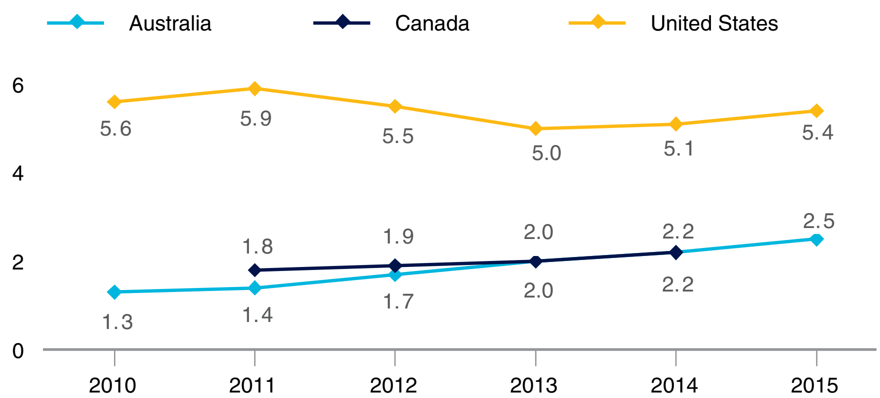


Note: No 2015 data available for Canada and France.
Source: Organisation for Economic Co-operation and Development.

Chart 7

Number of PET Exams, by Country and Year

(per 1,000 people)



Note: No 2015 data available for Canada and France.
Source: Organisation for Economic Co-operation and Development.

Based on the number of radiologists in Canada in 2016 (n = 2,351)[44] and the number of exams in 2014 (5,278,341 CT exams, 1,952,060 MRI exams, and 76,824 PET-CT exams),[45] the average diagnostic radiologist in Canada performs 2,245 CT exams, 830 MRI exams, and 33 PET-CT exams on a yearly basis. Clearly, overburdened equipment is only one side of the wait times story in Canada. Viewed from the perspective of patients and the public, long wait times are anecdotally attributed to insufficient operating hours, but the data show otherwise (not presented).[46] Canadian radiologists are performing more imaging exams than ever before.

Along with the increasing demand for radiology, there will also be growing workforce demands in several subspecialties: mammography, interventional radiology, cardiac imaging, neuroradiology, and pediatric radiology.[47] Potential areas where the demand may not meet the supply (i.e., where there may be radiology shortages) include mammography,

44 Canadian Medical Association, *Diagnostic Radiology Profile*.
45 Organisation for Economic Co-operation and Development, *Health Care Utilisation*.
46 Canadian Agency for Drugs and Technologies in Health, *The Canadian Medical Imaging Inventory*.
47 Ng and others, "National Survey to Identify Subspecialties."

cardiac imaging, and pediatric radiology.[48,49,50] Structured career counselling and mentoring in training programs would give students insight into their role in reducing underserviced subspecialty areas[51] to ensure greater value to population health and the health care system. For example, research shows that only 15 per cent of radiology residents received career counselling during their training, and of this 15 per cent, only half thought it was adequate;[52] the majority of radiology residents received their fellowship information from colleagues (68 per cent), staff radiologists (61 per cent), and university websites (58 per cent).[53]

Seeking Value in the Canadian Health Care System

Canadians are concerned about the sustainability of the public health care system, the share of overall costs financed by out-of-pocket spending, and how to rein in costs without compromising the delivery of appropriate, timely, and quality care. In 2015, total health expenditure in Canada was estimated at $219.1 billion, or $6,105 per person, representing 10.9 per cent of Canada's gross domestic product (GDP).[54] In terms of private sector expenditures, Canadians spent $56.9 billion in 2010 (mainly through private insurance and out of pocket), representing almost 30 per cent of total health care costs.[55] With such a hefty proportion of money being spent in one area, governments and health care administrators are forced to question how to derive better value from their health care spending (see "The Added Value of Radiologists") and how better care can be provided and received—now and in the future—for less (or the same amount of) money.

48 Ibid.
49 Maynard, "Academic Job Market."
50 Ryan and others, "Trends in Radiology Fellowship Training."
51 Ng and others, "National Survey to Identify Subspecialties."
52 Ibid.
53 Mok and others, "Factors Influencing Radiology Residents' Fellowship Training."
54 Canadian Institute for Health Information, *National Health Expenditure Trends*.
55 Sanmartin and others, "Trends in Out-of-Pocket Health Care Expenditures in Canada."

The Added Value of Radiologists—More Than Just Image Interpreters

Radiology's value-added services can be divided into five categories:[56]

Patient safety: There are potential risks from radiation exposure. Formal training in radiation biology and safety is mandatory for radiologists and nuclear medicine physicians.

Exam quality: Radiologists receive proper training in the technical aspects of imaging equipment and ensure that the most appropriate tests are conducted. Other important image-quality services that radiologists provide include optimizing imaging protocols, supervising and educating technologists, and overseeing the process of accreditation for technologists, equipment, and facilities. Radiologists are also instrumental in developing, supporting, and supervising continuous quality improvement programs in imaging departments.[57]

Interpretation quality: Radiologists can interpret images of any part of the human body, unlike other specialists who may focus on only one organ. Arriving at a diagnosis might involve integrating images from more than one modality, such as MRI, CT, or ultrasound.

Patient/referrer service: Radiologists often give clinicians second interpretations on cases and need to meet an increasing number of turnaround benchmarks and targets.

Cost containment: Adding value involves improving patient safety and treatment quality at lower cost.[58] Radiologists are able to maximize patient throughput across the health care system, which helps to keep unit costs down. Evidence shows that radiologists who participate in radiology benefits management programs, by consulting with referring physicians, can help improve appropriate imaging by at least 20 per cent.[59]

Radiologists' involvement in patient care depends on referral practices from both general and specialty medicine (e.g., cardiology, orthopedics),

56 Proval, "Value-Added Radiology, Defined."
57 Knechtges and Carlos, "The Evolving Role of Radiologists Within the Health Care System."
58 Proval, "Value-Added Radiology, Defined."
59 Yee, "Radiologists' Expertise Cuts Inappropriate Imaging."

A sustainable health care system requires the effective and efficient management of its human resources.

as well as on their access to advanced imaging technology. Value in radiology is achieved when:

- appropriate referrals to radiological tests are made by general and specialty medicine, whereby the benefits of testing far exceed potential harms (relating to both individual health and system efficiency);
- high-quality imaging technology is used to ensure the highest level of accuracy in identifying the presence of abnormalities (sensitivity)—adding value that exceeds any additional cost;
- radiologists and medical radiation technologists and sonographers acquire the necessary competencies through appropriate and high-quality education and training;
- radiologists effectively work with the interdisciplinary health team to ensure timely, appropriate, and well-coordinated care for the patient.

A Framework for Valuing Radiology From a Macroeconomic Perspective

A sustainable health care system requires the effective and efficient management of its human resources, which include radiologists. Exhibit 1 presents an overview of a measurement framework that provides guidance on evaluating the value of radiology. This framework can be applied to future research and policy analysis from the perspective of patients, clinicians, and the health care system as a whole. Articulating the value of radiology from different perspectives requires establishing the appropriate metrics. These metrics represent what is most important to the target audience, whether that be the patient, government, health care administrator, or society. It is also important to define ways in which these metrics can be captured. Research potential exists to value the impact of radiology differently—in ways that resonate with a broader audience, so that radiology is no longer seen as a cost but as a value-driver.

To use the framework, it is important to identify a specific service, intervention, or program to which the exercise of establishing “value” can be applied. The perspective(s) from which the valuing exercise is to

be conducted should then be established, followed by the collection of information or data on the different metrics for each perspective.

- From the patient perspective, the value of radiology can be articulated through improvements in life expectancy and quality of life, reductions in stress or anxiety from test result wait times, and reduced out-of-pocket costs (e.g., costs related to caregiving or travel, reduced caregiver burden due to improved patient health status, reduced absenteeism).
- From the perspective of other health care providers in the system (including other physician specialists, nurses, patient navigators), radiology can provide value through improved quality of care for patients, as well as better coordination, continuity of care, and treatment decisions, which ultimately improve the patient experience throughout the continuum of care.
- From the perspective of the broader health care system, the value of radiology could be measured as contributions to gains in system efficiency through rapid and precise diagnoses, early treatment initiation, reduced wait times, and quality of care improvements. Greater system effectiveness can be measured by patient health outcome improvements, increases in appropriate testing, and reductions in downstream costs (such as eliminating travel costs with teleradiology and reducing treatment costs through early-stage diagnosis and treatment with cancer screening).
- Finally, the value of radiology from a societal perspective takes into account all value from all perspectives. In societal value, The Conference Board of Canada typically includes the impact on the economy (such as the improvement in labour force participation and productivity due to improvements in health) and efficiency gains in the health care system, which can free up resources for other social programs. Some studies examine the value of radiology from the perspective of the local economy, such as the gains from teleradiology and the value of patients staying in their communities for treatment. The less tangible values of health, wellness, happiness, and life in general also have an impact.

A comprehensive value assessment would require many perspectives and metrics that would extend beyond those that we have identified in our own framework, and any data or information synthesized should be relevant to one common service, intervention, or program with the

same time horizons. For example, when compiling data on the value of mammography screening based on existing studies, it is important to use studies that have captured the value for the same type of mammography (technology and screening frequency) for similar populations over similar time periods (e.g., digital mammography for women aged 50 to 74 in developed countries between 1990 and 2010).

Establishing the value of the whole of radiology is next to impossible; therefore, it is important to segment radiology into manageable pieces when establishing and articulating value from different perspectives using different metrics. Such an exercise requires valid and reliable data; therefore, a quality assessment of the evidence is necessary when conducting this type of analysis.

Exhibit 1

Perspectives and Metrics for Valuing Radiology in Canada

Patient
- Extended life
- Improved quality of life
- Reduced anxiety
- Reduced out-of-pocket costs
- Reduced caregiver burden
- Reduced lost work days (absenteeism)

Other Health Care Providers
- Improved quality of care provided
- Improved continuity of care provided
- Better treatment decisions
- Better patient experience and outcomes

Value of Radiology

Health Care System
- Rapid and precise diagnoses and early initiation of treatment
- Reduced wait times
- Improved quality of care
- Improved patient outcomes
- Increase in appropriate testing
- Reduced downstream treatment costs

Society
- Improved productivity
- Population living longer, healthier, happier lives
- More efficient health care system allowing for investments in other social programs

Source: The Conference Board of Canada.

The following sections showcase four examples of how radiologists provide value to patients, the health care system, and society. These include breast cancer screening and diagnosis, teleradiology, interventional radiology, and clinical decision support systems.

Breast Cancer Screening and Diagnosis—Improving Population Health and Wellness, and Decreasing Downstream Costs

Screening for cancer is one of the most common uses of medical imaging today. In general, screening involves identifying a previously unrecognized disease or a disease precursor using tests that can be conducted quickly and economically on the targeted population.[60] More specifically, screening is "a preliminary to more specific diagnostic tests."[61] Screening in Canada is widely used for breast cancer. According to the most recent cancer statistics, approximately 25,000 Canadian women had a diagnosis of breast cancer in 2015, representing 26 per cent of all incident cancer cases in women that year.[62] Among this group, an estimated 5,000 women will die from breast cancer, representing 14 per cent of all cancer-related mortality in women in the same year.[63] The increasing prevalence of breast cancer is mostly attributable to population aging, which means that the number of total cases of disease is expected to rise with the aging of the baby boomer generation.[64]

Over time, breast cancer survivability has increased with the advancement of screening and treatment, as well as greater awareness in the general population. Although survivability is high, breast cancer is a disease that can shorten an individual's life expectancy or life potential because the median age of diagnosis is relatively young, with many women being diagnosed in their 50s, and some women being diagnosed even younger.[65]

60 Last, *A Dictionary of Public Health*.

61 Ibid.

62 Canadian Cancer Society, *Breast Cancer Statistics*.

63 Ibid.

64 Ellison and Wilkens, "Canadian Trends in Cancer Prevalence."

65 Oeffinger and others, "Breast Cancer Screening for Women at Average Risk."

Breast cancer screening reduces mortality via early detection.

Early breast cancer detection through mammography (breast x-ray) is used to identify tumours and to increase the chances of reducing premature mortality through early treatment. Research shows that women diagnosed with early-stage disease are more likely to have been screened than women who are diagnosed with late-stage disease.[66] In Canada, women can seek screening either through opportunistic screening (via referral from their family doctor) or through organized programs.[67] Organized breast cancer screening programs have been implemented in most provinces and territories since 1988. There are three phases to an organized program:

1. an invitation to screening for a target population (usually identified by age);
2. the provision of the screening examination;
3. further investigation if an abnormality is detected.

Although the age of the targeted population in organized screening programs varies slightly across regions, the Canadian Association of Radiologists supports breast cancer screening for women aged 40 to 49 on a yearly basis, as decided in concert with her caregivers, and yearly or biennial screening for women aged 50 to 74.[68]

The health and economic value of cancer screening in particular can be explained by stage-shifting. Breast cancer screening reduces mortality via early detection, when cases of cancer are caught at an earlier stage of disease compared with cases when no screening was done. Being diagnosed at an earlier stage of disease allows women to receive less invasive and less costly treatment, which may reduce patient anxiety and improves prognosis. For example, a study from 1997 showed that the cumulative costs of treating late-stage breast cancer were $50,000 to $60,000 per patient, compared with $18,000 to $25,000 for treating early-stage breast cancer.[69]

66 Allgood and others, “Explaining the Difference in Prognosis Between Screen-Detected and Symptomatic Breast Cancers.”

67 Canadian Cancer Society, *Screening for Breast Cancer*.

68 Canadian Association of Radiologists, *The Canadian Association of Radiologists Supports Breast Cancer Screening*.

69 Legorreta and others, “Cost of Breast Cancer Treatment.”

Both the benefits and the costs of screening increase with the number of screens per woman. Decisions surrounding the cost-effectiveness of these screening strategies depend on the willingness-to-pay and the proportion of recall for more examinations after a positive screening test result. Policy implications regarding whether to screen, the target group, modalities, and frequency of screening are best made when the health outcomes, potential harm, and economic outcomes are taken into account. One study that used a validated breast cancer simulation model showed that all active screening strategies were more effective than not having any screening strategies. Specifically, the cost per quality-adjusted life year (QALY) for active screening strategies compared with no screening at all was almost half of the willingness-to-pay amount for each QALY.[70]

In terms of economic burden, the Public Health Agency of Canada estimated that in 2008, the direct and indirect costs of breast cancer were almost $460 million.[71] This translates to approximately $512 million in current dollars. Of the total costs, 40 per cent was for drugs, 25 per cent was for hospitals, 3 per cent was for physician care, and 3 per cent was for productivity losses due to premature mortality. In the absence of screening, the expected costs would be much higher, particularly in terms of costs related to treatment and productivity losses, as the economic burden of disease is greater in later-stage disease. A Canadian study demonstrated that the lifetime cost burden of breast cancer was higher when the disease was diagnosed at a later stage, which is more likely in the absence of screening.[72] These costs include treatment, follow-up care, metastases diagnosis, continuing care, and end-of-life care. Inflating the costs to 2016 would translate to treatment costs ranging from $34,214 at stage I to $53,429 at stage IV—an average increase in cost by about 16 per cent from one stage to the next. (See Chart 8.)

70 Mittmann and others, “Total Cost-Effectiveness of Mammography Screening Strategies.”

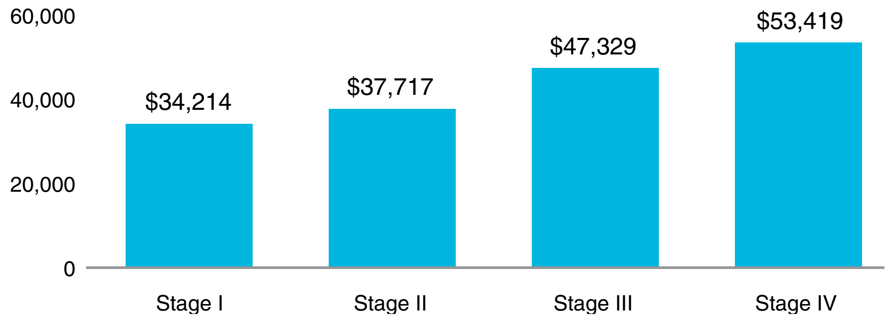
71 Public Health Agency of Canada, *Economic Burden of Illness in Canada*.

72 Will and others, “Estimates of the Lifetime Costs of Breast Cancer Treatment in Canada.”

Chart 8

Cumulative Cost of Breast Cancer, by Stage at Diagnosis in Canada, 2016

(C$)



Source: Will and others.

Innovation in cancer screening can be seen in a number of different and profound ways. In the last decade or so, there has been a complete shift from the use of film to digital mammography, which has increased the accuracy and efficiency of testing and improved women's confidence in a more accurate and timely result. Furthermore, image-guided procedures, usually with ultrasound and CT, are now being used in biopsies (specifically for lung, thyroid, and liver cancer) when an abnormality is detected. Image-guided biopsies benefit patients and the health care system because they require such a small incision—there is no need for stitches, there is no scarring, and the procedure is therefore safe and accurate.[73] Additionally, the recovery time is short, and image-guided biopsies are often performed as outpatient procedures.[74]

The Ottawa Hospital Breast Health Centre

The Ottawa Hospital Breast Health Centre's regional program provides its patients with high-quality care for breast imaging and diagnostics through its services and coordinated diagnostic follow-up. The program triages all

73 Newell and Mahoney, "Ultrasound-Guided Percutaneous Breast Biopsy."

74 RadiologyInfo.org, *Stereotactic Breast Biopsy.*

symptomatic patients[75] to ensure that no breast cancer is present. The Centre's interprofessional team—radiologists, breast imaging technologists, surgeons, nurses, and social workers (among others)—provides expertise and efficiency in breast screening, coordinates the diagnostic workup for breast abnormalities, and provides risk assessment and surgical planning, as well as psychosocial support. Within the past year alone, this program has done more than 33,000 diagnostic breast examinations, 2,200 breast biopsies, and 860 breast cancer diagnoses. Although the number of new consultations for breast cancer and other conditions seen at the Centre continues to increase, data show that the wait times from referral to consultation have been reduced by recruiting additional surgeons.

Improved breast screening and earlier detection of cancer are crucial, as more than a third of breast cancers are not palpable. Dr. Jean Seely and Dr. Carolyn Nessim have led a team of radiologists and other health care professionals in developing protocols and training for a new technique to localize breast cancers for surgery, called "radioactive seed localization." Essentially, the radiologist inserts a tiny seed embedded with a small dose of radioactivity into the breast cancer, so the surgeon can more easily identify the tumour at surgery. Benefits for the patient include reduced anxiety and improved scheduling of surgery, since the wire does not need to be inserted on the same day as the surgery.[76]

Teleradiology—Reaching Remote and Underserved Communities

Teleradiology is the ability to transmit medical images (such as x-rays, CTs, and ultrasounds) over a distance, so they can be reviewed and interpreted by a radiologist at another site—whether it is an office next to the CT scanner, across the country, or on another continent. Essentially, it allows radiologists to provide expert consultation on cases without being physically present with the patient. This is particularly important for remote and underserved communities. Moreover, as radiology is fundamental to modern-day health care, there is a demonstrated need for real-time interpretation of medical images around the clock. The use

75 Triaging prioritizes patients' treatment based on the severity of their conditions and/or when limited medical resources must be allocated.

76 Seely and others, *Women's Breast Health Centre*.

of "virtual" radiology has allowed more radiologists to assist with such coverage, empowering radiologists to be present wherever and whenever they are needed. Teleradiology plays an important role in radiologist coverage in a number of hospitals in Canada.

Currently, there are a range of telehealth or telemedicine programs across Canada's provinces and territories, many of which include radiology. Table 2 presents a high-level overview of radiology clinical services by province/territory based on survey data presented in the 2015 Canadian Telehealth Report.[77] These services may be provided by another jurisdiction, and the authors note that additional services may be available that are not included in their report. For example, we are aware of teleradiology programs in the territories, which we discuss later in this section.

Table 2
Clinical Services Available in Provincial and Territorial Telehealth Programs

Clinical service	N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	N.W.T.	Y.T.
Radiology—Diagnostic	●	○	●	○	●	○	●	●	○	●	○	○
Radiology—Oncology	○	○	○	● (yellow)	●	●	●	●	○	●	○	○

● The service is offered by a telehealth network/program for the clinical care of patients.
● (yellow) The service will be added in the next reporting period.
○ The service is not offered.
Source: Canada's Health Informatics Association.

The goal of teleradiology is to improve the timeliness of quality diagnostic care for patients through expedited diagnosis and treatment, particularly among patient populations that live in remote areas where radiologists do not practice or are not physically present on a daily basis. Teleradiology also reduces the travel costs required when patients must go to another centre to receive diagnostic imaging. A systematic review showed that teleradiology led to significantly higher diagnostic accuracy for patients seeking emergency neurosurgical diagnoses than that achieved via telephone-only consultations.[78] Other international studies have shown that the accuracy of diagnosis using an iPhone/iPad-based remote

77 Canada's Health Informatics Association, *2015 Canadian Telehealth Report*.
78 Williams, *A Systematic Review of Teleradiology for Remote Neurosurgical Evaluation of Patients*.

In addition to improving access, teleradiology in rural communities can also impact local economies.

control system as a real-time CT tool,[79,80] or other digital teleradiology technologies,[81,82] is high and does not significantly differ from using an on-site display. The introduction of teleradiology in a remote primary care practice also improved accuracy of fracture diagnoses and reduced the number of unnecessary trips to the hospital.[83] Although its impact on long-term population health is more difficult to ascertain (as it is confounded by the lasting social determinants and drivers of health, such as income, education, employment, social status, and physical environments), the impact of teleradiology on patients is qualitatively demonstrated through the implementation of the first CT scanner in a largely remote and underserved region—Nunavut (see "Nunavut's First CT Scanner").

In terms of economic impact, research shows that savings linked with reduced patient transfer rates depend on the type of transportation (ground or air) and the operational costs of teleradiology.[84] Currently, substantive data are not publicly available to evaluate the true cost savings of teleradiology in Canada. However, as more evaluation and new data emerge, we suspect that the health and economic benefits will be better articulated in the near future.

Some U.S. research shows that in addition to improving access, teleradiology in rural communities can also impact local economies.[85] These impacts include reductions in travel, transportation costs, and missed work, and increases in local lab and pharmacy work (since patients do not have to leave their local area to receive a diagnosis, follow-up can be done remotely or in a local pharmacy or lab). Hospitals also save with outsourcing telemedicine procedures as it is less costly than paying a full-time, on-site specialist for the same work.[86] One study estimated that teleradiology services could save a rural hospital US$61,600 to US$101,600 annually while also contributing an average of

79 Kim and others, "A Feasibility Study of Real-Time Remote CT Reading."
80 Salati and others, "Out of Hours Emergency Computed Tomography Brain Studies."
81 Salazar and others, "Evaluation of Low-Cost Telemammography Screening Configurations."
82 Schwartz and others, "The Accuracy of Mobile Teleradiology in the Evaluation of Chest X-rays."
83 Jacobs and others, "Fracture Diagnostics, Unnecessary Travel and Treatment."
84 Williams, *A Systematic Review of Teleradiology for Remote Neurosurgical Evaluation of Patients*.
85 Whitacre, "Estimating the Economic Impact of Telemedicine in a Rural Community."
86 Ibid.

US$522,000 to the local economy per year. These estimates cannot be directly scaled to the Canadian context due to significant differences in costs and context between the U.S. and Canada when it comes to health care systems. However, similar cost savings could be experienced by Canadian rural hospitals.

Technical and operational limitations, as well as risks, need to be better understood before the opportunities associated with teleradiology can be effectively integrated more broadly into the health care system and radiology practice.[87] Hospitals should run cost-analysis scenarios to ensure that they are able to not only purchase but also maintain the equipment required for teleradiology, and to assess the offsetting in costs and health outcome impacts.

Nunavut's First CT Scanner

The first CT scanner was installed in Nunavut in February 2014 with the goal of improving report quality and timeliness, thereby translating into efficient access. The scanner was installed in the Qikiqtani General Hospital in Iqaluit, some 2,000 kilometres from Ottawa. It is the only hospital in the territory and is responsible for covering the health needs of an area covering 1 million square kilometres. The proportion of the population aged 12 and older that smoke is exceptionally higher in the Baffin region of Nunavut than in the rest of Canada (62 per cent versus 18 per cent),[88] which could explain why lung and colorectal cancers are the leading types of cancer in the region and why rates of other infections like tuberculosis are also extremely high in Nunavut compared with the rest of Canada.[89] These types of illnesses, as well as other injuries, can be diagnosed at an earlier stage through X-ray or CT scans.[90]

No radiologists work permanently in Nunavut. Prior to implementation of the CT scanner, patients had to be flown south for their CT examinations, at a significant cost to the health care system. For example, in 2010, over 400 patients were transported to Ottawa. The average duration of the stay for these patients was 13 days, which translated into $2,600 per patient to cover accommodation

87 Thrall, "Teleradiology Part II. Limitations, Risks, and Opportunities."

88 Statistics Canada, *Smokers, by Sex, Provinces, and Territories*.

89 Sharpe, "Implementation of the First CT Scanner in the Eastern Arctic."

90 Zurawska and others, "What to Do When a Smoker's CT Scan Is 'Normal'?"

and other expenses. For emergency cases, which may include physicians and nurses as escorts, the average round-trip cost for the flight and crew was approximately $25,000. Additionally, wait times were long (3 to 4 months) and extended stays in Ottawa caused anxiety for some patients.[91]

Despite the paucity of quantitative evaluation data currently available, the Conference Board was able to gather qualitative information through expert consultations. In addition to more accurate diagnoses, CT services also reduced wait times overall, and reduced travel for many patients who no longer required being flown away from home to receive the same service. Instead of having to wait several weeks to receive a CT scan for a trauma, lung disease, abdominal pain, or other condition, patient wait times were reduced to approximately 1 week. Benefits to the patient may also translate into cost savings for the health care system. Physicians benefit from increased confidence in the diagnosis, improved communications with specialists, and a shorter turnaround time for radiology reports (1 hour versus 3 to 4 days).[92] In addition, radiologists in Ottawa find it rewarding to provide high-quality service to a population that is both underserved and has a high burden of illness.[93]

Overall, the acquisition of the CT scanner and the enhanced use of teleradiology has been "a game changer" in Nunavut. Before its implementation, patients and doctors had limited access to real-time radiology expertise. Not only are high-quality images being transmitted to the radiologist more quickly, but it is now possible to access an expert opinion within a short time frame of 60 to 90 minutes for emergency cases. The goal is to partner all 25 clinical sites in Nunavut with The Ottawa Hospital so that all images are centralized and transmitted directly to the hospital. For now, all radiology requirements for the entire territory of Nunavut are being filled at the Qikiqtani General Hospital.

Interventional Radiology—Enhancing Effectiveness and Efficiency

Most Canadians are not aware that radiology has, and continues to be, used in the treatment of a variety of conditions. A subset of radiologists

91 Sharpe, "Implementation of the First CT Scanner in the Eastern Arctic."

92 Ibid.

93 Dr. William Macdonald (Territorial Chief of Staff, Department of Health and Social Services, Government of Nunavut), telephone interview by Abhi Bhandari, August 2, 2016.

who practise interventional radiology (IR) provide minimally invasive treatment using real-time diagnostic imaging technologies. Interventional radiologists use imaging techniques to guide small catheters (tubes) through the body to treat diseases. Disease of the abdomen, central nervous system, chest, heart, and musculoskeletal system can be treated using IR (see "Using IR to Treat Acute Ischemic Stroke").[94]

The Millennium Research Group (MRG) conducted research on the landscape and cost-effectiveness of IR across several countries, including Canada.[95] MRG assessed the value of several IR therapies for lower extremity peripheral arterial disease, endovascular aortic repair, interventional oncology, vascular access, drainage, gastrostomy, and other therapy areas. The findings support IR's value to the health of Canadians and the health care system as a whole, as this type of treatment resulted in reduced length of patient hospital stays, complications, and costs, compared with traditional surgical therapies.[96] The key cost-effectiveness findings are summarized in Table 3.

Table 3

Key Effectiveness and Cost-Effectiveness Findings, by IR Therapy Area

Lower extremity peripheral arterial disease (PAD)	• Endovascular therapy for the treatment of lower extremity PAD was an average of $6,000 less expensive per patient compared with surgical bypass
Endovascular aortic repair (EVAR)	• EVAR saves an average of $9,900 per ruptured aneurysm and $11,600 per unruptured aneurysm compared to open repair
Interventional oncology	• Ablation for the treatment of hepatocellular carcinoma (HCC) saves on average $15,000 per patient compared with surgical resection
Vascular access	• Image guidance contributes to documented higher technical success rates, shorter procedural times, and lower incidence of procedural-related complications and re-intervention rates compared to surgical insertion techniques
Drainage	• Success rates of percutaneous drainage tend to be higher than those of endoscopic drainage, and the overall costs are lower
Gastrostomy	• Percutaneous radiologic gastrostomy (PRG) is less expensive than percutaneous endoscopic gastrostomy (PEG), with PEGs costing 44 per cent more than PRGs
Uterine fibroid embolization (UFE)	• UFE is minimally invasive with fewer major complications, faster recovery, and improved patient satisfaction compared with surgical interventions, and is associated with lower hospital cost and shorter hospital stay compared with myomectomy and hysterectomy
Thoracic endovascular aortic repair (TEVAR)	• TEVAR is a safe procedure that reduces perioperative risks of thoracic intervention compared with surgical repair, and results in shorter patient recovery times

Source: Millennium Research Group.

94 Cardiovascular and Interventional Radiological Society of Europe, *Patients: Interventional Radiology*.

95 Millennium Research Group, *Interventional Radiology*.

96 Ibid.

The adoption of IR has been slower than in other industrialized nations.

Although IR has been used in Canada since the 1960s, its overall adoption in Canada has been considerably slower than in other industrialized nations. For example, only 2 per cent of endovascular peripheral arterial disease (PAD) procedures are performed relative to the prevalence of endovascular PAD in Canada's population, compared with more than 12 per cent in the U.S. and 10 per cent for all G7 countries.[97] Factors that have led to this lag in Canada include reduced health care funding in Canada for IR procedures, human resource and time limitations, and lower awareness of IR. Recommendations to bring Canada in line with the comparator countries include improving budget allocations, and increasing resources and awareness to improve health care quality and access for Canadians.[98] Other recommendations are provided in the Next Steps section.

Using IR to Treat Acute Ischemic Stroke

Treating acute ischemic stroke is simple in principle; it involves restoring blood flow quickly and safely[99]—and IR plays a role to ensure this is done efficiently. Indeed, time is a significant predictor of outcome in patients with ischemic stroke.[100] A recent study shows that blood flow was restored faster in patients who underwent treatment with a stent retriever, which led to improved functional outcomes (compared with patients who were treated only with a clot-dissolving drug known as a tissue plasminogen activator). Detailed focus on the workflow, frequent feedback, and aggressive time goals likely played an important role in maintaining efficiency.[101] The efficacy of endovascular thrombectomy (using IR) over standard care in patients with acute ischemic stroke caused by a large vessel blockage has been established,[102] regardless of patient characteristics or geographical location.[103] Another large study also showed that using a generic stent retriever for large vessel ischemic stroke was safe, highly effective, and reduced disability.[104]

97 Ibid.
98 Ibid.
99 Muir and White, "HERMES: Messenger for Stroke Interventional Treatment."
100 Menon and others, "Analysis of Workflow and Time to Treatment on Thrombectomy Outcome."
101 Goyal and others, "Analysis of Workflow and Time to Treatment and the Effects on Outcome."
102 Zerna and others, "Imaging, Intervention, and Workflow in Acute Ischemic Stroke."
103 Goyal and others, "Endovascular Thrombectomy After Large-Vessel Ischaemic Stroke."
104 Campbell and others, "Safety and Efficacy of Solitaire Stent Thrombectomy."

To implement trial results into routine clinical practice, some barriers need to be addressed so that all patients can access timely and high-quality treatment. These barriers include geographic access to angiography (blood vessel imaging) centres, notifications to patients prior to their appointment, and ensuring "parallel processing" through a multidisciplinary team approach.[105] Goyal and others summarize key challenges as the 5Ts: transport, teamwork, technology, training, and technique. Adequate interaction and cooperation among the interdisciplinary team is required "to get the correct patient to the correct hospital to be treated by the correct team in the most efficient fashion."[106] The success of the IR treatment will also depend on a combination of appropriate technology and the skill of the radiologist, which needs to be developed through training.[107] Once these challenges are addressed, IR holds great promise in enhancing treatment effectiveness and efficiency.

Clinical Decision Support—Innovative Technology to Ensure Appropriate Testing

As previously mentioned, there is concern among health system administrators, payers, and radiologists themselves regarding the appropriateness of referrals to radiology in Canada. Appropriate imaging not only enhances the value of radiology but also reduces wait times and improves health system efficiency. It can also decrease harm to patients. For example, by reducing the risk of incidental findings that lead to investigation of conditions which are revealed to be benign, patients are spared the unnecessary exposure to radiation, anxiety, and invasive procedures.[108]

To ensure appropriate imaging referrals from general and specialty medicine, radiologists can provide valuable clinical decision support (CDS). In addition to the traditional dialogue that exists between radiologists and referring physicians on particular cases, this support can be offered via a computerized system that interfaces with other

105 Zerna and others, "Imaging, Intervention, and Workflow in Acute Ischemic Stroke."

106 Goyal and others, "Challenges and Opportunities of Endovascular Stroke Therapy."

107 Ibid.

108 Fraser and Reed, "Appropriateness of Imaging in Canada."

Implementing CDS may increase patient safety and quality, and reduce health care costs.

digital health technologies in use. Essentially, CDS systems are decision aids that assist care providers in making the best, evidence-based decisions for their patients. These systems are usually integrated with computer order entry systems that provide real-time feedback, as well as information on the appropriateness of the test to the radiologists who are ordering these imaging tests.[109] The CDS data help radiologists and other physicians ask proper questions, perform appropriate tests, and diagnose their patients. Features of effective computerized CDS systems include providing advice for both patients and doctors, and requiring health care providers to give reasons when overriding advice.[110]

Blackmore's study was one of the first to demonstrate decreased image utilization after the implementation of imaging CDS. In this retrospective cohort study, the use of imaging CDS was associated with a significant reduction in MRI exams for low back pain and headaches, and in CT scans for sinusitis. The authors concluded that implementing CDS may improve appropriateness of imaging, while simultaneously increasing both patient safety and quality, as well as potentially reducing health care costs. However, the study did not contain economic data to show its efficiency.[111] A more recent study also found that CDS software decreased the number of computerized provider order entries for advanced imaging services, which decreased inappropriate use.[112] Another large systematic review showed that although integrating CDS systems with electronic health records does not reduce mortality, there is some evidence that it improves morbidity (disease) outcomes.[113] With the ongoing trend of reimbursement for health care professionals being increasingly associated with process and clinical outcomes, CDS will play an important role in future medical practice.[114]

Generally, studies indicate that CDS improves prevention services, appropriateness of care, and clinical and cost outcomes.[115] Improving

109 Blackmore, Mecklenburg, and Kaplan, "Effectiveness of Clinical Decision Support."
110 Roshanov and others, "Features of Effective Computerised Clinical Decision Support Systems."
111 Blackmore, Mecklenburg, and Kaplan, "Effectiveness of Clinical Decision Support."
112 Moriarity and others, "The Effect of Clinical Decision Support."
113 Moja and others, "Effectiveness of Computerized Decision Support Systems."
114 Murphy, "Clinical Decision Support: Effectiveness in Improving Quality Processes."
115 Ibid.

appropriateness of examinations could save costs by reducing additional investigations, shortening patients' length of stay in hospital, and decreasing the demand for expensive invasive procedures. Other important considerations are quality and patient safety.[116] Policy- and decision-makers in the health care system require more research that articulates the impact of CDS on inpatient costs and cost-effectiveness[117], [118] (See "Application of Clinical Decision Rules.")

Application of Clinical Decision Rules

Clinical decision rules help doctors make evidence-based, diagnostic, or therapeutic decisions at the bedside through patient history, physical examination, or simple tests. In the emergency department, some of the most common injuries seen involve the foot and ankle, knee, cervical spine, and head. A team of researchers at The Ottawa Hospital have previously validated these clinical decision rules. In terms of clinical impact, before-and-after studies at The Ottawa Hospital have shown a 20 to 30 per cent reduction in imaging. An economic analysis was also conducted to examine the incremental cost-savings expected upon implementation of these clinical decision rules. For example, the authors found that implementing ankle/foot rules led to a total savings of about US$3,145,910 per 100,000 patients, and implementing knee rules resulted in cost savings of US$31 per Canadian patient. Along with providing standardized care to patients, these rules also help to decrease health care costs by improving the appropriateness of imaging tests.[119] These clinical decision rules could be integrated into clinical decision support systems.

Next Steps

This report has identified several examples of how radiology has improved the lives of Canadians and some areas where we expect to see significant progress in the coming years.

116 Fraser and Reed, "Appropriateness of Imaging in Canada."
117 Fillmore, Bray, and Kawamoto, "Systematic Review of Clinical Decision Support Interventions."
118 Bright and others, "Effect of Clinical Decision-Support Systems."
119 Perry and Stiell, "Impact of Clinical Decision Rules."

Radiologists must be where they are needed, when they are needed.

It discussed how radiology was first used and how it has evolved over time. It identified opportunities for how radiology helps to create a more effective and efficient health care system. Acknowledging the challenges of demonstrating the whole-system value of radiology, the Conference Board developed a general framework for evaluating value from a number of different perspectives, which take into account not only health, but also societal benefits. This framework could be applied to research to help demonstrate the added value of any new innovation in radiology that takes more of a systems-level approach.

It highlighted some areas where radiology has made significant contributions, such as screening and early detection, and demonstrated how screening programs over the past few decades have improved population health, wellness, and system efficiency through rapid, precise, and early diagnosis and treatment enabled by imaging. It also shed light on some areas of growth potential and showed how radiology is meeting the demands of a diverse population through teleradiology for remote communities. The report highlighted some important and often unknown innovations in radiology intervention, such as the use of interventional neuroradiology for the surgical treatment of stroke, which allows surgeons to operate less invasively and improves patient recovery. Finally, it discussed the role of radiologists in improving system effectiveness and efficiency by facilitating appropriate testing, by working with other medical professionals (including general practitioners and specialists) to reduce the number of unnecessary radiological testing referrals.

Radiologists can help to maximize the effectiveness of diagnostic imaging technology to improve timeliness and accuracy of diagnoses, while increasing appropriate utilization of these tools. Radiologists must be where they are needed, when they are needed—either physically or through technology links. Furthermore, the cost of diagnostic imaging is a concern to payers as technologies evolve. The role of radiologists will continue to be to provide the highest level of quality at the lowest cost. This will be achieved through diligent triage, interpretation, planning and consultations, as well as through system efficiency research in Canada and throughout the world.

Through research and consultations with experts, we realize that additional work could be conducted to increase knowledge of the value of radiology more generally. Specific areas of work could also help inform and strengthen the profession. These include:

- evaluating the broader measures of impact, such as efficiency gains in other parts of the health care system and societal gains such as improvements in individual and population productivity;
- identifying the impacts of new innovations that allow for early evaluation, which may facilitate broader scale-up (i.e., taking a program that has demonstrated efficacy and effectiveness, and expanding it to a larger eligible population);[120]
- increasing opportunities and support for radiologists to work collaboratively with other health care providers and health administrators (through interprofessional health teams) in multiple settings;
- enhancing the understanding of the uniqueness of radiology in terms of the dependence on expensive technology, which may require large initial capital costs;
- engaging radiologists in health policy on a regional scale, so they can mentor the new generation to develop leadership and management skills to mould the current field of radiology;[121]
- creating quality improvement programs, including benchmarking and auditing, not only to improve the quality of conducted studies but also to support their role as a consultant to ensure that medical resources are being used efficiently and appropriately.[122]

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120 Milat and others, "The Concept of Scalability."
121 Dhanoa, "'Boots on the Ground' Radiology."
122 Ibid.

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The Canadian Association of Radiologists is the national specialty society for radiologists in Canada. They represent 2,225 members who provide vital medical imaging for millions of patients. They are dedicated to maintaining the highest standards of care, promoting patient safety, and helping radiologists contribute to the very best health care for patients. They work with governments, health professionals, and technology leaders to make optimal use of diagnostic imaging.

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APPENDIX A

Bibliography

Allgood, P. C., S. W. Duffy, O. Kearins, E. O'Sullivan, N. Tappenden, M. G. Wallis, and G. Lawrence. "Explaining the Difference in Prognosis Between Screen-Detected and Symptomatic Breast Cancers." *British Journal of Cancer* 104 (May 3, 2011): 1680–85.

Advisory Panel on Healthcare Innovation. *Unleashing Innovation: Excellent Healthcare for Canada*. Ottawa: Health Canada, 2015. www.healthycanadians.gc.ca/publications/health-system-systeme-sante/report-healthcareinnovation-rapport-soins/alt/report-healthcare-innovation-rapport-soins-eng.pdf (accessed September 19, 2016).

Barua, Bacchus, Milagros Palacios, and Joel Emes. *The Sustainability of Health Care Spending in Canada*. Ottawa: The Fraser Institute, 2016. www.fraserinstitute.org/sites/default/files/sustainability-of-health-care-spending-in-canada.pdf (accessed September 19, 2016).

Barneveld Binkhuysen, Frits H., and Erik R. Ranschaert. "Teleradiology: Evolution and Concepts." *European Journal of Radiology* 78, no. 2 (May 2011): 205–09.

Beckman, Kip, Daniel Fields, and Matthew Stewart. *A Difficult Road Ahead: Canada's Economic and Fiscal Prospects*. Ottawa: The Conference Board of Canada, 2014.

Blackmore, C. Craig, Robert S. Mecklenburg, and Gary S. Kaplan. "Effectiveness of Clinical Decision Support in Controlling Inappropriate Imaging." *Journal of the American College of Radiology* 8, no. 1 (January 2011): 19–25.

Bradley, William G. "Teleradiology." *Neuroimaging Clinics of North America* 22, no. 3 (August 2012): 511–17.

Bright, Tiffani J., Anthony Wong, Ravi Dhurjati, Erin Bristow, Lori Bastian, Remy Coeytaux, Gregory Samsa, Vic Hasselblad, John W. Williams, Michael D. Musty, and others. "Effect of Clinical Decision-Support Systems: A Systematic Review." *Annals of Internal Medicine* 157 (April 24, 2012): 29–43.

Campbell, Bruce C. V., Michael D. Hill, Marta Rubiera, Bijoy K. Menon, Andrew Demchuk, Geoffrey A. Donnan, Daniel Roy, John Thornton, Laura Dorado, Alain Bonafe, and others. "Safety and Efficacy of Solitaire Stent Thrombectomy: Individual Patient Data Meta-Analysis of Randomized Trials." *Stroke* 47, no. 3 (March 2016): 798–806.

Canada's Health Informatics Association (COACH). *2015 Canadian Telehealth Report*. Toronto: COACH, 2015. www.lecsct.ca/wp-content/uploads/2012/10/2015-TeleHealth-Public-eBook-Final-10-9-15-secured.pdf (accessed August 11, 2016).

Canadian Agency for Drugs and Technologies in Health (CADTH). *The Canadian Medical Imaging Inventory*, 2015. Ottawa: CADTH, 2016. www.cadth.ca/canadian-medical-imaging-inventory-2015 (accessed August 4, 2016).

Canadian Association of Radiologists. *The Canadian Association of Radiologists Supports Breast Cancer Screening for Women in Their 40s*. Statement, Ottawa: CAR, April 21, 2015. www.car.ca/uploads/newspublications/car_statement_breast_screening_recommendation_20150421.pdf (accessed August 4, 2016).

—. *National Maximum Wait Time Access Targets for Medical Imaging* (MRI and CT). Ottawa: CAR, 2013. www.car.ca/uploads/standards%20guidelines/CAR_National_Maximum_WaitTime_Targets_MRI_and_CT_2013_EN.pdf (accessed September 19, 2016).

Canadian Cancer Society. *Breast Cancer Statistics*. www.cancer.ca/en/cancer-information/cancer-type/breast/statistics/?region=bc (accessed August 4, 2016).

—. *Screening for Breast Cancer*. www.cancer.ca/en/cancer-information/cancer-type/breast/screening/?region=on (accessed August 4, 2016).

Canadian Institute for Health Information. *How Canada Compares: Results From The Commonwealth Fund 2015 International Health Policy Survey of Primary Care Physicians*. Ottawa: CIHI, 2016. www.cihi.ca/sites/default/files/document/commonwealth_fund_2015_pdf_en.pdf (accessed August 4, 2016).

—. *National Health Expenditure Trends, 1975 to 2015*. Ottawa: CIHI, 2015. https://secure.cihi.ca/free_products/nhex_trends_narrative_report_2015_en.pdf (accessed August 4, 2016).

—. *Wait Times for Priority Procedures in Canada, 2015*. Ottawa: CIHI, 2015. https://secure.cihi.ca/free_products/2015%20Wait%20Time%20Report%20VP%20Approved_EN.pdf (accessed August 4, 2016).

Canadian Medical Association. *Canadian Specialty Profiles*. www.cma.ca/En/Pages/specialty-profiles.aspx (accessed August 12, 2016).

—. *Diagnostic Radiology Profile*. www.cma.ca/Assets/assets-library/document/en/advocacy/Diagnostic-Radiology-e.pdf (accessed August 12, 2016).

Cardiovascular and Interventional Radiological Society of Europe. *Patients: Interventional Radiology*. www.cirse.org/index.php?pid=4 (accessed August 4, 2016).

Dhanoa, Deljit. "'Boots on the Ground' Radiology: Practical Strategy and Value Innovation for Local Radiology Practices." *Canadian Association of Radiologists Journal* 64, no. 3 (August 2013): 180–81.

Dhanoa, Deljit, Tajinder S. Dhesi, Kirsteen R. Burton, Savvas Nicolaou, and Teresa Liang. "The Evolving Role of the Radiologist: The Vancouver Workload Utilization Evaluation Study." *Journal of the American College of Radiology* 10, no. 10 (October 2013): 764–69.

Ellison, Larry F., and Kathryn Wilkins. "Canadian Trends in Cancer Prevalence." Statistics Canada Catalogue No. 82-003-XPE. *Health Reports* 23, no. 1 (March 2012): 1–10.

Fillmore, Christopher L., Bruce E. Bray, and Kensaku Kawamoto. "Systematic Review of Clinical Decision Support Interventions With

Potential for Inpatient Cost Reduction." *BMC Medical Informatics and Decision Making* 13, no. 135 (February 21, 2013): 1–9.

Fraser, James, and Martin Reed. "Appropriateness of Imaging in Canada." *Canadian Association of Radiologists* Journal 64, no. 2 (May 2013): 82–84.

Goyal, Mayank, Ashutosh Jadhav, Alain Bonafe, Hans Diener, Vitor Mendes Pereira, Elad Levy, Blaise Baxter, Tudor Jovin, R. Jahan, Bijoy K. Menon, and J. L. Saver. "Analysis of Workflow and Time to Treatment and the Effects on Outcome in Endovascular Treatment of Acute Ischemic Stroke: Results From the SWIFT PRIME Randomized Controlled Trial." *Radiology* 279, no. 3 (June 2016): 888–97.

Goyal, Mayank, Bijoy K. Menon, Wim H. van Zwam, Diederik W. J. Dippel, Peter J. Mitchell, Andrew M. Demchuk, Antoni Dávalos, Charles B. L. M. Majoie, Aad van der Lugt, Maria A. de Miquel, and others. "Endovascular Thrombectomy After Large-Vessel Ischaemic Stroke: A Meta-Analysis of Individual Patient Data From Five Randomised Trials." *The Lancet* 387, no. 10029 (April 2016): 1723–31.

Goyal, Mayank, Michael D. Hill, Jeffrey L. Saver, and Marc Fisher. "Challenges and Opportunities of Endovascular Stroke Therapy." *American Neurological Association* 79, no. 1 (January 2016): 11–17.

Hughes, Christine M., Erich Kramer, Jennifer Colamonico, and Richard Duszak, Jr. "Perspectives on the Value of Advanced Medical Imaging: A National Survey of Primary Care Physicians." *Journal of the American College of Radiology* 12, no. 5 (May 2015): 458–62.

Itri, Jason N. "Patient-Centered Radiology." *RadioGraphics* 35, no. 6 (October 2015): 1835–46.

Jacobs, Jac J. W. M., Jan P. A. M. Jacobs, Eric van Sonderen, Thys van der Molen, and Robbert Sanderman. "Fracture Diagnostics, Unnecessary Travel and Treatment: A Comparative Study Before and After the Introduction of Teleradiology in a Remote General Practice." *BMC Family Practice* 16, no. 1 (May 2015): 1–9.

Kenny, Stephanie A., Kaisra Esmail, Rebecca M. Hibbert, and Matthew D. F. McInnes. "How Competitive Is the Canadian Diagnostic Radiology

Residency Match? Application and Matching Trends From 1991–2014." *Canadian Association of Radiologists Journal* 67, no. 2 (May 2016): 105–11.

Kim, Changsun, Bossng Kang, Hyuk Joong Choi, and Joon Bum Park. "A Feasibility Study of Real-Time Remote CT Reading for Suspected Acute Appendicitis Using an iPhone." *Journal of Digital Imaging* 28, no. 4 (August 2015): 399–406.

Knechtges, Paul Martin, and Ruth C. Carlos. "The Evolving Role of Radiologists Within the Health Care System." *Journal of the American College of Radiology* 4, no. 9 (September 2007): 626–35.

Last, John M., ed. *A Dictionary of Public Health*. Oxford: Oxford University Press, 2007.

Legorreta, Antonio P., Ronald J. Brooks, Arthur N. Leibowitz, and Lawrence J. Solin. "Cost of Breast Cancer Treatment: A 4-Year Longitudinal Study." *Archives of Internal Medicine* 156, no. 19 (October 28, 1996): 2197–2201.

Linton, Otha. "History of Radiology." *Academic Radiology* 19, no. 10 (October 2012): 1304.

—. "Moments in Radiology History: Part 5—Bullets and Bones." *AuntMinnie.com*, May 29, 2012. www.auntminnie.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=99482 (accessed August 15, 2016).

Maynard, C. Douglas. "Academic Job Market." *Journal of the American College of Radiology* 8, no. 6 (June 2011): 380–81.

Menon, Bijoy K., Tolulope T. Sajobi, Yukun Zhang, Jeremy L. Rempel, Ashfaq Shuaib, John Thornton, David Williams, Daniel Roy, Alexandre Y. Poppe, Tudor G. Jovin, and others. "Analysis of Workflow and Time to Treament on Thrombectomy Outcome in the Endovascular Treatment for Small Core and Proximal Occlusion Ischemic Stroke (ESCAPE) Randomized, Controlled Trial." *Circulation* 133, no. 23 (June 7, 2016): 2279–86.

Merriam-Webster. "Radiology." www.merriam-webster.com/dictionary/radiology (accessed August 4, 2016).

Milat, Andrew J., Lesley King, Adrian E. Bauman, and Sally Redman. "The Concept of Scalability: Increasing the Scale and Potential Adoption of Health Promotion Interventions Into Policy and Practice." *Health Promotion International* 28, no. 3 (2013): 285–98.

Millennium Research Group. *Interventional Radiology: Global Landscape and Cost Effectiveness.* Toronto: MRG, April 2014. www.ciraweb.org/uploads/files/RFP2671InterventionalRadiology-GlobalLandscapeandCostEffectiveness.pdf (accessed August 4, 2016).

Mittmann, Nicole, Natasha K. Stout, Pablo Lee, Anna N. A. Tosteson, Amy Trentham-Dietz, Oguzhan Alagoz, and Martin J. Yaffe. "Total Cost-Effectiveness of Mammography Screening Strategies." Statistics Canada Catalogue No. 82-003-X. *Health Reports* 26, no. 12 (December 2015): 16–25.

Moja, Lorenzo, Koren H. Kwag, Theodore Lytras, Lorenzo Bertizzolo, Linn Brandt, Valentina Pecoraro, Giulio Rigon, Alberto Vaona, Francesca Ruggiero, Massimo Mangia, and others. "Effectiveness of Computerized Decision Support Systems Linked to Electronic Health Records: A Systematic Review and Meta-Analysis." *American Journal of Public Health* 104, no. 12 (December 2014): e12–22.

Mok, Philip S., Linda Probyn, and Karen Finlay. "Factors Influencing Radiology Residents' Fellowship Training and Practice Preferences in Canada." *Canadian Association of Radiologists Journal* 67, no. 2 (May 2016): 99–104.

Moriarity, Andrew K., Chad Klochko, Matthew O'Brien, and Safwan Halabi. "The Effect of Clinical Decision Support for Advanced Inpatient Imaging." *Journal of the American College of Radiology* 12, no. 4 (April 2015): 358–63.

Muir, Keith W., and Philip White. "HERMES: Messenger for Stroke Interventional Treatment." *The Lancet* 387, no. 10029 (April 23, 2016): 1695–97.

Murphy, Elizabeth V. "Clinical Decision Support: Effectiveness in Improving Quality Processes and Clinical Outcomes and Factors That May Influence Success." *Yale Journal of Biology and Medicine* 87, no. 2 (June 2014): 187–97.

Newell, Mary S., and Mary C. Mahoney. "Ultrasound-Guided Percutaneous Breast Biopsy." *Techniques in Vascular and Interventional Radiology* 17, no. 1 (March 2014): 23–31.

Ng, Kai-Ling, Jo Yazer, Mohammed Abdolell, and Peter Brown. "National Survey to Identify Subspecialties at Risk for Physician Shortages in Canadian Academic Radiology Departments." *Canadian Association of Radiologists Journal* 61, no. 5 (December 2010): 252–57.

Oeffinger, Kevin C., Elizabeth T. H. Fontham, Ruth Etzioni, Abbe Herzig, James S. Michaelson, Ya-Chen Tina Shih, Louise C. Walter, Timothy R. Church, Christopher R. Flowers, Samuel J. LaMonte, and others. "Breast Cancer Screening for Women at Average Risk: 2015 Guideline Update From the American Cancer Society." *Journal of the American Medical Association* 314, no. 15 (October 20, 2015): 1599–614.

Organisation for Economic Co-operation and Development. *Health Care Utilisation: Diagnostic Exams*. https://stats.oecd.org/Index.aspx?DataSetCode=HEALTH_PROC (accessed August 10, 2016).

—. *National Health Expenditure Trends*, 1975 to 2015. Ottawa: CIHI, 2015. https://secure.cihi.ca/free_products/nhex_trends_narrative_report_2015_en.pdf (accessed August 4, 2016).

Perry, Jeffrey J., and Ian G. Stiell. "Impact of Clinical Decision Rules on Clinical Care of Traumatic Injuries to the Foot and Ankle, Knee, Cervical Spine, and Head." *Injury: International Journal of the Care of the Injured* 37 no. 12 (December 2006): 1157–65.

Proval, Cheryl. "Value-Added Radiology, Defined." *Radiology Business*, November 6, 2012. www.radiologybusiness.com/topics/business/value-added-radiology-defined (accessed August 4, 2016).

Public Health Agency of Canada. *Economic Burden of Illness in Canada, 2005–2008*. Ottawa: PHAC, 2014. www.phac-aspc.gc.ca/

publicat/ebic-femc/2005-2008/assets/pdf/ebic-femc-2005-2008-eng.pdf (accessed August 13, 2016).

RadiologyInfo.org. S*tereotactic Breast Biopsy: What Are the Benefits vs. Risks?* www.radiologyinfo.org/en/info.cfm?pg=breastbixr (accessed August 11, 2016).

Robson, William B. P. *Healthcare Spending Decelerating? Not So Fast!* Ottawa: C.D. Howe Institute, 2016. www.cdhowe.org/sites/default/files/attachments/research_papers/mixed/e-brief_246_1.pdf (accessed September 19, 2016).

Roshanov, Pavel S., Natasha Fernandes, Jeff M. Wilczynski, Brian J. Hemens, John J. You, Steven M. Handler, Robby Nieuwlaat, Nathan M. Souza, Joseph Beyene, and others. "Features of Effective Computerised Clinical Decision Support Systems: Meta-Regression of 162 Randomised Trials." *British Medical Journal* 346 (February 14, 2013): 1–12.

Ryan, John, Ashish Khandelwal, and Najla Fasih. "Trends in Radiology Fellowship Training: A Canadian Review 2009–2011." *Canadian Association of Radiologists Journal* 64, no. 3 (August 2013): 176–79.

Salati, Umer, Sum Leong, John Peter Donnellan, Hong Kuan Kok, Orla Buckley, and William Torreggiani. "Out of Hours Emergency Computed Tomography Brain Studies: Comparison of Standard 3 Megapixel Diagnostic Workstation Monitors With the iPad 2." *Canadian Association of Radiologists Journal* 66, no. 4 (November 2015): 363–67.

Salazar, Antonio J., Javier Romero, Oscar Bernal, Angela Moreno, Sofia Velasco, and Xavier Diaz. "Evaluation of Low-Cost Telemammography Screening Configurations: A Comparison With Film-Screen Readings in Vulnerable Areas." *Journal of Digital Imaging* 27, no. 5 (October 2014): 679–86.

Sanmartin, Claudia, Deirdre Hennessy, Yuqian Lu, and Michael Robert Law. "Trends in Out-of-Pocket Health Care Expenditures in Canada, by Household Income, 1997 to 2009." Statistics Canada Catalogue No. 82-003-X. *Health Reports* 25, no. 4 (April 2014): 13–17.

Schwartz, Adam B., Gina Siddiqui, John S. Barbieri, Amana L. Akhtar, Woojin Kim, Ryan Littman-Quinn, Emily F. Conant, Narainder K. Gupta,

Bryan A. Pukenas, Parvati Ramchandani, and others. “The Accuracy of Mobile Teleradiology in the Evaluation of Chest X-rays.” *Journal of Telemedicine and Telecare* 20, no. 8 (December 2014): 460–63.

Seely, Jean, Jim Watters, Susan Domina, and Jennifer Smylie. *Women’s Breast Health Centre: Annual Review, April 2014–March 2015*. Ottawa: The Ottawa Hospital. www.ottawahospital.on.ca/wps/wcm/connect/3f94038049ccfd1f9058d9fbadbb217c/WBHC-2014-15+English.pdf?MOD=AJPERES (accessed August 11, 2016).

Sharpe, Jennifer. “Implementation of the First CT Scanner in the Eastern Arctic.” PowerPoint Presentation. *2015 Joint Congress on Medical Imaging and Radiation Sciences Conference*. Held at Montréal, May 28–30, 2015.

Statistics Canada. *Smokers, by Sex, Provinces, and Territories*. www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/health74b-eng.htm (accessed August 11, 2016).

Thrall, James H. “Teleradiology Part II. Limitations, Risks, and Opportunities.” *Radiology* 244, no. 2 (August 2007): 325–28.

Whitacre, Brian E. “Estimating the Economic Impact of Telemedicine in a Rural Community.” *Agricultural and Resource Economics Review* 40, no. 2 (August 2011): 172–83.

Will, B. P., J. M. Berthelot, C. Le Petit, E. M. Tomiak, S. Verma, and W. K. Evans. “Estimates of the Lifetime Costs of Breast Cancer Treatment in Canada.” *European Journal of Cancer* 36, no. 6 (April 2000): 724–35.

Williams, Dinsie B. *A Systematic Review of Teleradiology for Remote Neurosurgical Evaluation of Patients in Facilities Without Neurosurgery Specialists*. MSc Thesis, Toronto: University of Toronto, 2009. https://tspace.library.utoronto.ca/bitstream/1807/30129/5/Williams_Dinsie_B_200911_MSc_thesis.pdf (accessed August 11, 2016).

Yee, Kate Madden. “Radiologists’ Expertise Cuts Inappropriate Imaging.” *AuntMinnie.com*, July 25, 2016. www.auntminnie.com/index.aspx?sec=ser&sub=def&pag=dis&ItemID=114723 (accessed August 4, 2016).

Zerna, C., Z. Assis, C. D. d'Esterre, B. K. Menon, and M. Goyal. "Imaging, Intervention, and Workflow in Acute Ischemic Stroke: The Calgary Approach." *American Journal of Neuroradiology* 37, no. 6 (June 2016): 978–84.

Zurawska, Joanna H., Rachel Jen, Stephen Lam, Harvey O. Coxson, Jonathon Leipsic, and Don D. Sin. "What to Do When a Smoker's CT Scan Is 'Normal'? Implications for Lung Cancer Screening." *Chest* 141, no. 5 (May 2012): 1147–52.

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