Canada's Drug and
Health Technology Agency

CADTH Health Technology Review

The Canadian Medical Imaging Inventory: 2022–2023

Evidence Preview

What Is the Context?

Imaging Is Widely Used and Needed

- Advanced medical imaging (CT, MRI, PET-CT, single-photon emission computerized tomography [SPECT], SPECT-CT, and PET-MRI) is integral to the management of many diseases.
- Diagnostic imaging typically takes place early in a patient's clinical journey,[1] although imaging is increasingly used to monitor response to treatment and to guide interventional procedures.[2]
- Limited imaging resources can create bottlenecks in health care delivery, leading to delays in patient diagnosis and treatment.[3]

Imaging Is Expensive

- Advanced imaging equipment are high-cost medical devices, sometimes requiring special facilities. The estimated procurement and construction costs for a PET-CT unit are around $10 million.[4,5]
- Imaging incurs ongoing operational costs for maintenance and repair, imaging contrast agents and radioisotopes, and staff skilled in operation.[6]
- Aging of equipment and ongoing technological development incur costs for equipment repair, upgrade, and replacement.[7-9]

Imaging Faces Increased Demand and Skills Shortages

- Demand for imaging exams has outstripped capacity in some settings, leading to long wait times that can strain the health care system. Excessive wait times can result in adverse outcomes for patients, and lead to inefficiencies and increased costs.[10]
- The aging of the population in Canada, with an increasing incidence of diseases such as cancer, results in a greater demand for imaging.[11]
- An aging workforce also leads to a loss of expertise as radiologists and technologists retire.[12]
- There is greater demand for skilled technicians and radiologists to keep pace with technological and clinical advances.[13]
- The COVID-19 pandemic exacerbated existing challenges in imaging departments, leading to worsening staffing shortages as well as exhaustion and burnout among health care professionals.[14]
- Staffing shortages limit the hours that machines can operate, exacerbating challenges in access.[3,14]

What Did CADTH Do?

This Evidence Preview provides a summary of imaging capacity for CT, MRI, PET-CT, PET-MRI, SPECT, and SPECT-CT across Canada at the national level. The data presented are based primarily on the results of the Canadian Medical Imaging Inventory (CMII), a national survey of imaging facilities in every province and territory.

The CMII

- The CMII documents current practice and developments in the supply, distribution, technical characteristics, and general clinical use of advanced imaging modalities in public (and some private) health care facilities.
- Data are supplemented with information from provincial and territorial validators, peer reviewers, other CMII reports, and searches of the published and grey literature.
- This is the fourth iteration of the current version of the CMII, which resumed in 2015. CADTH's predecessor (the Canadian Coordinating Office for Health Technology Assessment [CCOHTA]) and the Canadian Institute for Health Information (CIHI) tracked inventory at intervals between 2001 and 2012.

Data collected include:

- number and location of imaging equipment (CT, MRI, PET-CT, SPECT, SPECT-CT, and PET-MRI)
- volume of exams
- technical specifications of machines
- hours of equipment operation
- age of imaging equipment
- international comparisons.

The CMII also presents data on human resources, funding structures, ordering and referral practices, and the adoption of tools that may support appropriate imaging, system efficiencies, and wait-list reductions.

Comparisons between Canadian data and data from other countries are also reported, as are trends and projections on imaging capacity.

What Does Each Advanced Imaging Modality Do?

- **CT** units use x-rays and computer analysis to create quick, cross-sectional images of the body.
- **MRI** units employ electromagnetic and radiofrequency fields to produce cross-sectional images of the body without ionizing radiation.
- **PET-CT** combines positron-emitting radioisotopes and CT scans to create detailed images of the body and metabolic functions.
- **SPECT** units detect gamma rays from ingested radiopharmaceuticals to create cross-sections of organ systems.
- **SPECT-CT** combines SPECT and CT modalities to get 3-dimensional images of the body with metabolic and physiologic information.
- **PET-MRI** is the newest advanced imaging modality, combining radioisotope tracers with MRI to create high-sensitivity metabolic imaging with high resolution.

Why Did CADTH Do This?

CADTH maintains the CMII to help health systems mitigate challenges in meeting demand for imaging. Robust data are required to ensure health systems can deliver the imaging required to provide timely, safe, patient-centred care, improve health outcomes, and deliver health care efficiencies. The data collected for the CMII can be used by decision-makers for the following purposes:

- to identify gaps in service
- to inform benchmark practices
- to define outcomes and promote processes that are responsive to patients, workforce, and health system needs
- to enable data-driven decisions to be made, highlighting system-level pressure points to improve service delivery and reduce wait times
- to monitor the adoption of innovations within medical imaging
- to identify implementation concerns associated with the introduction of new therapies and innovations outside medical imaging
- to understand existing and future demand for services
- to enable decision-makers to plan for future sustainability
- to compare Canada's inventory with that of other countries.

Imaging Equipment Capacity in Canada: 2022–2023

Results from the national CMII survey, jurisdictional validators, and international data are presented below.

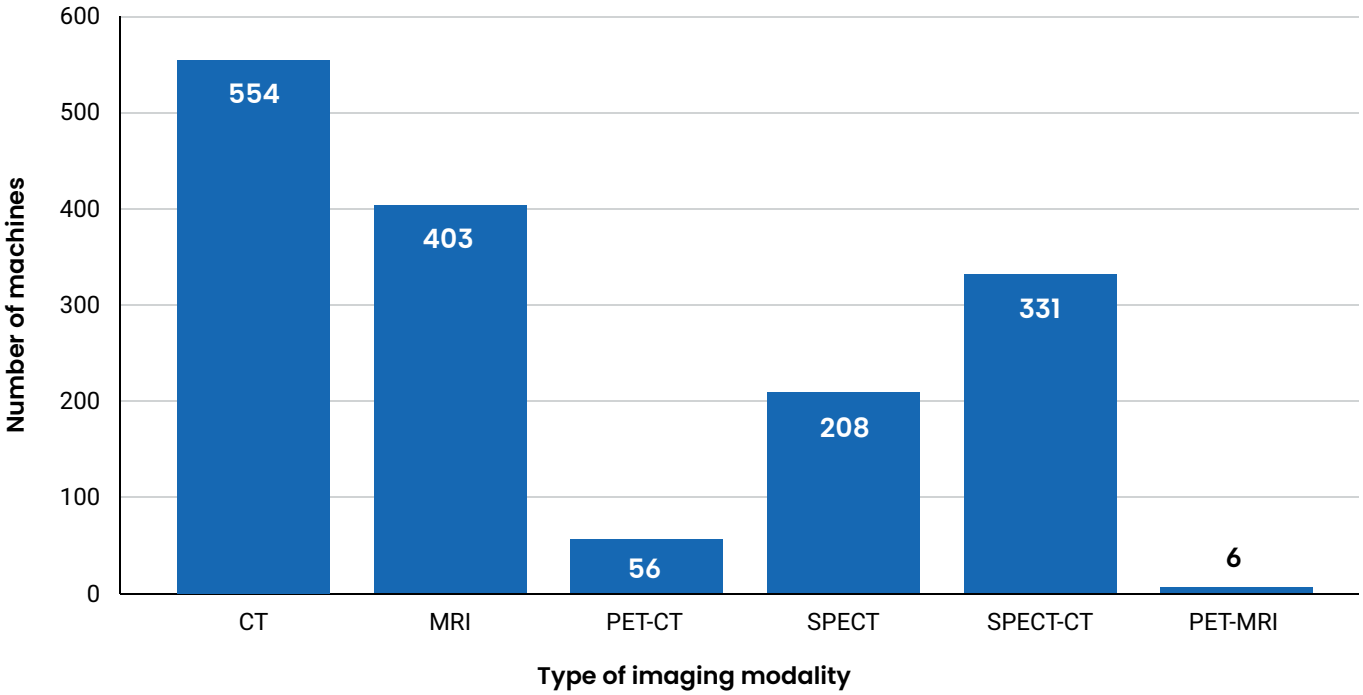
Numbers of CT, MRI, SPECT-CT, and PET-CT Units Are Generally Increasing

The numbers of CT, MRI, SPECT-CT, and PET-CT units have been increasing over the last 10 years. However, a large decrease in SPECT units (due to widespread adoption of SPECT-CT) has offset these gains, resulting in a 1.5% decrease in the total number of medical imaging units over the last 10 years. This equipment is mostly concentrated in urban centres with patient access concerns remaining for rural and remote populations.

Due to data availability, data for 2022 are compared with 2012 for CT and MRI and with 2015 for PET-CT, SPECT, and SPECT-CT.

Figure 1

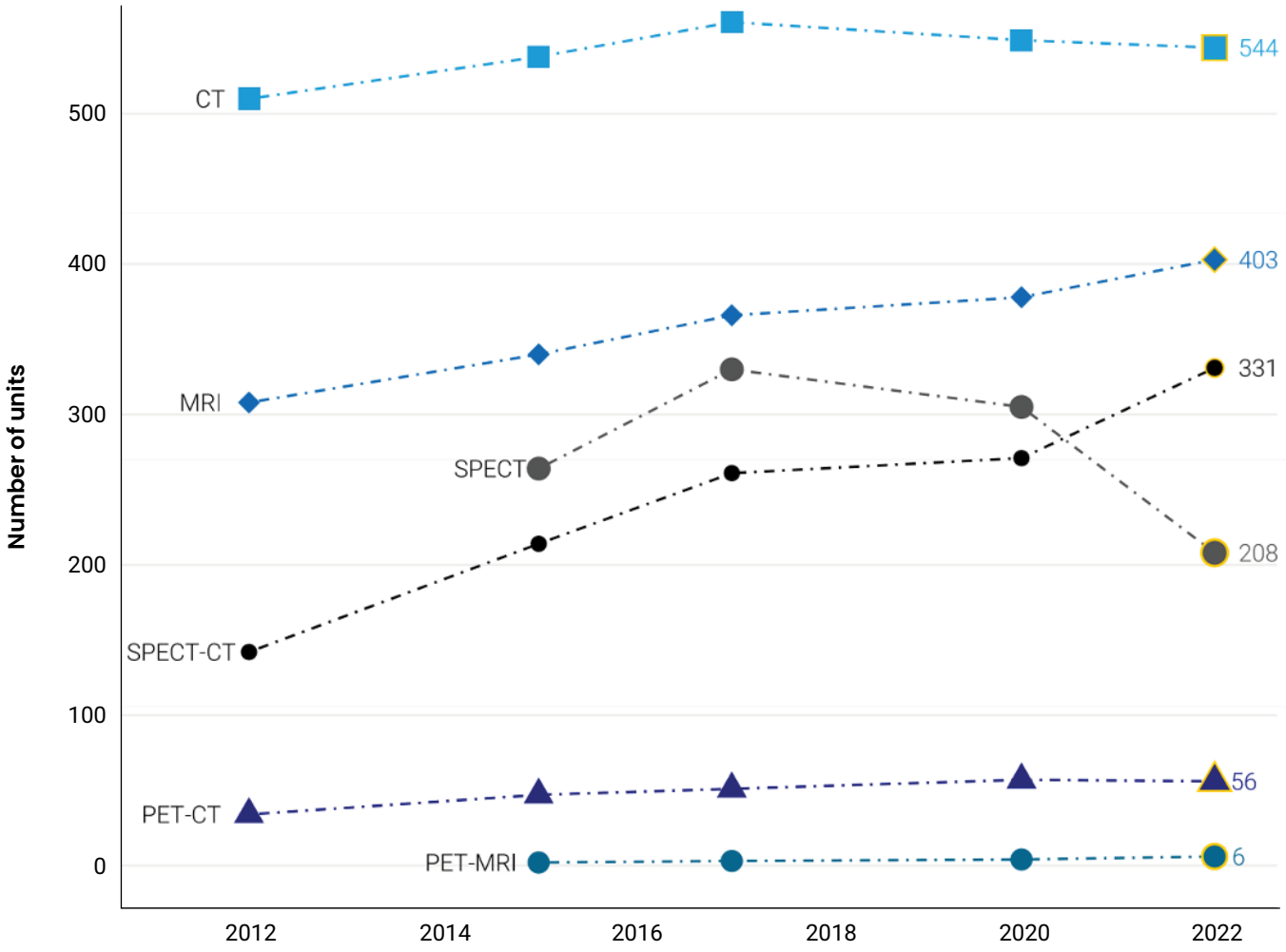
Total Advanced Medical Imaging Machines in 2022–2023



SPECT = single-photon emission computed tomography.

Figure 2

Trend in Number of Units of Advanced Medical Imaging Machines From 2012 and 2015 to 2022–2023 in Canada



SPECT = single-photon emission computed tomography.

From 2012 to 2022:

- **CT units** increased in Canada from 510 in 2012 to 544 in 2022–2023, representing a 6.7% unit increase over the 10-year period. They are available in all provinces and territories.
  - The slower growth of CT compared to other imaging modalities may be influenced by the fact that many sites that would be expected to have a CT unit already have at least 1 unit, and replacing older CT units provides faster imaging speeds, increasing exam throughput.
- **MRI units** increased from 308 in 2012 to 403 in 2022–2023, representing a 30.8% unit increase over the 10-year period. They are available in all provinces and 1 territory.

From 2015 to 2022:

- **PET-CT units** increased from 47 in 2015 to 56 in 2022–2023, representing a unit increase of 19.1% over 7 years. They are available in 9 provinces.
- **PET-MRI units** increased from 2 in 2015 to 6 in 2022–2023. They are available in 3 provinces and are primarily used for research purposes.
- **SPECT-CT units** increased from 214 in 2015 to 331 in 2022–2023, representing a 54.7% unit increase over 7 years. They are available in all provinces.
- **SPECT units** decreased from 264 in 2015 to 208 in 2022–2023, representing a 21.2% unit decrease over 7 years. They are available in 9 provinces.

Mobile Units

Mobile imaging units improve patient access to health care by bringing advanced imaging equipment to rural and other underserved communities. Most mobile imaging units are shared between several sites with geographic proximity. Mobile units may spend anywhere from a half-day to a few weeks in a community before rotating to the next community.[15] Some mobile equipment operates as a fixed unit stationed to a single site, often while new equipment is being installed, repaired, or replaced.

Canada's current mobile unit inventory includes:

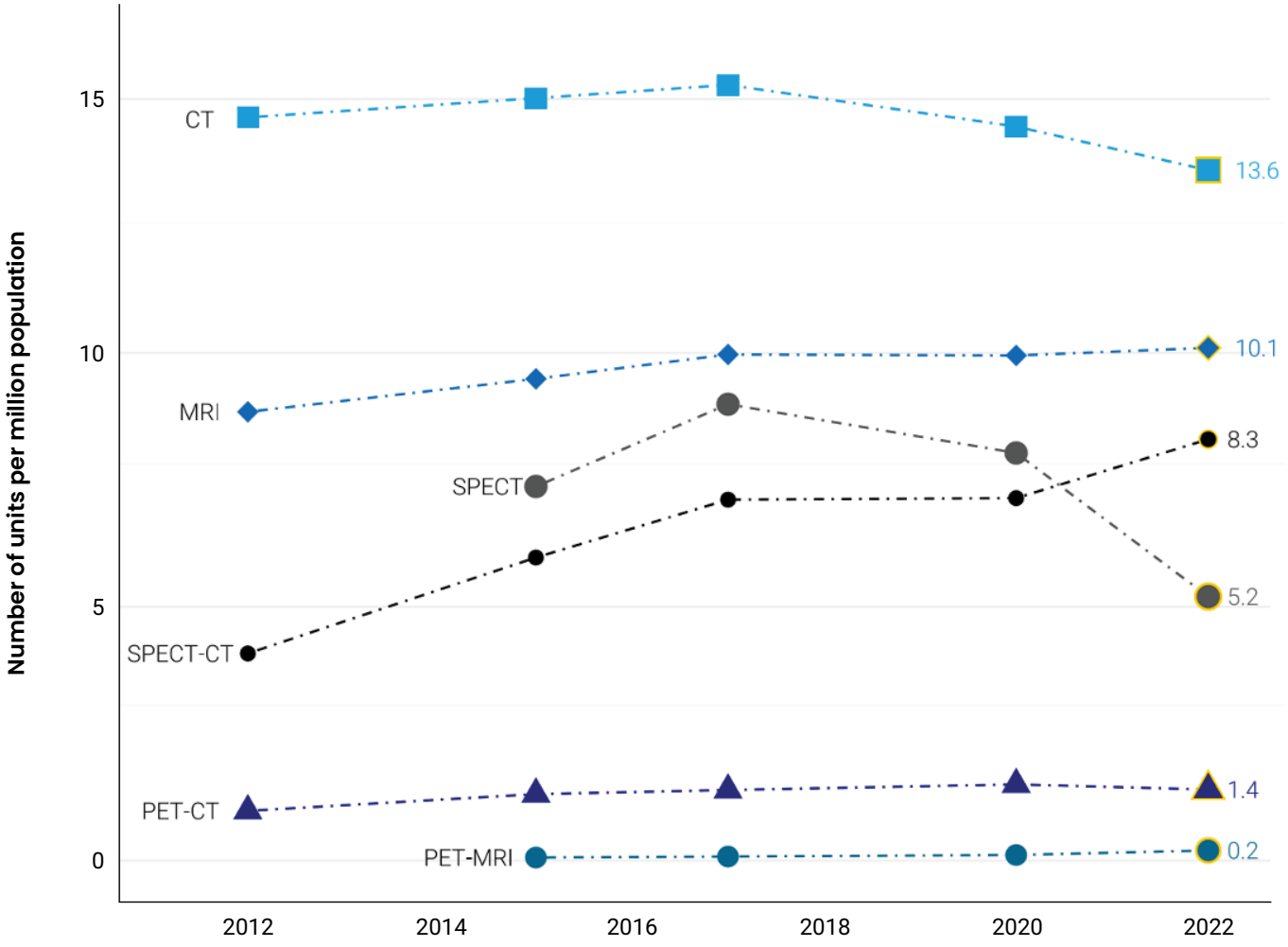
- 2 publicly funded **mobile CT units** in 2 provinces, both operating as fixed units
- 7 publicly funded **mobile MRI units** serving 12 sites in 5 provinces, 2 as fixed units.

Medical Imaging Units per Million Population Are on the Rise

Advanced medical imaging units per million population have increased over time (with the exceptions of CT and SPECT units); however, Canada remains below average in units per million population compared to other Organisation for Economic Cooperation and Development (OECD) countries.[16]

Figure 3

Trends in Units per Million Population of Each Imaging Modality From 2012 and 2015 to 2022–2023 in Canada



SPECT = single-photon emission computed tomography.

From 2012 to 2022:

- **CT units per million population** decreased by 7.5% over 10 years, from 14.7 per million people in 2012 to 13.6 per million population in 2022–2023.
  - In 2022, Canada lagged behind the OECD average for CT units per million population, **ranking 30th among 34 countries**.[16]
- **MRI units per million population** increased by 13.5% over 10 years, from 8.9 units per million population in 2012 to 10.1 units per million population in 2022–2023.
  - In 2022, Canada lagged behind the OECD average for MRI units per million population, **ranking 28th among 33 countries**.[17]

For 2015 to 2022:

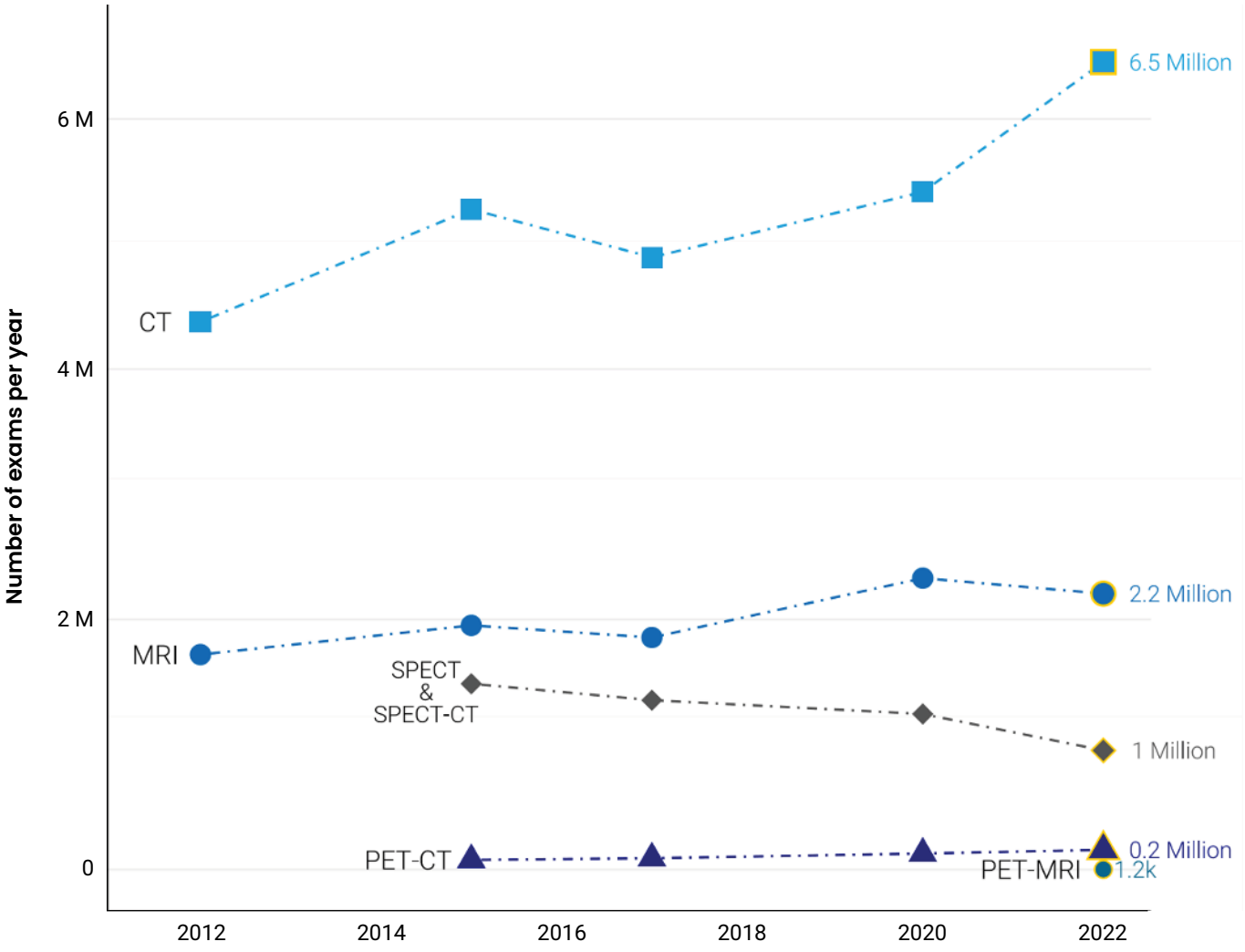
- **PET-CT units per million population** increased by 7.7% over 7 years, from 1.3 units per million population in 2015 to 1.4 units per million population in 2022–2023.
- **SPECT-CT units per million population** increased by 38.3% over 7 years, from 6.0 units per million population in 2015 to 8.3 units per million population in 2022–2023.
- **SPECT units per million population** decreased by 29.7% over 7 years, from 7.4 units per million population in 2015 to 5.2 units per million population in 2022–2023.

Volume of Exams Is Increasing for Most Modalities

Overall exam volumes have increased for CT, MRI, and PET-CT, with overall advanced imaging exam volumes reaching more than 9.7 million in 2022–2023. However, the demand for imaging is outpacing capacity, with wait times beyond the maximum 4-week threshold recommended by the Canadian Association of Radiologists.[18]

Figure 4

Trends in Exam Volumes for all Modalities From 2012 and 2015 to 2022–2023 in Canada



SPECT = single-photon emission computed tomography.

From 2012 to 2022:

- The volume of **CT exams** conducted in 2022–2023 was approximately 6.5 million, compared to 4.4 million exams in 2012, representing a 47.7% increase over a decade.
- The volume of **MRI exams** conducted in 2022–2023 was approximately 2.2 million, compared to 1.7 million exams in 2012, representing a 29.4% increase over a decade.

From 2015 to 2022:

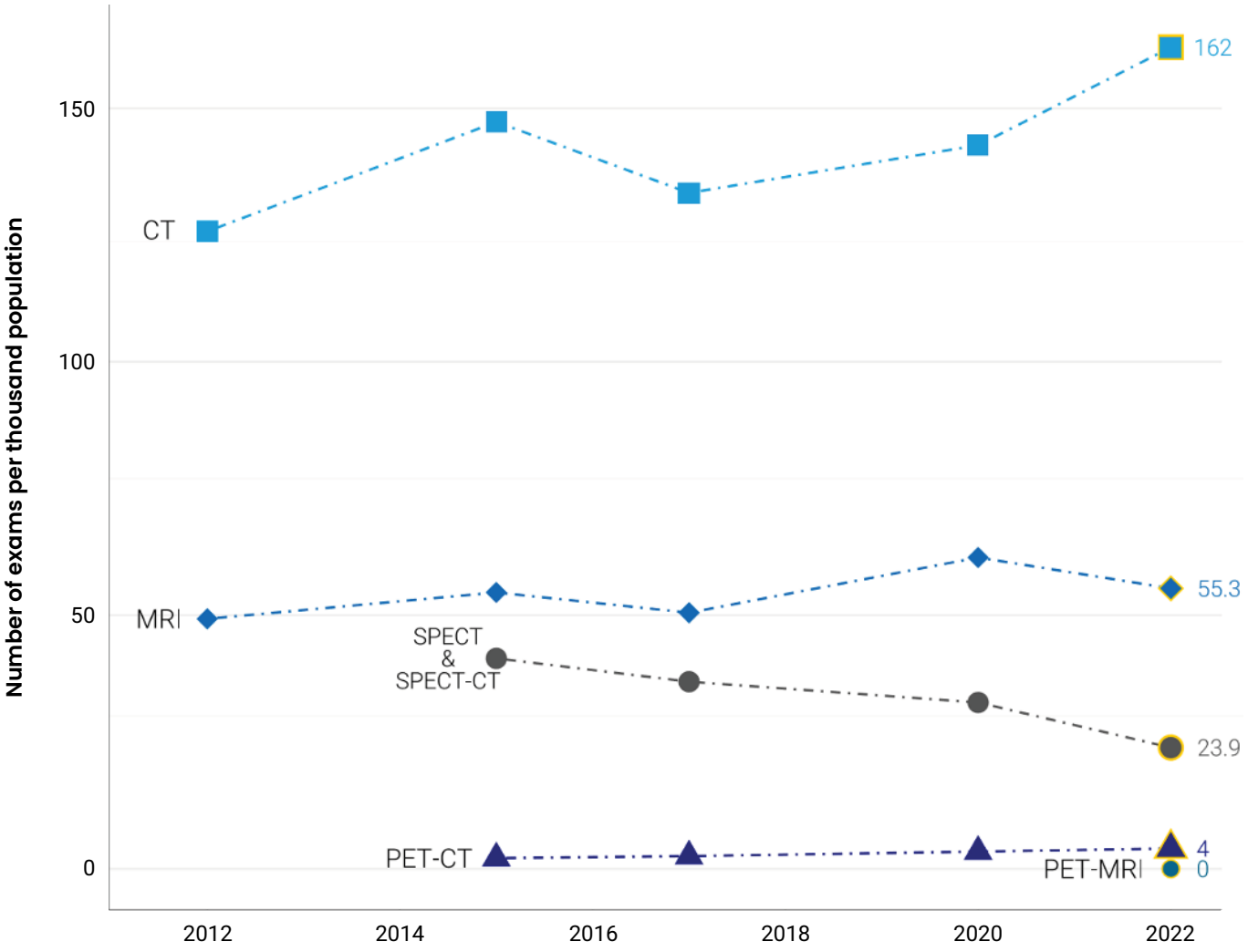
- The volume of **PET-CT exams** conducted in 2022–2023 was approximately 0.2 million, compared to 0.1 million exams in 2015, representing a 100.0% increase over 7 years.
- The combined volume of **SPECT** and **SPECT-CT exams** conducted in 2022–2023 was approximately 1.0 million, compared to 1.5 million in 2015, representing a decrease of 33.3% over 7 years.

Exam Volume per Thousand Population Is Increasing With Population Growth

Exam volume per thousand population has increased across almost all imaging modalities over the past 10 years. However, according to the Canadian Association of Radiologists, the demand for imaging exams is still outgrowing imaging capacity.[19]

Figure 5

Trends in Exams per Thousand Population for Each Advanced Imaging Modality From 2012 and 2015 to 2022–2023 in Canada



SPECT = single-photon emission computed tomography.

From 2012 to 2022:

- **CT exams per thousand population** increased by 28.9% over 10 years, from 125.7 in 2012 to 162.0 in 2022–2023.
  - Canada ranks **12th out of 28 countries** for CT exams per thousand population.[20]
- **MRI exams per thousand population** increased by 12.2% over 10 years, from 49.3 in 2012 to 55.3 in 2022–2023.
  - Canada ranks **21st out of 28 countries** for MRI exams per thousand population.[21]

From 2015 to 2022:

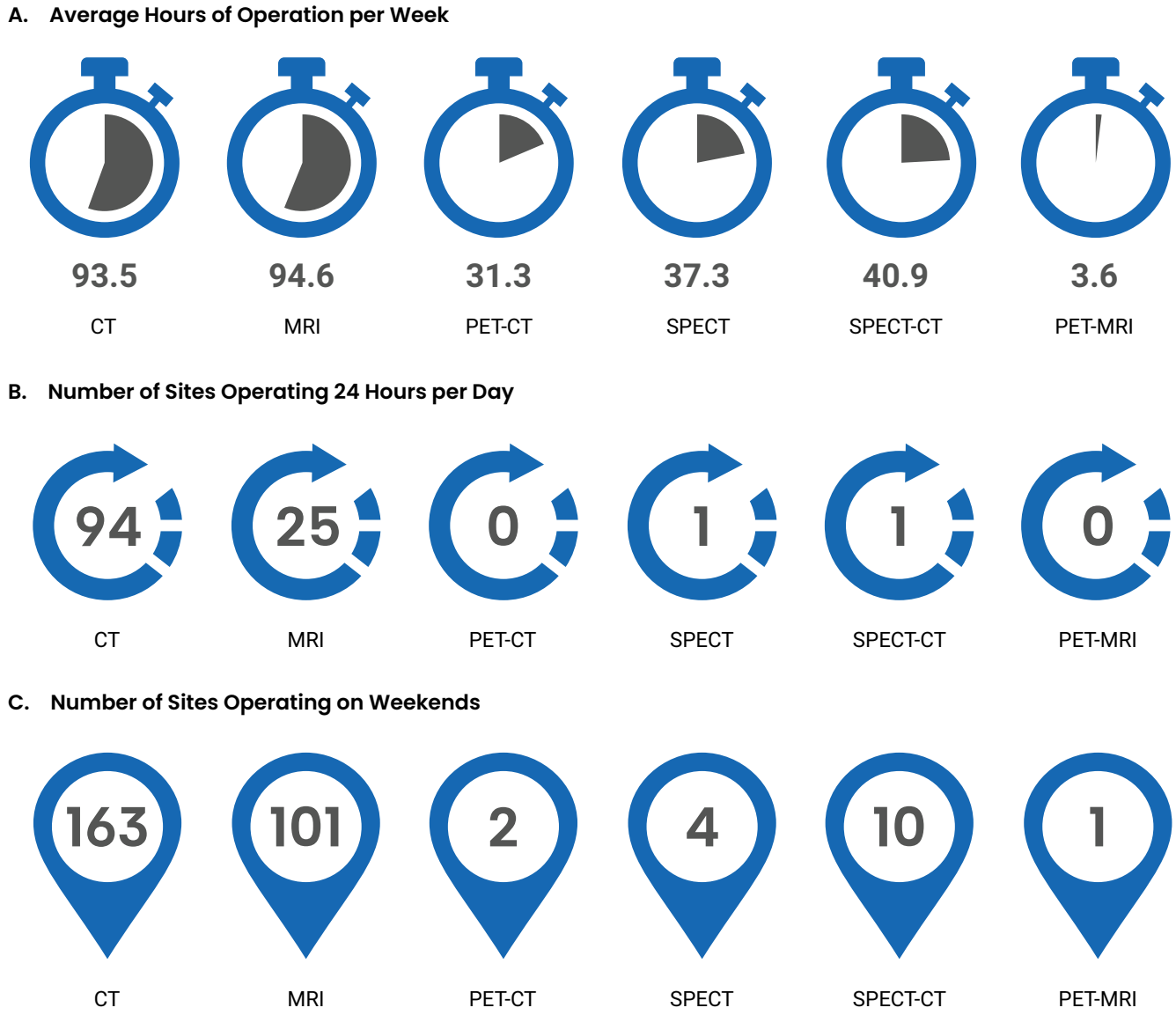
- **PET-CT exams per thousand population** increased by 100.0% over 7 years, from 2.0 in 2015 to 4.0 in 2022–2023.
- **SPECT** and **SPECT-CT exams per thousand population** are combined, and decreased by 42.3% over 7 years, from 41.4 in 2015 to 23.9 in 2022–2023.

Hours of Equipment Operation

CT and MRI units operate for approximately the same average number of hours per week across Canada, between 93 and 95 hours. The other imaging modalities operate on average between 3 and 41 hours per week. Extending the hours of operation of imaging equipment is a strategy used to help reduce wait times. The ability to extend hours may be limited by other factors, including staffing shortages, age of the equipment, and availability of other resources.[18]

Figure 6

Equipment Operation in 2022–2023



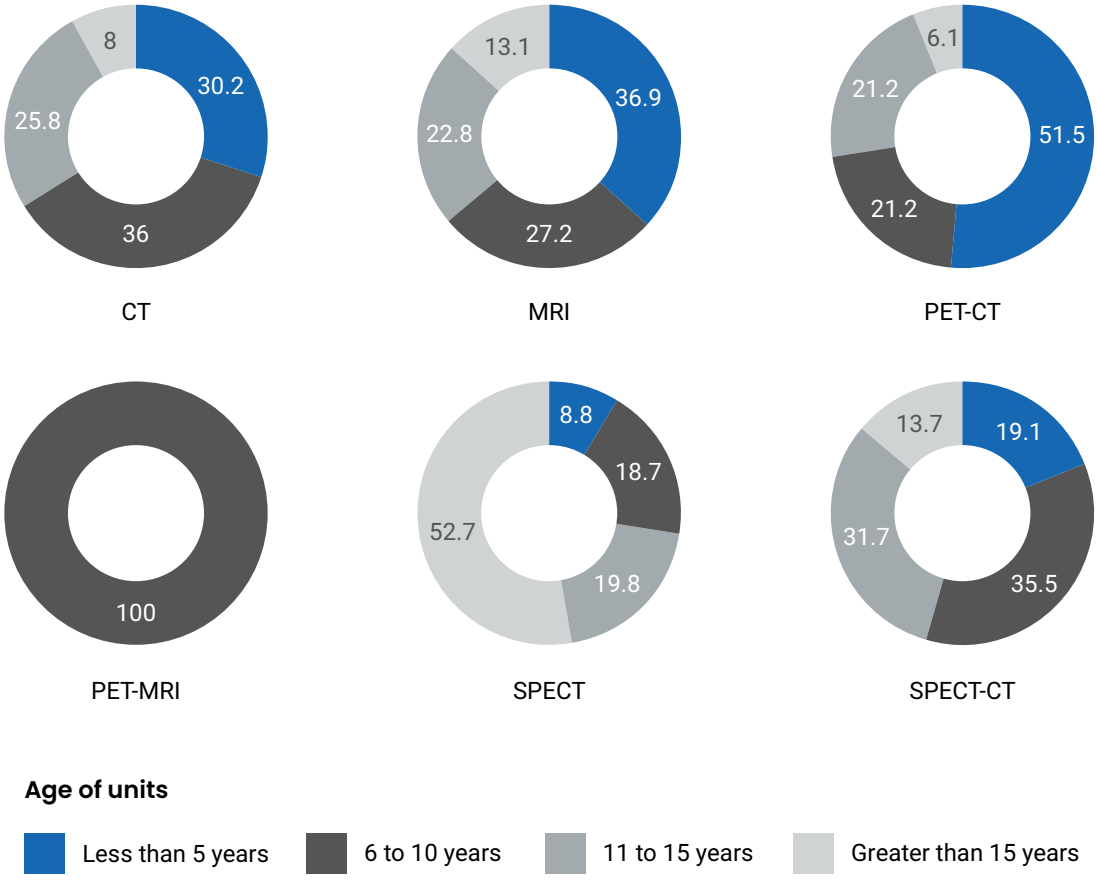
SPECT = single-photon emission computed tomography.

Canada's Imaging Equipment Is Aging

- Age is one of the main drivers of the decision to replace imaging equipment. The CMII collects information on the age of equipment to help decision-makers plan budgets and develop sustainable equipment replacement strategies.[3,9]
- Newer imaging technologies can provide faster and more accurate diagnoses, resulting in improved health outcomes and quality of life for patients.[22] Older imaging equipment may require higher radiation doses, may have reduced diagnostic capabilities, and allows a lower throughput of patients.[23] Older imaging equipment is more likely to break down and may be more challenging to maintain and repair.[24]
- Guidelines have recommended lifetimes for imaging equipment.[3,9]
    - The Canadian Association of Radiology recommends that maximum life expectancy and clinical relevance for any imaging equipment should not exceed 15 years.
    - According to the European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (COCIR), no more than 10% of inventory should be more than 10 years old.[3,9]

Figure 7

Age of Canadian Imaging Equipment, 2022–2023



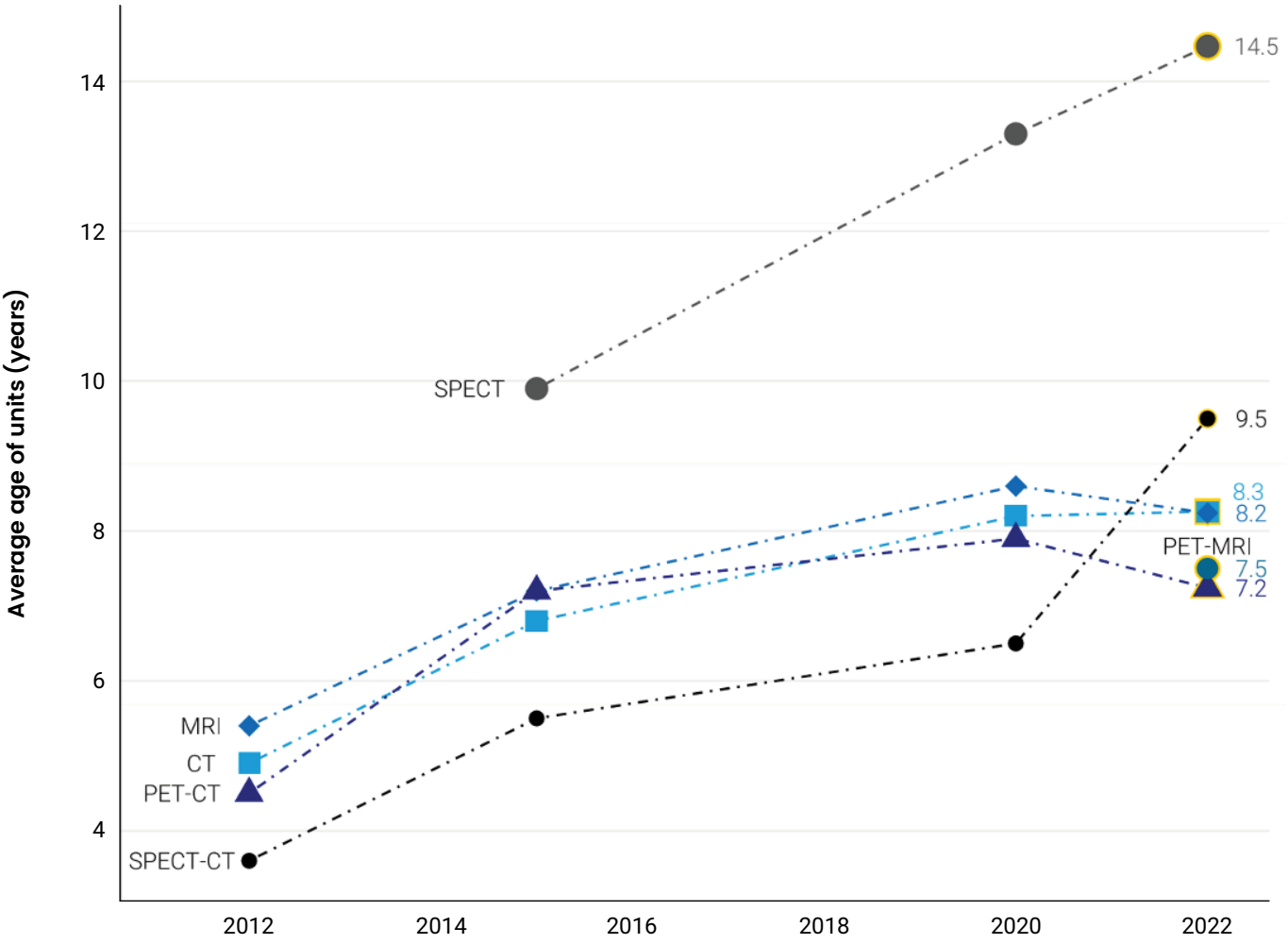
SPECT = single-photon emission computed tomography.

- High procurement and installation costs mean older equipment is used beyond its optimal life cycle.
- In the 2022–2023 survey, one-third of CT and MRI units, more than one-quarter of PET-CT units, nearly three-quarters of SPECT units, and nearly half of SPECT-CT units were at least 10 years old.

Past iterations of the inventory have shown an upward trend in ages of imaging equipment. Since 2012, the average age of equipment has increased between 46% and 69% for CT, MRI, and SPECT, and by 1% for PET-CT. SPECT-CT machines have experienced the largest age increase, increasing by 73% since 2015, with an average increase of 3 years from 2020.

Figure 8

Average Age of Canadian Imaging Equipment, 2012 to 2022–2023



SPECT = single-photon emission computed tomography.

Adopting Technological Innovations to Support Medical Imaging Sustainability

With health care systems struggling to keep up with the increasing demand for imaging services, in addition to health care provider shortages, there is increased interest in technological innovations that can increase capacity, optimize modality operations, and speed up diagnoses. The following technologies may play a crucial role in addressing immediate demand and building greater resilience for the future.

Portable imaging equipment is typically wheeled to the bedside, reducing patient intrahospital transfer times and allowing for immediate imaging.

- Portable imaging equipment is rapidly being recognized and adopted for its clinical and economic value in providing diagnosis-quality images for lower costs at greater patient convenience.
- Reduced procurement costs and facility requirements enable portable imaging equipment to be placed in hospitals or outlying communities that otherwise could not house or afford conventional medical imaging machines.[25-27]
- Portable MRI units require minimal training and can be operated by noncredentialed staff.[28]
- Canada is currently piloting this new equipment and has 4 portable CT units in 3 provinces, and at least 4 portable MRI units in 3 provinces.

Artificial intelligence (AI) is playing a greater role in the delivery of imaging services due to rapid advances in deep learning technology and may improve efficiency and patient safety.[12]

- AI is used in some form across all advanced imaging modalities in some medical imaging departments in Canada, with the current focus on image reconstruction, lowering radiation dose, and reading and interpreting images.
  - AI usage has yet to reach widespread adoption in most imaging facilities.
- In 2022, the majority of AI use is with CT in image reconstruction and lowering radiation doses.
  - Since the last iteration of the survey, AI use for CT in these areas has grown at the site level by 108.5%, from 47 sites to 98.

Clinical decision support (CDS) tools can help family physicians and hospital clinicians in selecting the optimal imaging modality for the most common clinical scenarios at the point of care.[29]

- CDS tools can help to reduce low-value imaging and can suggest alternate tests.[12]
- CDS tools have yet to be widely adopted in Canada. Most imaging facilities across the country do not use them in any of the surveyed imaging modalities.

Centralized booking at a regional level allows for the identification of sites with underutilized imaging equipment and allocates patients to those sites, lowering wait times and increasing overall access to medical imaging.[30]

- Centralized order entry tools assist in this process and have been widely adopted in most provinces to varying extents for CT and MRI.
- Centralized booking is less common for SPECT, SPECT-CT, and PET-CT modalities.

Teleradiology (the remote reading of radiology exams) is commonplace in Canada. Teleradiology services can play an important role in reducing wait times and in providing imaging services to rural and remote locations.[31] Canada's most remote communities often rely solely on teleradiology for image interpretation.[32]

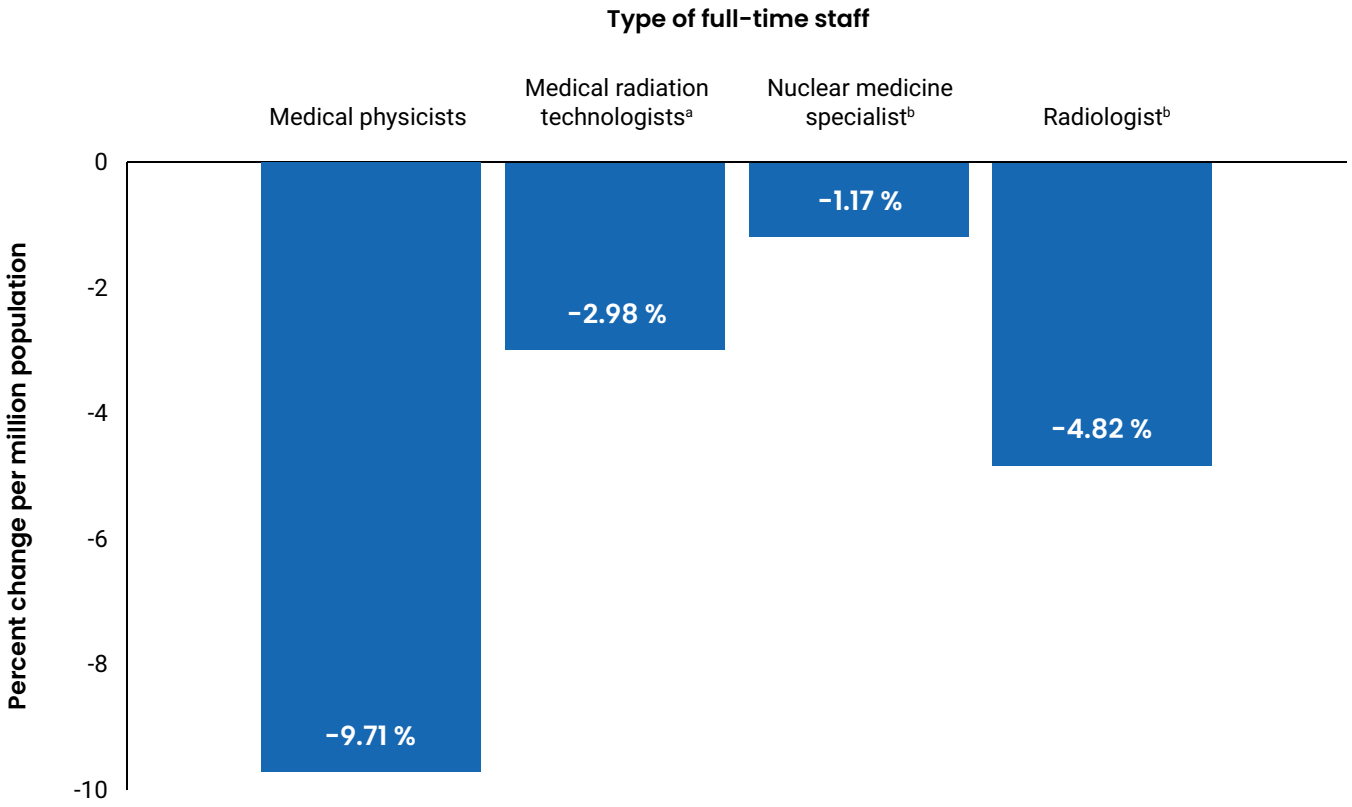
- Eight provinces and territories use teleradiologists within their borders.
- Six jurisdictions use out-of-province teleradiological services.
- At least 1 province uses international teleradiology services.

The Shortage of Health Human Resources in Canada Is Increasing

Without considering staffing, investing in new equipment may not achieve the increased capacity required to meet growing imaging demand. Ongoing staffing shortages have been exacerbated by COVID-19 and contribute to extended wait times, limited access to services, and reduced quality in patient care.[33,34]

Figure 9

Percent Change in Full-Time Staff per Million Population From 2019 to 2022–2023



MRT = medical radiation technologist.

[a] MRT data from 2021.[35]

[b] Nuclear medicine specialist and radiologist data from 2019. Assumed unchanged staff retention since 2019 and increased population growth[36,37].

- Between 2019 and 2023,[35-38] the number of full-time medical imaging staff per million population decreased. Medical physicists had the largest decrease at 9.71%, while nuclear medicine specialists experienced the lowest change at 1.17%.

Since 2019, medical radiation technologists (MRTs) have experienced a 2.98% reduction in staff per million, while the volume of CT and MRI exams per MRT has increased by 16% and 8%, respectively.[39]

Imaging Staff Report Worsening Symptoms of Burnout

Burnout and **mental health concerns** among medical imaging staff worsened during the COVID-19 pandemic, with negative implications on the quality of patient care and experience, and access to services. These factors contribute to the trend in professionals leaving their positions.[14,33,40]

MRTs have reported an 80% increase in burnout symptoms compared to prepandemic levels, with emotional exhaustion increasing by 78% and feelings of reduced personal accomplishment growing by 26%.[14,18,33]

Factors that contribute to burnout and lower mental health include:[14,18,33]

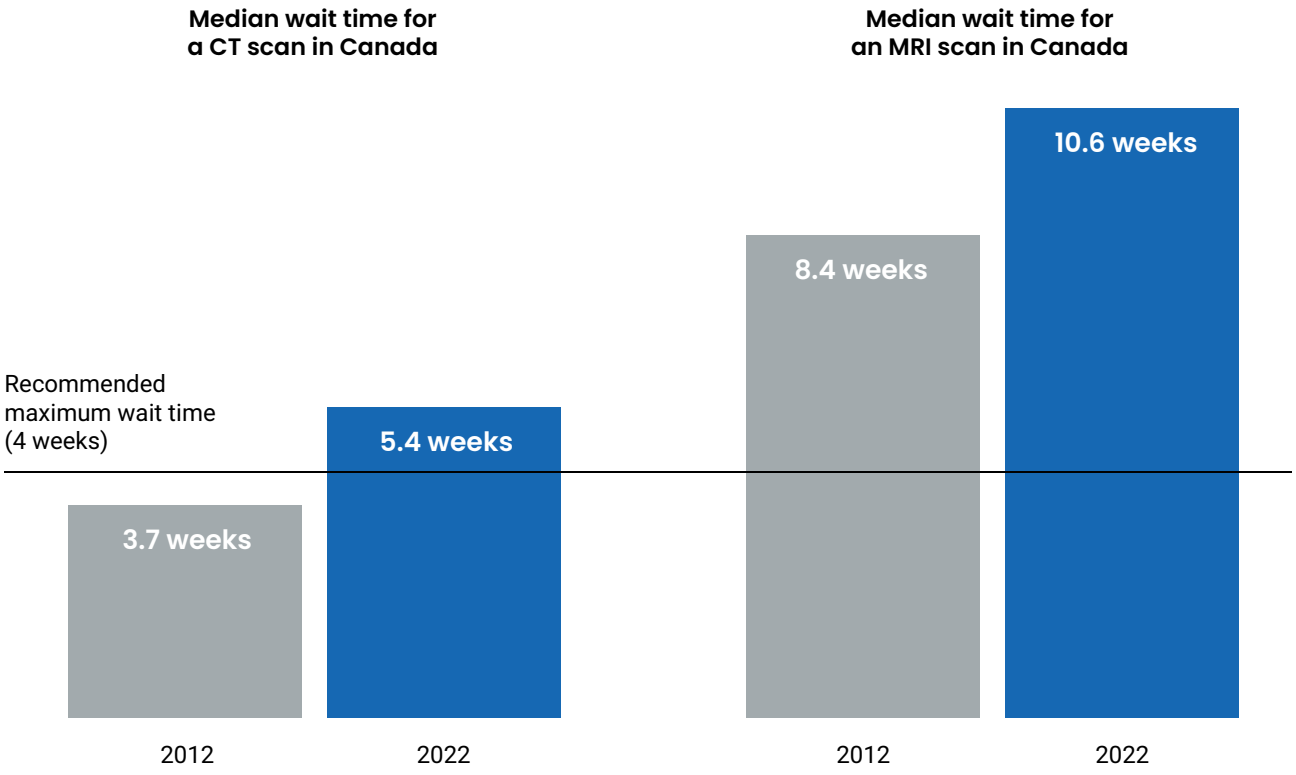
- high-stress work environments with limited support
- increased workload burden (e.g., COVID-19, aging population)
- underdeveloped health human resource strategies
- lack of equipment or less efficient equipment
- limited career progression opportunities.

Wait Times Are Increasing

Despite ongoing strategies to reduce wait times, over the past decade, wait times for advanced imaging exams have increased beyond the recommended maximum wait time of 4 weeks.[10,41] According to the Fraser Institute, between 2012 and 2022, the median wait time for CT increased by 45%, from 3.7 weeks to 5.4 weeks. During the same time period, the wait time for MRI increased by 26%, from 8.4 weeks to 10.6 weeks.[10,41]

Figure 10

Comparison of Median Wait Time for a CT Scan and MRI Scan From 2012 to 2022–2023



There are various potential causes of long wait times, and specific causes may vary between jurisdictions and facilities. There is no single solution to improve wait times for exams, but rather a variety of different actions are needed to help manage wait lists.[18]

Factors that contribute to long wait times include:[18]

- inadequate access to health care facilities and resources
- funding and budgetary considerations
- staffing factors
- demographic factors and population growth.

Strategies to help with wait times and staff shortages include:[18]

- increasing access
- ensuring equitable distribution of equipment
- providing training programs
- incentivizing professionals to practice in underserved regions
- exploring alternative health care providers.

What Did We Learn?

Based on the results of our national survey and other CMII research, there are some key takeaways on the status of advanced medical imaging equipment in Canada.

- Advanced imaging equipment is undersupplied in Canada compared to other OECD countries.
- There is no current international benchmark for the optimal number of imaging units per population, but there is a general assumption that too few units may limit access problems and increase wait times while too many units may encourage low-value imaging.
- Advanced imaging equipment is aging, and some units are operating beyond their recommended lifetime.
- Investing in new equipment to meet growing demand may not increase imaging capacity without also considering staffing.
- The imaging workforce is under strain and experiencing high rates of burnout, which has been made worse by the postpandemic recovery.
- New investment in radiology staff, particularly imaging technologists, is required, including renewed recruitment and retention policies.
- Wait times for medical imaging remain above the recommended maximum wait time in many jurisdictions and are influenced by a variety of factors.
- The adoption of supportive tools and technologies — such as CDS tools, automated order entry, and AI-driven solutions — can assist the workforce, add value to imaging services, and increase access to medical imaging.

CMII data, particularly data collected on current demand and available resources, may help guide strategies and identify planning opportunities to improve timely access to medical imaging.

Limitations of Findings

Our findings are limited in the following ways.

- For feasibility, recent survey iterations have been restricted to 6 advanced imaging modalities, creating a bias toward urban areas.
- The restriction means that potential relationships among modalities (for example, in pathways that involve multiple modalities) may not be fully captured.
- We attempted to contact all imaging and nuclear medicine departments in Canada, but were not successful in some instances, especially for private sites. The picture for private imaging in Canada is incomplete, as response from private sites was poor.
- Complete data are available from validators for units and exams. Approximately 60% of sites entered or updated data. Where appropriate, we have carried forward data from the 2019–2020 or 2017 CMII.
- While we asked about replacement of units, we did not ask about technical upgrades that improve the operation of existing units.

What Else Is CADTH Doing?

This Evidence Preview is part of a series of publications that CADTH will produce as part of the CMII national survey.

Additional publications not detailed in this report will be published on the CMII webpage, starting in January 2024 to April 2024, to provide jurisdiction-level information on medical imaging modalities and resources. These include:

- *An Overview of Medical Imaging Across Canada 2022–2023*
- *CT in Canada 2022–2023*
- *MRI in Canada 2022–2023*
- *PET-CT and PET-MRI in Canada 2022–2023*
- *SPECT and SPECT-CT in Canada 2022–2023*
- *The Medical Imaging Team*
- provincial and territorial summaries.

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December 2023