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Canadian Medical Imaging Inventory Service Report

Portable MRI for Use at the Bedside

Context

Recent innovations in MRI focused on advancements in low-magnetic-field technology, have brought MRI to the point of care.[1] A portable MRI (pMRI) unit can be wheeled to the bedside, allowing the acquisition of clinically meaningful examinations that enable physicians to diagnose and monitor patients[2] even in the presence of ferromagnetic equipment.[3]

The device is not intended to replace conventional MRI[4]; rather, pMRI can be used to provide enough information to inform immediate clinical management of patients for some clinical indications.[2] It is currently used clinically for brain imaging,[3,5] although future possible clinical applications for pMRI could be much broader.[6]

Portable MRI has the potential to improve patient outcomes by providing useful imaging that is quick, safe, accessible, and cost-effective.[1,7] It may be used in a variety of unconventional settings, which may help reduce health inequities.[8] As well, pMRI may help reduce wait lists in overburdened imaging departments[9] by maximizing the use of conventional MRI for the clinical indications for which it is most needed.

Objective

This report summarizes information on pMRI. The key objectives are as follows:

- to describe the technology
- to determine the main uses of pMRI
- to identify its availability and the extent of use in Canada.

About This Document

This document summarizes information identified through a limited literature search.

Results

The Technology

A pMRI system can be wheeled directly to the bedside where it covers the patient's head. It is powered through a standard electrical wall outlet and is controlled through a wireless tablet.[10] The system uses a permanent magnet that precludes it from needing sophisticated cooling services.[11] The radiofrequency transmitter and receiver coils are supported inside the gantry with patient-specific customized fittings.[12,13] The small footprint of the system allows it to be moved easily by a single person within space-constrained settings[11] without disruption to workflow.[12]

Unlike most conventional MRIs, pMRIs can function in the presence of common medical ferromagnetic devices, including ventilators, infusion pumps, electrocardiogram monitors, dialysis machines, and compressed gas tanks, but should remain outside the 5 gauss line (a safety line drawn around the perimeter of the main magnet of a MRI unit).[8] Portable MRI also permits bedside imaging of individuals with implanted medical devices that may not be compatible with conventional MRI,[14] such as defibrillators, pacemakers, cochlear implants, and nerve stimulators.[6] The open geometry design of the scanner allows for easy access to IV lines, ventilation tubing, and intraventricular drains during examinations.[7]

The image quality from a pMRI is lower than that provided by conventional MRI, and may be vulnerable to high interference noise from medical equipment in the room and from patient motion inside the device.[8,15] Software upgrades[8] and processing reconstruction technology,[8] including deep learning–based reconstruction approaches,[13] can be used to enhance the quality of the images.[8,13] However, pMRI is not intended to outperform its conventional counterpart.[4,15] Instead, it is intended for use in settings where access to conventional MRI is limited and/or in situations in which the image quality of pMRI is sufficient for physicians to diagnose patients.

Although a whole-brain structural examination can be acquired in less than 10 minutes with pMRI,[16] the total acquisition time for some examinations may be longer compared with conventional MRI.[8] However, the overall time for setup, scan acquisition, and patient removal from the system may still be less than that of conventional MRI when taking into consideration time from order placement to completion and intrahospital transport-associated delays.[8]

Neither patients nor staff experience adverse events while the pMRI is in use and they can safely remain in the hospital room during scan acquisition.[3,7] Portable MRI does not require a licensed medical radiation technologist to operate the scanner as required with the more complex conventional systems; instead, it can be operated by any non-credentialled staff member with basic training.[8]

Clinical Uses

Currently, pMRI is only available for brain imaging,[6] and research is ongoing to determine its sensitivity for detecting neurological investigations.[17]

Portable MRI has been used for the initial detection and characterization of intracerebral hemorrhage[3,7] and to investigate brain injury in patients with severe COVID-19. For patients with COVID-19, acquiring images with conventional MRI may be challenging or not possible if the patient is too unstable to be safely transported to the radiology department.[12] By avoiding the transfer of patients with COVID-19, the risk of disease transmission is reduced. The pMRI also is easier to clean compared with conventional MRI; therefore, it can potentially scan more patients because it is quicker to clean.[18]

Other potential uses of pMRI may include extremity and neonatal imaging, as well as more diverse emergency and urgent care indications, such as detection, delineation, and serial monitoring of soft tissue pathologies (e.g., pleural effusions, extremity abscesses requiring drainage, or subdural or epidural hematomas) or infections, or to provide guidance for interventional procedures (e.g., catheter placement, lumbar punctures, or biopsies).[2,19] Further research on pMRI will help to better characterize its role in radiology and the clinical applications for which it is appropriate.[6] As well, future design modifications are anticipated to expand its usability.[4]

Who Might Benefit?

Patients in the Emergency Department and Intensive Care Unit

Portable MRI is primarily used in the emergency and critical care settings where patients often require urgent neuroimaging to rule out a wide variety of intracranial problems.[12,6] Critically ill patients who require an MRI may be too unstable to be transported to a centralized dedicated radiology centre where a conventional MRI is housed.

Transporting patients to a conventional MRI presents numerous challenges that pMRI circumvents. A transfer can potentially compromise patient connection to monitoring equipment and IV lines and may result in endotracheal tube dislodgment.[11] This can lead to secondary injuries including airway displacement, oxygen desaturation, hypotension or hypertension, increased intracranial pressure, and hypoxia.[8] The risks inherent in the transfer are reported to occur in up to 70% of cases, even when patients are under the supervision of a well-trained transport team.[7,6]

The transportation process is time-consuming and labour-intensive, especially for patients on isolation precaution.[12] It includes coordinating clinical schedules and the staff to support the transfer process. It also puts strain on nurses who may be caring for multiple patients.[8]

Before entering the MRI suite, critical care patients must be screened carefully to ensure that metal artifacts in their supporting equipment will not become ferrous projectiles.[8] As well, physiologic monitoring of the patient may be challenging during the acquisition of a conventional MRI examination because the sequences run on the MRI may interfere with the monitor signal and the electrocardiogram cannot be reliably interpreted.[8] It is in this capacity that pMRI may be able to address an unmet need in the delivery of advanced medical imaging.

Portable CT (pCT) has been introduced into the clinical setting; however, from a neuroimaging perspective, the lower spatial resolution, amplified noise, and higher radiation dose compared with its fixed-location counterpart makes it disadvantageous for broad adoption in a hospital setting.[7] As well, pCT requires trained CT technologists and collaboration with other staff (such as ICU nurses and critical care technicians) to operate the device and execute the examination.[8] The smaller size of pMRI, which is approximately a third of the size of a portable pCT,[11] may make it easier to deploy in the confines of an intensive care unit.[8]

Other Potential Patient Groups

The device can potentially be used with other patient groups, such as those at stroke units and rehabilitation centres, outpatient neurology clinics, and nursing homes as well as with the pediatric population and patients who require ground and air ambulance assistance.[2,6,20]

The lower cost of pMRI, and that it can be operated by non-credentialled staff, may contribute to reducing health inequities by expanding access to advanced medical imaging to unconventional settings such as rural and underserved areas or other resource-limited settings, including disaster and war zones.[8,11]

Patient Preferences

Many people cannot undergo a conventional MRI because they are claustrophobic.[6] Some patients with claustrophobia may tolerate pMRI better than conventional MRI due to its open geometry design and that only the head is encased in the device rather than the whole body.[8,21] As well, the low acoustic noise levels generated during a pMRI scan may be safer for patients; this removes the risk of permanent or temporary hearing loss that may be experienced with conventional MRI.[21]

Health Canada Approval

The first pMRI was approved by Health Canada in February 2020,[22] and at least 1 type of Health Canada–approved pMRI includes advanced reconstruction software that uses deep learning.[23]

Use in Canada

At least 3 pMRI systems have already been distributed to hospitals across Canada to investigate possible uses in research and clinical settings. This includes the Djavad Mowafaghian Centre for Brain Health at the University of British Columbia[24] where pMRI is being investigated for its use in imaging multiple sclerosis.[25] A 2-year pilot program in Northern Ontario at the Weeneebayko General Hospital in Moose Factory is investigating pMRI primarily for brain imaging, particularly for the assessment of stroke and infection and monitoring of neurological diseases and injury. Usually, patients in this region travel to Kingston for non-emergent exams at a cost of $600,000 annually to the health care system.[19] In Nova Scotia, the Queen Elizabeth II Health Sciences Centre is also piloting a pMRI in their emergency department.[26]

Cost

The cost of a pMRI ranges from US$50,000[27] to US$100,000[28] compared with the cost of a conventional MRI, which starts at US$1 million.[27] With pMRI, costly infrastructural configuration expenses as well as high maintenance costs for helium refills and regular services are avoided.[21]

Conclusion

Portable MRI provides a means of delivering urgent imaging to patients in settings where access to conventional MRI is limited or infeasible. This may help reduce disparities and inequities in health care, accelerate patient management, optimize strained resources, and help reduce wait lists.

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