CADTH

Canadian Medical Imaging Inventory Service Report

The Future of PET-CT in Canada

Context

It is widely recognized that PET-CT provides improved image quality compared to conventional imaging such as CT, particularly for cancer.[1] Its superiority derives from the fact that it has the most specific and sensitive means for imaging molecular interactions and pathways within the human body.[2] Evidence shows that PET-CT can more accurately inform the staging of cancers and influence treatment and management strategies. PET-CT may also lead to improved quality of care for patients and better utilization of medical resources,[3] with information from PET-CT changing up to 50% of planned therapies and surgeries.[3] PET-CT can also lead to cost savings by avoiding unnecessary imaging tests, biopsies, or treatments.[3]

As decision-makers plan for PET-CT needs over the next 10 years, there are several considerations that may help to inform future capacity requirements. First, the volume of exams in Canada continues to increase and shows no sign of abatement.[4] Indeed, with an increasing aging population, where 25% of Canadians will be seniors by 2030,[5] demand for medical imaging procedures will continue to increase more rapidly than overall population growth.[6] Second, while PET-CT is predominantly used in oncology, with between 80% to 90% of all use dedicated to this purpose, PET-CT is increasingly used for diagnostic purposes in various other disciplines such as infectious diseases, cardiology, and neurology.[4]

Technical advances with digital[7] and whole body[2] PET-CT, as well as advances in reconstruction algorithms and computer sciences, are further expanding the potential uses of PET-CT.[1] Other developments may also expand the potential uses of PET-CT, such as exploring the data mining capabilities of radionomics for decision support,[8] theranostics for treatment delivery and predicting treatment response and toxicity,[9] and new radiopharmaceuticals to image and treat specific cancers.[1] At the same time, there are also opportunities for the restriction of PET-CT and these may include funding for equipment, which is very expensive, limiting publicly funded indications, human resource capacity, geography, and availability of and access to radiopharmaceuticals.[4]

Objective

This document summarizes the opinions of experts working with PET-CT on the anticipated future direction of this imaging modality in Canada over the next decade. The purpose is to inform planning for the growth of PET-CT.

Methods

The findings of this report are based on responses to a CADTH survey on the potential future of PET-CT in Canada. An 8-question survey was developed and revised following expert review and was distributed via email to experts in all provinces with existing PET-CT capacity. Survey respondents were invited to provide their opinions on key areas pertaining to PET-CT and its anticipated direction over the next 10 years.

Results

A total of 18 survey responses were received, with representation from all provinces with PET-CT capacity. Some responses reflect the individual perspectives of clinicians and others reflect an overall provincial perspective. The professions of survey respondents were identified as professors in medicine, medical doctors (nuclear medicine and oncology), imaging physicists, and employees at centres with PET-CT scanners. In several instances, respondents answered the survey anonymously and therefore survey results are presented from a pan-Canadian perspective and do not summarize information about specific jurisdictional or organizational perspectives.

Technological Innovation

Respondents were asked if they were aware of technological innovations that may impact patient care, the quality of PET-CT images, and/or the delivery of PET-CT. Most respondents (14 out of 18) stated that they were aware of technological innovations and advances to PET-CT scanner technology.

The most commonly reported technological advancement, as noted by 8 respondents, is digital PET-CT. Survey respondents commented that digital PET-CT can increase sensitivity and improve image quality, leading to improved lesion detectability and diagnostic confidence. Specific improvements to image quality that were noted by survey respondents — either as part of digital PET-CT or as general advancements to hardware, software, and acquisition methods — include improved time-of-flight calculations, longer axial field-of-view systems, improved image reconstruction capabilities, spatial resolution precision, and more sensitive motion correction algorithms. It is noted that improved image quality, during the scan or during post-processing, allows for improved ability to diagnose pathologies and facilitates shorter scan times to produce a comparable or higher-quality image when compared to older PET-CT equipment.

Several survey respondents commented that shortened scan times allow for more people to be scanned per day, which in addition to reducing motion artifacts (e.g., for patients who find it challenging to stay still during longer scans), can also lower wait times and enhance access to PET-CT. Similarly, several survey respondents noted that technological advances have allowed for PET-CT to produce images at a reduced radiopharmaceutical tracer dose, resulting in less radiation exposure for patients and reduced drug costs per scan.

Three survey respondents expressed an interest in dynamic whole-body PET-CT. This modification in PET-CT technology allows the entire body to be imaged just once using a scanning bed that continuously moves through the scanner. It was reported that this can improves patient satisfaction and elevates diagnostic certainty and assessment of response to therapy. It was also noted that, like digital PET-CT, whole-body scanning allows for significant improvements in image quality, scanning time, and reduction in radiation dose. One survey respondent commented that the larger, up-front, capital expense of whole-body PET-CT could be balanced by significant cost reductions in radiopharmaceuticals, particularly expensive novel imaging drugs such as prostate-specific membrane antigen (PSMA) for prostate cancer and DOTATATE for neuroendocrine cancer.

Three survey respondents commented on the role of artificial intelligence (AI) in PET-CT, with 1 noting that after-market AI reconstruction software may improve image quality in older PET-CT units and another noting that, in newer PET-CT equipment, AI and machine learning are embedded into units, often without a user's realization, to shorten scanning times. One respondent noted that AI had not taken a hold for PET-CT yet but had the potential to improve

image reconstruction quality. It is noted in the Canadian Medical Imaging Inventory (CMII) report[4] that AI is used clinically in some PET-CT units in Quebec to lower radiation dose, improve image reconstruction, and support treatment planning.

From a patient satisfaction perspective, 1 survey respondent noted that increased bore size can ease a patient's anxiety of being in a small space. Two other innovations reported include computer-aided detection tools to identify and stage cancers, and tools that can help identify which patients need to be prioritized for imaging and reduce the need for repeat exams.

Expanding Oncology Indications

Respondents were asked if they were aware of new clinical oncology indications that are anticipated to be introduced into clinical practice over the next 10 years that may impact patient care and/or the delivery of PET-CT services. Most survey respondents (16 out of 18) stated that they were aware of expanded clinical oncology indications with the primary focus on new targeted radiopharmaceuticals rather than 18F-fluorodeoxyglucose (^{18}F-FDG) — the established and most widely used cancer imaging radiopharmaceutical.

The most commonly anticipated new indication for the use of PET-CT was for the diagnosis of prostate cancer using 18F-fluorodeoxyglucose PSMA and/or gallium-68 (^{68}Ga) PSMA, with 15 survey respondents referencing its anticipated introduction into clinical care. Twelve survey respondents reported neuroendocrine tumours as the second most-likely cancer indication anticipated to enter clinical care, using ^{68}Ga-labelled 1,4,7,10-tetraazacyclododecane-1,4,7,10-tetraacetic acid-tyrosine-3-octreotate (^{68}Ga-DOTATATE), and 3 survey respondents reported the anticipated use of 18F-sodium fluoride (^{18}F-NaF) for the detection of cancer originating from or spreading to the bone. Other oncology indications mentioned by survey respondents included central nervous system neoplasms and brain tumours using amino acid radiopharmaceuticals. The therapeutic application of radiotracers, particularly lutetium-177 (or ^{177}Lu) for endocrine tumours and Yttrium-90 (or ^{90}Y) for liver malignancies were also reported as potential new applications for oncology. It may be of interest that the CMII[4] reports that at least 6 PET-CT centres already use ^{18}F NaF and one centre uses ^{68}Ga-DOTATATE in a clinical capacity.

PET-CT is primarily used for diagnosis, but some respondents noted that it is increasingly being used for other purposes, such as follow-up to assess disease response during treatment (e.g., to determine if a tumour is responding to chemotherapy), which is currently being assessed in pharmaceutical-sponsored trials and for assessment of recurrence. If the treatment is shown to not be effective, it can be stopped, allowing patients to avoid harmful side effects and reducing health care costs. Another potential application is theranostics, as reported by 2 survey respondents, which incorporates both diagnosis and delivery of therapy by utilizing radiotracers to diagnose and provide targeted treatment so drugs will only target tumour cells.

Survey respondents were also asked to comment on the anticipated volume of exams for these new oncologic indications. The survey included a list of 3 options (low volume: less than 5 patients per week, per scanner; medium volume: 6 to 10 patients per week, per scanner; or high volume: more than 10 patients per week, per scanner).

For both prostate and bone cancer, and cancer that has spread to the bone, most survey respondents reported medium to high anticipated patient volume. For neuroendocrine cancer, survey respondents reported a low to medium expected volume of exams.

Expanding Non-oncology Indications

Respondents were asked if they were aware of new non-oncologic indications anticipated to be introduced into clinical practice over the next 10 years. Most survey respondents (16 out of 18) stated they anticipate clinical non-oncologic indications to expand, with the primary focus on cardiac and neurodegenerative indications, as reported by 10 and 7 respondents, respectively. The most commonly reported cardiac indication is myocardial perfusion imaging, particularly using rubidium-82 (^{82}Rb) and also using ammonia to detect ischemic heart disease. Imaging for other cardiac conditions (sarcoidosis, myocardial inflammation, vascular inflammation, valvular inflammation, and valvular calcification) is less frequently reported by survey respondents.

The most commonly anticipated neurodegenerative indication, as reported by 7 respondents, is dementia — particularly Alzheimer disease — using amyloid plaque imaging. Three respondents specifically noted that PET-CT may play an expanded role in monitoring patients for treatment response for new pharmaceuticals aimed at slowing dementia progression. Other non-oncologic indications mentioned included inflammatory and infectious conditions, as reported by 5 respondents, and bone scans for arthritis, as reported by 2 survey respondents. One survey respondent noted that it is recognized in their province that there is a lack of approved indications outside of oncology and it is an issue that needs to be addressed within their province.

Survey respondents were also asked to comment on the anticipated volume of exams for expanded non-oncologic indications. The survey included a list of 3 options (low volume: less than 5 patients per week, per scanner; medium volume: 6 to 10 patients per week, per scanner; or high volume: more than 10 patients per week, per scanner).

For cardiac indications, most survey respondents anticipate a high volume of exams primarily using ^{82}Rb but also ammonia. It is noted that ^{82}Rb cardiac perfusion exams are already conducted in a clinical capacity in some facilities in 3 provinces. The high volume of exams, as noted by 3 respondents, may help justify the cost of generating ^{82}Rb radiopharmaceuticals. One respondent commented that to make optimal use of the generator-based isotope, there is a minimum annual number of scans (1,200 per year) expected to be performed by each participating site as part of funding criteria. Imaging for other cardiac conditions (sarcoidosis, myocardial inflammation, vascular inflammation, valvular inflammation, and valvular calcification) are anticipated to generate a low volume of exams.

For dementia-related indications, most survey respondents anticipate a high volume of exams. Indeed, one respondent noted that there is potential for dementia-related imaging to significantly impact overall PET-CT volumes. As well, the volume of exams for infections and inflammatory conditions is anticipated to be medium to high, depending on the accessibility of radioisotopes.

Survey respondents anticipate a low volume of exams for bone scans for arthritis.

Resources for Maintaining the Standard of Care

Oncology

Respondents were asked if they had sufficient resources to manage current standard of care for oncology indications. Most respondents (14 out of 18) said they do not have sufficient resources. The most commonly reported concerns, as noted by 10 respondents, is insufficient numbers of PET-CT units and 3 respondents commented that wait times are longer than clinically recommended targets. Inadequate human resources capacity was also reported by most survey respondents, the results of which are summarized more fully in this report under Human Resources Capacity.

Overall, growing oncology demand, especially for patient follow-up, response to therapy (particularly for lymphoma), and assessment for recurrence were noted as new uses of PET-CT that may put pressure on existing capacity.

One respondent reported that in some instances patients who should receive a PET-CT exam for an oncology investigation do not receive one. It was also noted that for provinces that have only one PET-CT unit (4 provinces), there is no back-up to provide care if the unit breaks down, which may result in all appointments for the day being cancelled and rebooked for another day. Prior to COVID-19, some patients were sent out-of-province or to the US to be imaged. Another respondent noted that over the past 15 years, the use of PET-CT has increased beyond what was envisaged when PET facilities were initially designed, particularly injection sites and patient waiting areas, and they are not optimized for current patient volume.

Four respondents noted that the current radiopharmaceutical supply was insufficient to manage the existing standard of care, 3 reported that access to novel radiopharmaceuticals was a barrier to managing care requirements, and 2 respondents commented that the cyclotron capacity was inadequate to manage current needs. Concerns were also raised about potential funding cuts due to pandemic-related fiscal pressures, which would lead to reduced resources for PET-CT use and development. Two respondents reported a lack of resources specifically to provide PET-CT exams for neuroendocrine cancers, possibly because of difficulties accessing needed novel radiopharmaceuticals.

Non-oncology

Respondents were asked if they had sufficient resources to manage the current standard of care for non-oncologic indications. Like the responses provided for oncology indications, most respondents (13 out of 18) said they did not have sufficient resources to manage the current standard of care for non-oncologic exams.

Eight respondents noted that wait lists for oncology exams are long and take priority over all other indications. Two respondents more specifically noted that PET-CT capacity is very limited because of the prioritization of oncology exams and, to a lesser extent, myocardial perfusion imaging, and that long wait lists for these indications limits the use for PET-CT for other indications. It was pointed out by 1 respondent that non-oncologic exams have chronically long wait times, to the extent that clinicians often consider PET-CT not available within clinically relevant timelines (e.g., FDG PET brain imaging wait times are more than 1 year, as are amyloid PET-CT, with some patients waiting up to 3 years before exams were finally cancelled). It was also noted by 2 respondents that there is currently no means of prioritizing non-oncologic exams.

The specific resource concerns were consistent with those reported for oncologic indications: limitations from PET-CT unit availability, lack of funding, and staff shortages. Respondents from 2 provinces said that they did not have either an approved list or clinical guidance for standard of care for any non-oncologic indications.

Another respondent reported that their current cyclotron capabilities and capacity limit their PET-CT service offerings.

Availability and Production of PET-CT Radiopharmaceuticals

Routine Radiopharmaceuticals

Respondents were asked if they were aware of any issues related to the availability and production of routine PET-CT radiopharmaceuticals that may impact patient care and/or the

delivery of PET-CT services. Most respondents (14 out of 18) reported that they were aware of issues related to accessing or producing routine radiopharmaceuticals.

Six survey respondents reported that they were reliant on a single supplier, which can increase the risk of service disruption in the supply chain and limit redundancy when there are radiopharmaceutical production issues. Two respondents noted that supply interruptions have impacted the availability and/or the cost of ^{18}F-FDG for weekend or extended-hour use. It was noted that it can be challenging to source radiopharmaceuticals from alternative vendors, particularly at short notice, and that some vendors may be less willing to supply service for short-term needs, resulting in the cancellation and rebooking of appointments.

For PET-CT sites that do not have their own cyclotron or access to radiopharmaceuticals from a local source, service continuity was noted by 4 respondents to be dependent on the availability and reliability of transportation, air and road traffic delays, and poor weather conditions, although disruptions were reported to be infrequent.

Lack of funding for the development of radiopharmaceuticals, as well as funding for those already clinically approved, was reported by 2 survey respondents as a barrier to the delivery of PET-CT services, particularly for non-FDG radiopharmaceuticals, with 1 respondent commenting that his facility lacked sufficient funding to make full use of its cyclotron.

Two respondents commented that because of the limited number of radiopharmaceutical suppliers, prices are high and provincial reimbursement for pharmaceutical costs may not justify reducing their use. One respondent noted that their vendor agreement limits them to a 10 millicurie (mCi) radiopharmaceutical dose per patient. Newer PET-CT units designed for a lower radiopharmaceutical dose enables a single 10 mCi dose to be used for up to 14 patients, resulting in potential savings of more than $5,000 daily in radiopharmaceutical costs. However, existing agreements with 1 respondent's facility and its radiopharmaceutical provider prevents a 10 mCi dose from being used with more than 1 patient and acts as a disincentive to investment in these innovations. Another respondent noted that Health Canada regulatory requirements for good manufacturing practices and new requirements for sterility testing have driven up the cost of radiopharmaceuticals.

A respondent noted that for radiopharmaceuticals that are produced at a single site in Canada, such as florbetaben F-18, logistical complications (short half-life and short expiry time compounded by ground and air transport delays) can render these radiopharmaceuticals as effectively unavailable for PET-CT units that are not local. Others reported cyclotron capacity issues impacting their ability to produce radiopharmaceuticals, which are discussed more fully in this report under Cyclotron Capacity.

Novel Radiopharmaceuticals

Respondents were asked if they were aware of any issues related to the availability and production of novel PET-CT radiopharmaceuticals that may impact patient care and/or the delivery of PET-CT services. Most respondents (15 out of 18) stated they were aware of issues, most of which centred around different barriers to access.

Seven respondents stated there were challenges in making novel radiopharmaceuticals available to patients. Four respondents noted that although novel radiopharmaceuticals are approved and used as a standard of care in other jurisdictions, they are not yet approved in Canada and can only be used in clinical trials. Regulatory approval in Canada requires a producer to file a Health Canada Notice of Compliance (NOC) for a novel radiopharmaceutical to be considered for routine clinical use. A respondent noted that whether a producer is incentivized to do so depends on business

or economic considerations, if they are interested in distributing the novel tracer outside of their institution, and if they have an adequate human resource capacity to support an NOC submission. Obtaining access to these radiopharmaceuticals was reported by 3 survey respondents as a slow process and it often depends on external funding from tertiary centres and research trials.

For radiopharmaceuticals approved by Health Canada, lack of funding for their use and the transition to new radiopharmaceuticals was noted as a barrier to access by 5 respondents, with 1 respondent noting that a clinical trial in their province with ^{68}Ga-DOTATATE is dependent on external funding from their hospital foundation. Four survey respondents reported that novel radiopharmaceuticals can be very expensive and 2 noted that packaging requirements prevent the extraction of more than 1 dose from a single vial, which promotes wastage. As with the issues reported with routine radiopharmaceuticals that can disrupt PET-CT service delivery, logistical issues like problems with vendors' production machinery or transportation were reported.

Six respondents noted that PSMA radiopharmaceuticals for prostate cancer are only available under clinical trials and 5 respondents reported the same scenario for ^{68}Ga-DOTATATE for neuroendocrine tumours.

One respondent commented that novel radiopharmaceuticals are also more complex compared to conventional radioisotopes and need to undergo expensive and complicated quality control processes. As well, expertise is required to navigate the clinical trial approval process.

Cyclotron Capacity

Respondents were asked if they had concerns related to cyclotron capacity that may impact patient care and/or the delivery of PET-CT services. Most respondents (14 out of 18) stated they were aware of concerns with cyclotron capacity, with an overall focus on continuity of service and ability to manage increased demand.

Among the 14 respondents who reported cyclotron capacity concerns, the most commonly reported concern echoed by all provinces that have a single cyclotron (6 provinces; another province does not have a cyclotron) is that unplanned downtime, due to technical problems or unanticipated maintenance, can create a "single point of failure," resulting in all patient appointments across the province being cancelled for the day. A respondent from 1 province with several cyclotron options noted that while there were no direct concerns regarding cyclotron capacity, most cyclotrons operate as part of academic partnerships (versus primarily to support clinical supply), where radioisotopes are provided by the vendor(s) using a centralized model for production and distribution. Two provinces that are geographically remote noted that when their cyclotron is down, other vendors may not be able to supply radiopharmaceuticals for short-term orders.

Three respondents noted that Health Canada approval of cyclotron-produced ^{68}Ga and PSMA agents could potentially improve access to care for patients but would put pressure on existing capacity. One respondent commented that newer, higher-yield automated synthesizer units are still awaiting Health Canada approval.

Three respondents noted that insufficient staffing levels impact cyclotron capacity, with 1 respondent noting it affects patient care by limiting clinical use to an average of 4 days per week and another noting that there is a lack of funding to support staff training. Two respondents stated that they have sufficient capacity now, but that this may change if demand continues to increase.

Concerns were noted about the large initial capital expenditure and significant operating costs of cyclotrons, as well as the significant planning required around the placement of equipment and the scheduling of time for the regulatory oversight by the Canadian Nuclear Safety Commission. From a technical perspective, the following comments were made: cyclotrons with a single hot cell (a shielded nuclear radiation containment chamber where the chemical reaction takes place to manufacture the radiopharmaceutical) at 1 site limit cyclotron production to a single product per day, limited production of ^{82}Rb and PSMA radioisotopes restrict patient access to optimal care, hardware issues can result in lower yield, and older equipment requires more downtime.

Education and Training

Respondents were asked if they had concerns related to education and training that may impact patient care and/or the delivery of PET-CT services for different occupations (imaging physicians, technologists, medical physicists, and cyclotron operators and maintenance staff). While responses varied across different occupations, themes that were commonly mentioned across all, included the lack of funding for training; the limited number of scanners, which may limit training opportunities; and the potential need to expand training for new radiopharmaceuticals and new protocols.

Diagnostic Imaging Physicians

Most respondents (11 out of 18) reported challenges related to the education and training for diagnostic imaging physicians. Several stated there is a shortage of radiologists and nuclear medicine physicians, especially dual-trained physicians who are certified to conduct PET-CT scans, and that this may be due, at least in part, to increased hiring demand. One respondent commented that, while nuclear medicine residencies and fellowship training programs now often include PET as part of standard training, there are few training sites overall for accredited nuclear medicine residencies and fellowships. Physicians may also require additional training on new indications and new radiopharmaceuticals (e.g., their use and interpreting scans), as well as training for managing spills and contamination events, improving patient preparation to reduce the frequency of non-diagnostic scans, and enhancing reporting criteria.

Technologists

Seven respondents reported concerns regarding education and training for technologists, with a further 3 respondents commenting that the expansion of PET-CT to new radioisotopes will create further education and training needs. The most common reported issue was that most technologists are trained in nuclear medicine and need additional training for PET-CT, and there are limited programs in Canada that provide PET-CT training for technologists.

Medical Physicists

Most respondents (15 out of 18) stated they were not aware of concerns related to the education or training of medical physicists. The few reported concerns noted by respondents included a lack of funding for training and a limited number of PET-CT units to train on. Two respondents noted that the approval of novel radioisotopes may create education and training needs for medical physicists.

Cyclotron Operators and Maintenance Staff

Some respondents (7 out of 18) stated they were aware of concerns about the training of cyclotron operators and maintenance staff. The primary concern related to a lack of training programs for cyclotron operators and radiochemists in Canada. It was noted that many are trained in other occupations and require in-house, on-the-job, training. It was noted that the development of a formal education program in Canada may help with cyclotron capacity. One

respondent commented that staff need to keep abreast of Health Canada standards for good manufacturing practices, which essentially requires retraining in radiopharmaceutical production. Respondents also reported some issues that are common across other occupations, such as requiring training for novel radiopharmaceuticals and the limited number of cyclotrons that can be used for training opportunities.

Human Resources Capacity

Respondents were asked if they had concerns related to human resources capacity that may impact patient care and/or the delivery of PET-CT services for different occupations (imaging physicians, technologists, medical physicists, and cyclotron operators and maintenance staff). Many of the responses overlap with those reported concerns related to education and training. Most respondent reported human resources capacity issues for at least 1 position, with an emphasis on technologists. An issue that was reported across multiple positions was a shortage of staff created by an increased demand for PET-CT (due to the installation of additional PET-CT units and expanded clinical indications). What follows is a summary of some of the commonly reported human resources issues for specific occupations.

Diagnostic Imaging Physicians

Six respondents reported issues related to human resources capacity of diagnostic imaging physicians and radiologists. Two respondents commented that there is a short-term gap in trained staff due to the upcoming retirement of a wave of nuclear medicine physicians. One respondent noted that, in the future, if physicians need to physically attend radiopharmaceutical treatment settings, this will impact their ability to attend to their other responsibilities.

Two respondents also noted issues related to recruiting physicians who are dual-trained in nuclear medicine and radiology. This skill is in high demand across Canada (except Quebec, where single-specialty nuclear medicine is still predominant).

Another respondent noted that retention of trained physicians is challenging and that if a centre is not using the new innovations that their physicians were trained on, these same physicians will often relocate to centres where there is availability and capacity for expanded indications and where the innovations they trained on have been adopted.

Technologists

Most respondents (13 out of 18) reported a shortage of nuclear medicine technologists trained in PET. The shortage of technologists may also be due to increased hiring demand prompted by the recent installation of new PET-CT units that are ready for operation and increased clinical demand for currently approved indications. this shortage may also be a result of the new clinical indications for PET-CT that continue to expand.

Medical Physicists

Most respondents (15 out of 18) stated they were not aware of any issues for human resources capacity related to medical physicists. A minority, however, stated that there is a shortage of human resources, especially as new PET scanners are being installed and upgraded, and will require more medical physicist assistance. It was noted that additional staff and training may also be needed as new radiopharmaceuticals are introduced into clinical practice.

Cyclotron Operators and Maintenance Staff

Responses were mixed regarding human resourcing for cyclotron operators and maintenance staff, with 10 respondents reporting no issues with human resources capacity and the remaining stating they were aware of staff shortages. Three respondents reported shortages with radiochemists, radiopharmacists, and radiotechnologists because of limited funding and training programs.

One respondent commented that the development of a formal training program in Canada would help address anticipated shortages in cyclotron operators. They also noted that it is challenging to recruit new staff. Another noted that cyclotron and radiopharmacy operators have also had to catch up to Health Canada standards concerning good manufacturing practices (which involves retraining in the full scope of pharmaceutical production). Another noted that many staff are trained in-house and losing 1 such staff member can put an entire program in jeopardy. It was also reported that there was inadequate staffing for novel radiopharmaceutical synthesis development and support of clinical trials.

Other Human Resources Positions

Other positions with reported shortages were support staff such as clinical trial coordinators, clerical staff, clinical trial nurses, and clinical trial technologists. Support staff are needed for regulatory affairs and requirements for current products, novel tracer development, and new drug submissions (e.g., NOC, Drug Identification Number [DIN]).

Other Issues

Respondents were asked if there were other concerns not addressed elsewhere in the survey that may impact patient care and/or the delivery of PET-CT scans. Reported issues included a lack of space to safely deliver radiopharmaceuticals (particularly newer radiopharmaceuticals with longer half-lives), restrictive guidelines, some challenges with the radiopharmaceuticals approval pathway, and the absence of a systematic triage process for PET-CT requests, which may be a cause of inefficiency and longer wait times. Infrastructural changes may be needed based on changes in PET-CT technology advances or changes in policy (e.g., if more patients are scanned per day, a facility may need to increase the number of uptake rooms to accommodate the expanded patient volume).

Conclusion

Numerous technological innovations have been developed that improve diagnostic confidence by enhancing image quality, reducing scanning time, and lowering radiation dose. These innovations continue to expand the uses of PET-CT for cancer and other indications. The regulatory approval of novel radiopharmaceuticals will further expand the uses of PET-CT beyond traditional diagnostic capabilities to include therapy. With wait lists already past clinically recommended targets for oncology exams and many non-oncology exams remaining unfulfilled, Canada's existing PET-CT infrastructure is experiencing challenges managing existing need and may have issues with expanded use. Financial investment in all aspects of PET-CT will help to ensure patients receive the best quality care. This investment could start with the procurement of new PET-CT units and investment in the workforce through education and training opportunities, and recruitment and retention policies.

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References

1. Standard operating procedures for PET/CT: A practical approach for use in adult oncology. *(IAEA Human Health Series No. 26)*. Vienna (AT): International Atomic Energy Agency; 2013: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1616_web.pdf. Accessed 2021 Mar 25.
2. Jones T, Townsend D. History and future technical innovation in positron emission tomography. *J Med Imaging (Bellingham).* 2017;4(1):011013-011013.
3. Martinuk S. The use of positron emission tomography for cancer care across Canada: Time for a national strategy. Vancouver (BC): Advanced Applied Physics Solutions (AAPS); 2011: https://www.triumf.ca/sites/default/files/TRIUMF-AAPS-Martinuk-PET-Across-Canada-REPORT.pdf. Accessed 2021 Mar 25.
4. Chao YS, Sinclair A, Morrison A, Hafizi D, Pyke L. The Canadian Medical Imaging Inventory 2019-2020. *Can J Health Technol.* 2021;1(1). https://cadth.ca/sites/default/files/ou-tr/op0546-cmii3-final-report.pdf. Accessed 2021 Feb 17.
5. Government of Canada — Action for Seniors report. Ottawa (ON): Government of Canada; 2014: https://www.canada.ca/en/employment-social-development/programs/seniors-action-report.html. Accessed 2021 Mar 25.
6. Enhancing patient care through medical imaging. Ottawa (ON): Canadian Association of Radiologists; 2019: https://www.ourcommons.ca/Content/Committee/421/FINA/Brief/BR10596272/br-external/CanadianAssociationOfRadiologists-e.pdf. Accessed 2021 Mar 25.
7. López-Mora DA, Lagos LA, Estorch M, Carrio I. Future challenges of multimodality imaging. *Recent Results Cancer Res.* 2020;216:905-918.
8. Gillies RJ, Kinahan PE, Hricak H. Radiomics: images are more than pictures, they are data. *Radiology.* 2016;278(2):563-577.
9. Gomes Marin JF, Nunes RF, Coutinho AM, et al. Theranostics in nuclear medicine: emerging and re-emerging integrated imaging and therapies in the era of precision oncology. *Radiographics.* 2020;40(6):1715-1740.

ABOUT CADTH

CADTH is an independent, not-for-profit organization responsible for providing Canada's health care decision-makers with objective evidence to help make informed decisions about the optimal use of drugs and medical devices in our health care system.

CADTH receives funding from Canada's federal, provincial, and territorial governments, with the exception of Quebec.

October 2021

CADTH Evidence Driven.

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