Feasibility and Cost Analysis of Portable MRI Implementation in a Remote Setting in Canada

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Disclosures

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Friends of Parkinson's Inc., Advisory Board Member

WebDoctors.com, Advisory Board Member

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Project Background

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2020

HYPERFINE

Portable MR Imaging

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Weeneebayko Area Health Authority

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Hudson Bay
Belcher Islands
James Bay
Akimiski Island
Kashechewan
Albany River
Moosonee
ONTARIO
QUEBEC
NORTH
0
100
200
Kilometres


MANITOBA
Fort Severn
Hudson Bay
ONTARIO
Peawanack
Webequie
Attawapiskat
Balmertown
Red Lake
Ogoki
Fort Albany
Moosonee
Keewatin
Sioux Lookout
Kenora
Dryden
Nakina
QUEBEC
White Fish Bay
Longlac
Hearst
Rocky Bay
Kapuskasing
Red Rock
Terrace Bay
Thunder Bay
Cochrane
Iroquois Falls
Marathon
Minnesota
Lake Superior
Wawa
Chapleau
Timmins
Haileybury
Sault Ste. Marie
Elliot Ridge
Michigan
Sudbury
Massey
North Bay
Pembroke
Huntsville
Ottawa
Parry Sound
Lake Huron
Wisconsin
Perth
Owen Sound
Brockvil
Barrie
Petersborough
Michigan
Toronto
Oshawa
Brampton
Lake Ontario
Kitchener
Hamilton

Introduction

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Introduction

- Equitable access to health care is a fundamental principle of the Canadian healthcare system. However, persistent inequity in healthcare delivery exists, particularly in Northern communities where **remote geography is one contributing factor**.
- Weeneebayko Area Health Authority (WAHA) provides health services to approximately 12,000 predominantly Indigenous people, along the James Bay and Hudson Bay coastal regions.
- **At Weeneebayko General Hospital (WGH), there is no MR imaging available. Currently, patients requiring MRI are transported via daily charter flights bringing patients 841 km (522 miles) from WGH to Kingston Health Sciences Centre (KHSC) in Kingston.**

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Introduction

- Transportation of patients from a remote setting is complex and is associated with a substantial increase in risk.
- The ability to perform cerebral imaging locally would reduce such risks.
- An additional consideration is the financial implications of patient transport within the framework of limited healthcare resources.

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Introduction

- Up until recently, the technology for portable MRI has not existed. Health Canada has recently provided licensing for a portable, POC low field (0.064T) MRI that is capable of producing images for a number of neurological indications.
- The portable MRI has been used in academic centers throughout the United States as of 2019 and in COVID intensive care units for cerebral imaging.
- In 2021, portable MRI has also been successfully deployed to a low resource setting in Malawi (Bill and Malinda Gates Foundation).

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Introduction

- The use of this technology in a remote setting offers the potential advantages of reduced transportation of patients, improved triaging, as well as the ability to perform frequent re-imaging, without radiation exposure.
- However, **there are no data to date on the feasibility of using portable MRI in a remote setting, such as in Canada's North.**
- Although a systematic review has been conducted comparing mobile versus fixed MRI, **a cost analysis from the perspective of a Canadian context in a remote setting has also not been previously performed.**

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Introduction

- We sought to evaluate a) the **feasibility**, and b) the **cost analysis** of deploying portable MRI in a remote setting in comparison to transporting patients to a larger centre.
- We defined **feasibility** as:
  - The local capacity to perform imaging in a remote setting.
  - The ability to capture images of patients that are of sufficient quality to be interpreted by KHSC staff neuroradiologists.
  - The ability to transfer and report images of patients in a timeframe meeting or exceeding that of Department practice for urgent and emergent scans.

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Methods

Methods

- Single center cohort study
- After receiving Investigational Testing Authorization – Class II by Health Canada (Sept 14, 2021), an FDA approved portable MRI scanner [**Swoop Portable MR** Imaging System, RC8 software; **ultra-low field (0.064 T), Hyperfine**] was delivered via rail and then by barge to the island of Moose Factory, Ontario.

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Methods

Ethics

- WAHA Ethics Committee approval.
- Queen's University Research Ethics Board approval was received (TRAQ #: 6034296)
- The study was conducted in alignment with the **OCAP Principles** for governance of Indigenous Health Data (that of ownership, control, access, possession, and use).

Methods

Scanning Protocol and Image Data Transfer

- All clinical indications for portable MRI were documented. Following each scan, an acceptability checklist was administered to the WGH staff performing the scan to assess local capacity to perform imaging and document any adverse events.
- A secure PACS link was established between WAHA and KHSC for transfer and storage of DICOM images from the portable MRI to KHSC PACS.

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Methods

Scanning Protocol and Image Data Transfer

- All imaging was reported by board-certified Neuroradiologists at KHSC, providing 24/7 coverage. Prior to study start, all Neuroradiologists received training on portable MRI through online seminars provided by the vendor.
- All pathologies observed on imaging were documented in standardized reports, stored on KHSC servers.
- Report turnaround time was determined by the time from image acquisition to radiology report generation.

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Methods

Cost Analysis

Dr. Ana Johnson

- Professor, Public Health Sciences, Queen's University
- Health Services and Policy Research Institute Senior Scientist, Institute for Clinical Evaluative Sciences (ICES)

Methods

Cost Analysis

- A cost analysis was conducted from the healthcare system's perspective in 2022 Canadian dollars (CAN) (http://www.statcan.gc.ca).
- It included costs borne out of the healthcare system and excluded any patient related costs, such as out-of-pocket costs (parking, local travel, childcare), or lost income.
- One-way sensitivity analysis was conducted. Any costs related to evaluation research were excluded.

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Methods

Cost Analysis

- The cost analysis conducted here is applicable to locations that already have an existing radiology infrastructure.
- Resource utilization, procedure related costs and patient and nurse direct travel costs were examined.
- A budget impact analysis was conducted over 5 years between 2022 and 2026, examining difference in costs of gradually adopting portable MRI in a remote community in Canada compared with fixed MRI only as standard of care.

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Results

Results

Feasibility

- Portable MRI was successfully delivered and implemented at WAHA
- From unboxing to testing, the total time for device setup was 3 hours. 14 staff members received training on operation (8 physicians, 3 nurses, and 3 x-ray technologists). Training sessions were on average 45 minutes

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Results

- Investigational Testing Authorization – Class II approval was received from Health Canada for up to **50 patients**. All patients who received a portable MRI from November 14, 2021, to September 7, 2022, approximately a 10-month period, were included in the study. No patients were excluded.
- The preliminary results are presented for the **first 25 patients** who underwent portable MRI examination. Specific demographic characteristics of these patients are not included in alignment with the OCAP principles.

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Results

- The most common clinical indication for imaging was **acute stroke** (n = 5) (Table 1).
- The studies were reported by 4 staff neuroradiologists at KHSC (O.I. = 10, I.S. = 8, D.T. = 3, J.O.J = 2).
- No acute infarction, hydrocephalus, herniation, or clinically significant pathologies were identified in any of the studies (Table 2).
- 19 of the studies were reported as normal.

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Results

Image findings	No. of studies
Normal portable MRI of the brain	19
Mild frontoparietal volume loss	3
Few cerebral white matter lesions	1
Prominent left transverse and sigmoid sinuses as an anatomic variant	1
IT connection issues preventing scanning	1

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Results

Technology Adoption

- There was not a substantial change in MRI referral volumes or clinical indications with the implementation of portable MRI.
- For the same 10-month period a year prior to portable MRI implementation (November 14, 2020–September 7, 2021) there were **30** MRI head studies performed (12 in Kingston, Ontario and 18 in Timmins, Ontario).

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Results

Technology Adoption

Clinical indication	No. of portable MRI studies	No. of fixed MRI studies from the year prior
Acute stroke	5	5
Head iInjury	3	0
Dizziness	2	1
Hearing loss	5	1
Follow-up post-stroke	1	0
Cranial neuropathy	1	1
Epilepsy	1	4
Headache	1	2
Numbness/tingling	2	3
Memory lapses	1	0
Pseudotumor cerebri	1	0
Multiple sclerosis	1	2
Post-operative surveillance	0	4
Tumor	0	5
Syncope	0	1
Pineal cyst follow-up	0	1
IT connection issues preventing scanning	1	0
Total	***25***	***30***

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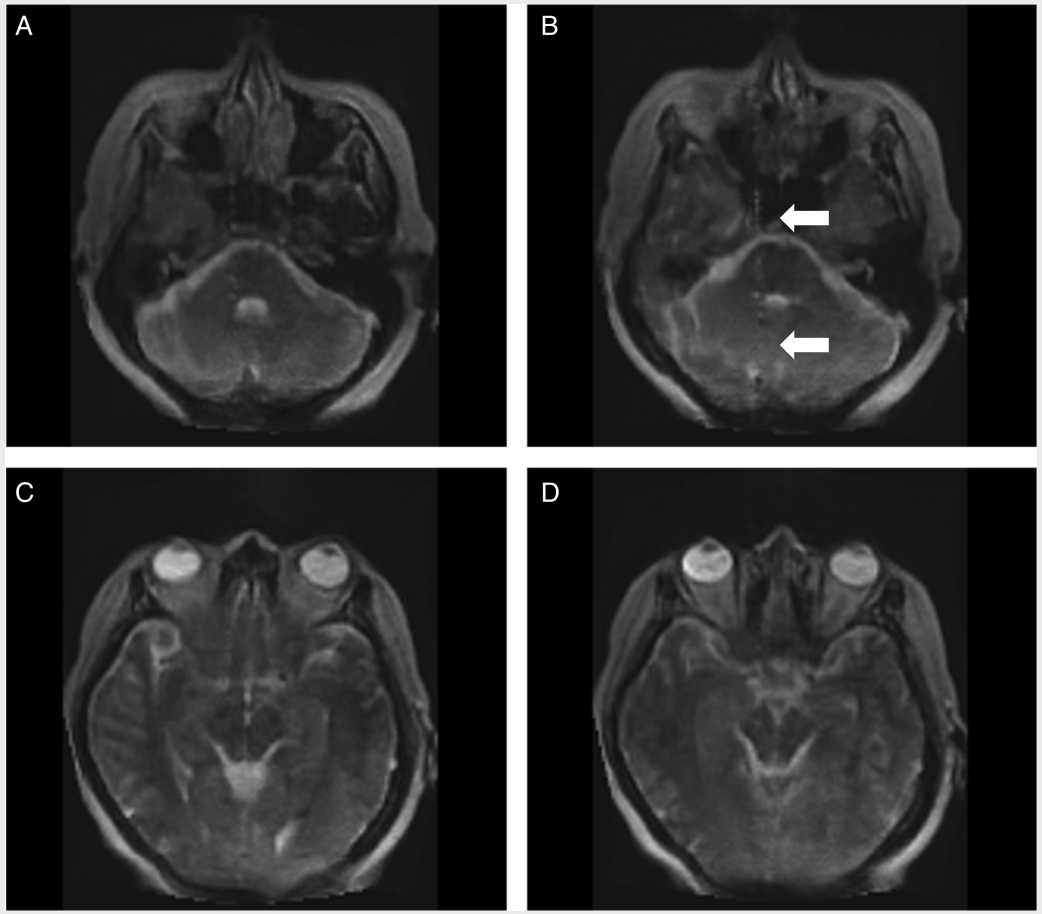
Results



- Select T2 images (a-d) through the brainstem show normal appearance of the midbrain and pons. There is no mass in the cerebellopontine angle cisterns.
- Images from portable MRI are of sufficient quality for diagnostic interpretation.
- This case also depicts a zipper artifact on image b (arrows).

A patient presenting with two weeks of sudden intermittent dizziness with left ear tinnitus and left eye decreased vision.

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Results

- Based on the indication for imaging and the results of the portable MRI, if the portable MRI was available for routine clinical use:
  - **14 patients (56%) would not require transfer** to a center with MRI imaging due to the availability of portable MRI onsite.
  - The median time from scan completion to the time reported by a neuroradiologist for non-urgent indications was **8.1 hours** (IQR, 1.5–22.2 hours).

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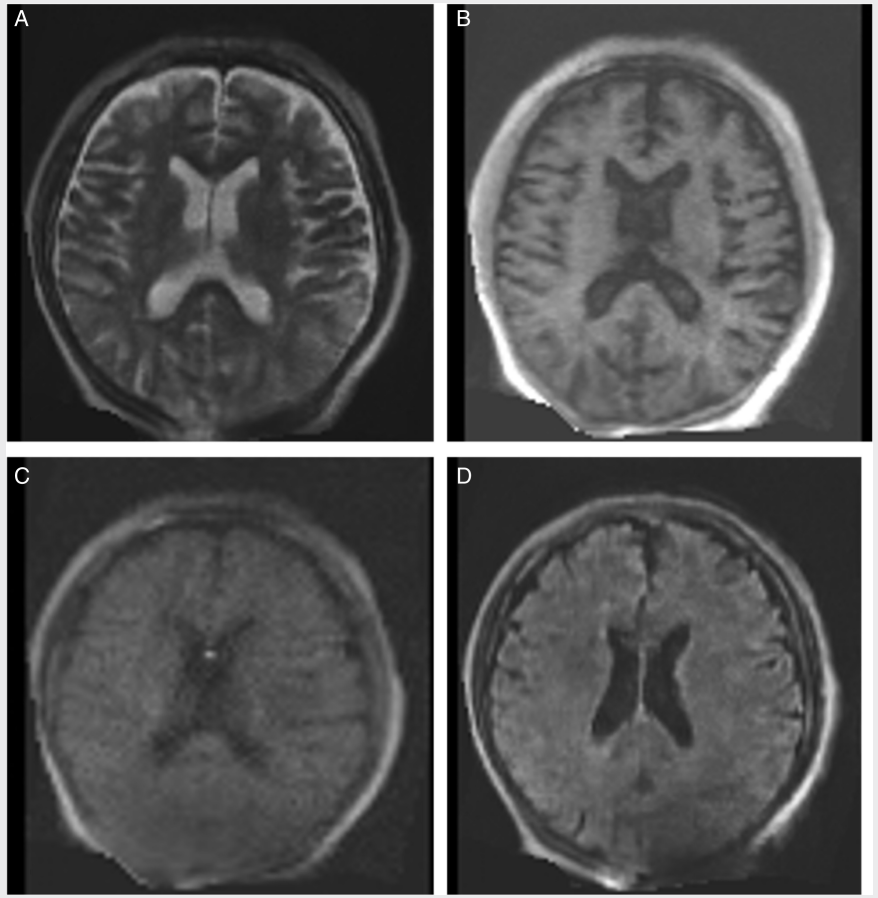
Results



- Axial T2 (a), Axial T1 (b), Axial DWI (b = 900 s/mm^2) (c), and Axial FLAIR (d) at the level of the lateral ventricles show normal appearance of the cerebrum, apart from mild volume loss affecting the frontal and parietal lobes. **The diffusion sequence (c) shows no acute infarction.**
- It is postulated that **this patient would not require transfer** to a facility with MR imaging based on the results from the portable MRI.

A patient presenting with headache and left arm paresthesia. The patient's CT taken 24 hours prior was negative, and they were started on dual antiplatelet therapy.

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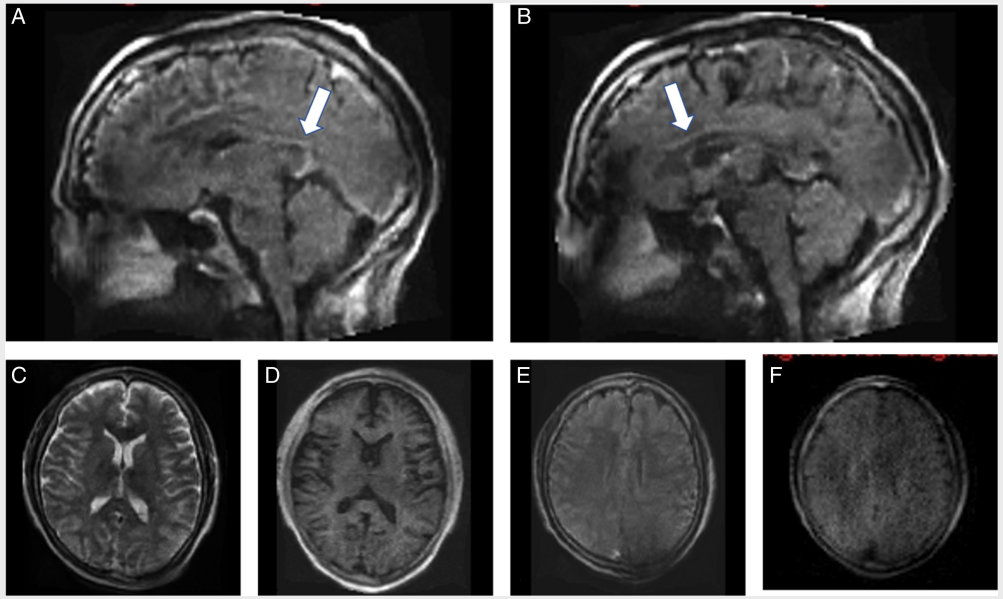
Results



- The portable MRI study is normal, with no signs of large demyelinating plaques. Sagittal FLAIR (a) and (b) demonstrate normal appearance of the corpus callosum (white arrows) and provide an example of the multiplanar capability of portable MRI. Axial T2 (c), axial T1 (d), axial FLAIR (e), and axial DWI (b = 900 s/mm^2) (f) demonstrate normal cerebral white matter at the level of the lateral ventricles and corona radiata.
- The image quality is sufficient to confidently exclude medium to large-sized plaques; however, the resolution is not sufficient for confident identification of small plaques.
- **As such, this patient would require transfer for neuroimaging on fixed MRI for complete evaluation.**

A patient presenting with left and right upper extremity numbness.

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Results

Total 1-Year Cost Savings

	Fixed MRI		Portable MRI	
	Cost per patient (N=50)	Total costs	Cost per patient (N=50)	Total costs
Total costs	$26,105	$1,305,258	$9,008	$450,417
Per patient cost savings	**$17,097**			
Total cost savings	**$854,841**			

- Total costs of fixed MRI were approximately triple compared to portable MRI
- Cost per patient for fixed versus portable MRI was $26,105 and $9,008, respectively
- Total cost savings from uptake of portable versus fixed MRI were $854,841

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Results

Budget Impact Analysis (Years 1 – 5)

- Projected 5-year savings of $7,835,162

Scenario 1: Fixed MRI only			Scenario 2: Uptake of portable MRI		Budget impact
Year	Number of patients using fixed MRI	Fixed MRI expenses	Portable MRI uptake	Portable + Fixed MRI expenses	Savings from implementing portable MRI
1	100	$2,610,516	50%	$1,755,675	$854,841
2	100	$2,696,663	75%	$1,372,087	$1,324,575
3	100	$2,785,652	100%	$961,270	$1,824,382
4	100	$2,877,579	100%	$992,992	$1,884,586
5	100	$2,972,539	100%	$1,025,761	$1,946,778
TOTAL		**$13,942,949**		**$6,107,786**	**$7,835,162**

*Over 5 years, savings: $13,942,949 – ($1,979,424 + 4,128,363) = **$7,835,162**

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Discussion

Discussion

Feasibility

- Portable MRI can be successfully implemented in remote communities as it requires limited resources, can be housed and operated in a low-cost environment, and has the ability to transfer images to radiologists who typically may be offsite.
- The setup of the portable MRI at WGH was efficient, only taking 3 hours and not requiring changes to infrastructure, power supply, or magnetic safety considerations.

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Discussion

Feasibility

- A benefit of portable MRI observed was that it did not require extensive training to operate. 14 staff members at WGH received training, only taking an average of 45 minutes.
- Given the high rate of staff turnover, especially in Northern Canadian healthcare settings, the rapid training of new staff is important to the sustainability of a portable MRI program.

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Discussion

Indications for imaging

- Acute stroke was the most common indication for imaging (n = 5). This is also perhaps the most clinically relevant indication, as traditional MRI DWI sequences offer a higher sensitivity in detecting acute blood compared to CT.
  - Kuoy *et al.* found 13% of portable MRI demonstrated acute infarctions that were not apparent on comparison CT scans.
- Access to portable MRI may also be of benefit for other less urgent neurological indications, where patients may otherwise face substantial wait times.
- Limitations due to study size.

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Discussion

Technology Adoption

- As a new technology, portable MRI operation is not covered under the scope of practice for Canadian X-ray technologists or nurses, which could present hesitancy of adoption. Further, the financial remuneration for such services has yet to be implemented.
- In remote settings where staff resources are already limited, staffing factors represent a barrier to the use of portable MRI.
- It is recommended that where possible, a designated staff member other than physicians or nurses is designated the scanning lead and financially compensated.

Discussion

Cost Analysis

- Projected 5-year cost savings are **$7,835,162** and remained substantial after one-way sensitivity analysis
- Literature on costs for portable MRI is scant; one systematic review deemed mobile and fixed CT and MRI cost-effective compared with fixed CT and MRI[1]
- Estimated annual total costs of mobile MRI were 2018 US$1,890,620, higher than our annual portable MRI total costs at 2022 CAN$450,417

1. Mohammadshahi M et a. Iran J Public Health. 2019;48:1418–27.

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Discussion

Study Limitations

- As this is an initial feasibility study, the analysis is limited due to a small sample size. Health Canada approval was obtained for scanning **50** patients, of which the first **25** are presented here.
- Given that the study was initiated under Health Canada Investigational Testing Authorization and prior to Health Canada approval of portable MRI for clinical use, the portable MR images obtained as part of this study were not used in the clinical decision-making pathway.

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Conclusion

Conclusion

- This study may serve as a model to help democratize MRI access in remote areas where conventional MRI is unavailable.
- **Portable MRI implementation is feasible**; however, the clinical utility remains an active area of study.
- Currently, this technology cannot fully replace conventional MRI neuroimaging but may be useful in triaging patients in remote communities and provide timely care.

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Conclusion

- **Projected cost savings are substantial**, largely due to patient transportation costs averted.

“The preliminary study findings can guide the implementation of portable MRI at other Canadian and international sites, especially in remote communities.”

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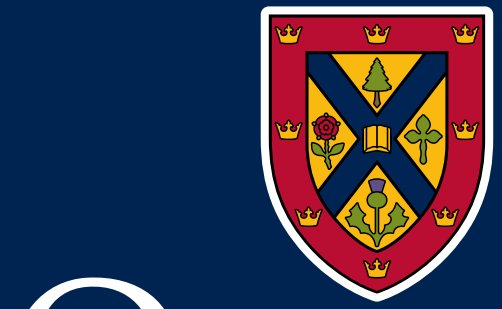

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Thank You

Potential Application of Ultra-low Field Portable MRI in the ICU to Improve CT and MRI Access in Canadian Hospitals: A Multi-center Retrospective Analysis

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Background

- Urgent neuroimaging is commonly required in ICU. Typically, ICU patients are transported to Radiology for assessment in fixed CT and MRI units.
- Resource challenged – both in Radiology and in ICU
- “HHR Divide”

Background

- Portable MRI use in Canadian ICU settings offers the potential advantages of reduced transport risk, earlier diagnosis, improved triaging, as well as the ability to perform frequent re-imaging at the bedside. This frees up time on fixed CT and MRI units, leading to enhanced capacity to perform CT and MRI on other patients.
- Portable MRI use case scenarios in Canadian institutions have not been established and potential beneficial effect on wait times has not been analyzed.

Objective

- To highlight the value of Portable MRI in ICU
- To recommend use case scenarios for portable MRI in ICU patients that may increase capacity for fixed CT and MRI units.
- To assess impact of Portable MRI in ICU on fixed CT and MRI wait lists

Methods

- A retrospective semi-quantitative descriptive analysis was performed using all ICU neuroimaging requisitions (CT and MRI) over a **12-month period** between January and December 2021, at Kingston Health Sciences Centre, Queen's University (Kingston, Ontario) and St. Michael's Hospital, Unity Health, University of Toronto (Toronto, Ontario)
- Indications for portable MRI in ICU patients were established. The number of ICU patients who could potentially undergo portable MRI was determined. Fixed CT and MRI scan times saved were calculated

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Clinical Indications

- Based on the authors collective experience, clinical indications have been proposed for brain imaging performed using portable MRI rather than fixed unit MRI or CT.

Table 1

Subdural hematoma
Epidural hematoma
Hydrocephalus assessment
Extra ventricular drain placement/shunt assessment
Elevated intracranial pressure
Suspected cerebral (ACA, MCA, PCA) stroke assessment and follow-up

Table 1. Proposed clinical indications for brain imaging using portable MRI in ICU patients.

- These indications represent **43.9% and 12.4%** of fixed unit MRI brain scans and **15.8% and 22.6%** of fixed unit CT brain scans at KHSC and SMH, respectively.

Results

- At KHSC, 69 out of 157 non-contrast fixed unit brain MRI scans (**43.9%**) and 140 out of 888 non-contrast fixed unit brain CT scans (**15.8%**) can be performed using the portable MRI method in ICU (Table 2 and Table 3)

- At SMH, 31 out of 250 non-contrast fixed unit brain MRI scans (**12.4%**) and 698 out of 3,094 non-contrast fixed unit brain CT scans (**22.6%**) can be performed using portable MRI in ICU ICU (Table 2 and Table 3)

Results

Re-route from fixed MRI

	Total number of ICU patients undergoing non-contrast fixed Brain MRI (2021)		Expected number of ICU patients eligible for Portable MRI based on proposed clinical indications (Table 1)		Percentage of ICU patients eligible for Portable MRI based on proposed clinical indications (Table 1)	
	KHSC	SMH	KHSC	SMH	KHSC	SMH
January	21	25	9	3	42.9%	12.0%
February	18	22	8	0	44.4%	0.0%
March	20	14	11	3	55.0%	21.4%
April	13	25	3	6	23.1%	24.0%
May	8	21	3	6	37.5%	28.6%
June	7	17	4	3	57.1%	17.6%
July	8	24	3	2	37.5%	8.3%
August	13	17	8	3	61.5%	17.6%
September	14	16	7	0	50.0%	0.0%
October	18	22	7	1	38.9%	4.5%
November	7	20	2	2	28.6%	10.0%
December	10	27	4	2	40.0%	7.4%
Total	157	250	69	31	43.9%	12.4%

Results

Re-route from fixed CT

	Total number of ICU patients undergoing non-contrast fixed CT (2021)		Expected number of ICU patients eligible for Portable MRI based on proposed clinical indications (Table 1)		Percentage of ICU patients eligible for Portable MRI based on proposed clinical indications (Table 1)	
	KHSC	SMH	KHSC	SMH	KHSC	SMH
January	75	337	11	100	14.7%	29.7%
February	55	291	13	88	23.6%	30.2%
March	70	336	5	74	7.1%	22.0%
April	58	342	13	81	22.4%	23.7%
May	62	312	10	71	16.1%	22.8%
June	66	341	7	50	10.6%	14.7%
July	96	219	16	60	16.7%	27.4%
August	84	169	13	14	15.5%	8.3%
September	79	141	12	20	15.2%	14.2%
October	101	177	16	39	15.8%	22.0%
November	77	197	15	45	19.5%	22.8%
December	65	232	9	56	13.8%	24.1%
Total	888	3,094	140	698	15.8%	22.6%

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Results

- Using the combined ICU data from both centers, the number of ICU patients who may be eligible to be performed using portable MRI in ICU:
  - 100 out of total 407 **(24.6%)** fixed brain MRI scans
  - 838 out of 3,982 **(21.0%)** non-contrast fixed brain CT scans
- At our institutions, diversion of select ICU patients to portable MRI would result in an increased capacity of **300** additional outpatient fixed unit MRI and **1,676** additional outpatient fixed unit CT on an annual basis

Conclusion

- Portable MRI implementation in the ICU setting is feasible for a select range of neurological indications
- Based on the combined analysis performed at 2 Canadian centers, a small but significant number of ICU patients could be diverted from conventional practice of fixed unit MRI and CT to portable MRI
- This will have a beneficial effect on wait times at resource constraints sites across Canada

Thank You

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