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Advancing Imaging Care Through Innovation

Potential Application of Ultra Low Field Portable MRI in the ICU to Improve CT and MRI Access in Canadian Hospitals – A Multi-Centre Analysis

Omar Islam (Queen's University), Amy Lin (University of Toronto,
Aditya Bharatha (University of Toronto)



Canadian Association of Radiologists
L'Association canadienne des radiologistes

#CAR2023
www.car.ca

 CARadiologists
info@car.ca

Disclosure of Conflict of Interest

I have a relationship with a for-profit and/or a not-for-profit organization to disclose

- * Rytol Pharma, Scientific Advisory Board Member
- * Friends of Parkinson's Inc., Advisory Board Member
- * WebDoctors.com, Advisory Board Member

**Omar Islam*

Disclosure of Conflict of Interest

- I do not have a relationship with a for-profit and/or a not-for-profit organization to disclose

**Amy Lin*

**Aditya Bharatha*

Learning Objectives

1. Understand the challenges of fixed CT and MRI imaging for ICU patients, contributing to increased wait times
2. Highlight the value of Portable MRI in ICU for a subset of neurological indications
3. Recommend use case scenarios for portable MRI in ICU patients that may free up space and help increase access for fixed CT and MRI units

Background

- Urgent cerebral imaging is commonly required in the Intensive Care Unit (ICU) setting for critically ill patients.
- Assessment for acute changes in level of consciousness, acute stroke, Transient ischemic attack, hydrocephalus, CNS infections, elevated intracranial pressure, and progression of intracranial pathology are some of the common indications for CT and MR imaging in ICU patients.¹

Background

- Typically, if neuroimaging is required, patients are transported from the ICU to the radiology department for assessment in fixed unit CT and MRI.
- Transportation of patients can be complex and is associated with substantial risk.

Background

- Adverse events related to intra-hospital transfer of critically ill patients can be as high as 60%, with serious adverse events occurring in nearly 10% of transports.^{2,3,4,5}
- Serious adverse events can include severe hypoxia and hypotension, accidental extubation, and equipment failure.^{2,6}
- Transport of sick ICU patients requires porter and ICU staff availability, including respiratory technologists, nurses, and/or physicians, all of which are typically resource-challenged.

Background

- Portable MRI (ultra low-field MRI) is a recent technological innovation that allows point-of-care cerebral imaging.



Background

- The Hyperfine™ portable MRI is an FDA and Health Canada approved 64 mT scanner that is capable of producing T1, T2, FLAIR, and diffusion weighted images of the brain.^{7,8}
- The use of this novel technology in Canadian ICU settings offers the potential advantages of reduced transports of patients, earlier diagnosis, improved triaging, and the ability to perform frequent re-imaging at the bedside.⁸

Background

- The potential diversion of patients from traditional MRI and CT units frees up time on fixed unit CT and MRI, leading to enhanced flexibility to perform fixed unit CT and MRI on other patients.
- This can have a positive effect on MRI and CT wait times.

Portable MRI use case scenarios in Canadian institutions have not been established and potential beneficial effect on wait times has not been analyzed

Method

- A retrospective analysis of ICU neuroimaging requisitions was performed over a 12-month period between January and December 2021.
- Study sites: Kingston Health Sciences Centre (KHSC), Queen's University (Kingston, Canada) and St. Michael's Hospital (SMH), Unity Health, University of Toronto (Toronto, Canada).
- We proposed clinical indications where portable MRI was best suited to assess patients in an ICU setting, rather than being transported to Radiology (Table 1).

Method

Table 1: Proposed Clinical Indications for Brain Imaging using Portable MRI in ICU Patients

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

Method

Reasoning behind proposed clinical indications:

- Portable MRI is excellent for assessing anatomical distortions in the brain, allowing confident assessment of subdural and epidural hematomas, ventricular calibre, and shunt placement.
- It can be used in the assessment of suspected or confirmed cases of elevated intracranial pressure due to its ability to assess the ventricular system and identify lesions that lead to mass effect and/or herniation.

Method

Reasoning behind proposed clinical indications:

- Large territory cerebral strokes are well visualized using portable MRI on DWI, FLAIR, and T2-weighted images, using the B900 Diffusion-weighted sequence (slice thickness 5.8mm) and the FLAIR sequence to view cortical signal alteration due to cerebral edema.
- Small posterior fossa (brainstem and/or cerebellar) strokes are less well assessed on portable MRI due to propensity for artifacts in this area. Sensitivity for assessment of these structures, especially the brainstem, may not be sufficient for confident diagnosis.

We therefore suggest limiting stroke assessment to the supratentorial compartment

Method

- We then determined the number of the subset of ICU patients who could potentially undergo portable MRI in ICU instead of fixed CT or MRI in the Radiology department based on the defined clinical indications.
- The resulting potential time saving on fixed unit CT and MRI were then calculated based on established ICU patient average time requirements in fixed unit CT and MRI.
- Fixed unit CT and MRI time requirement was defined as the minutes the units were unavailable for other use because of room preparation, actual scan time, and clean up for ICU patients.

Results

Table 2: Expected number of fixed unit Brain **MRI** scans potentially replaceable by portable MRI in ICU patients (Jan-Dec 2021)

	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
Jan	21	25	9	3	42.9%	12.0%
Feb	18	22	8	0	44.4%	0.0%
Mar	20	14	11	3	55.0%	21.4%
Apr	13	25	3	6	23.1%	24.0%
May	8	21	3	6	37.5%	28.6%
Jun	7	17	4	3	57.1%	17.6%
Jul	8	24	3	2	37.5%	8.3%
Aug	13	17	8	3	61.5%	17.6%
Sep	14	16	7	0	50.0%	0.0%
Oct	18	22	7	1	38.9%	4.5%
Nov	7	20	2	2	28.6%	10.0%
Dec	10	27	4	2	40.0%	7.4%
Total	157	250	69	31	43.9%	12.4%

Results

Table 3: Expected number of fixed unit brain CT scans potentially replaceable by portable MRI in ICU patients (Jan-Dec 2021)

	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
Jan	75	337	11	100	14.7%	29.7%
Feb	55	291	13	88	23.6%	30.2%
Mar	70	336	5	74	7.1%	22.0%
Apr	58	342	13	81	22.4%	23.7%
May	62	312	10	71	16.1%	22.8%
Jun	66	341	7	50	10.6%	14.7%
Jul	96	219	16	60	16.7%	27.4%
Aug	84	169	13	14	15.5%	8.3%
Sep	79	141	12	20	15.2%	14.2%
Oct	101	177	16	39	15.8%	22.0%
Nov	77	197	15	45	19.5%	22.8%
Dec	65	232	9	56	13.8%	24.1%
Total	888	3094	140	698	15.8%	22.6%

Results

Based on the proposed list of clinical indications of portable MRI in ICU settings (Table 1), a small but significant number of brain MRI and CT scans can be performed using portable MRI instead of traditional fixed MRI or CT

- 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.
- At SMH, 31 out of 250 non-contrast fixed unit brain MRI scans (12.4%) and 698 out of 3094 non-contrast fixed unit brain CT scans (22.6%) can be performed using the portable MRI method in ICU.

Results

Using the combined ICU data from both centres, **100 out of total 407 (24.6%)** fixed brain MRI scans and **838 out of 3982 (21.0%)** fixed brain CT scans on ICU patients may be eligible to be performed using portable MRI in ICU

Results

Effect on MRI Wait times

- At our institutions, the average time commitment in the fixed unit MRI is typically **90 minutes** per ICU patient.
- For those **100 ICU patients** at KHSC and SMH (Table 2) who fulfill the selected indications outlined in Table 1, **the total time commitment saved on a fixed MRI unit on an annual basis is 9000 minutes.**

This equates to the total time saved on the fixed MRI on an annual basis at the two centres if these ICU patients are scanned using portable MRI rather than being transported to the fixed unit MRI

Results

Effect on MRI Wait times

- The average time commitment for an out-patient scanned on a fixed unit MRI is typically **30 minutes**.
- If extrapolated based on the potential fixed unit MRI time saved by **diverting 100 ICU patients using portable MRI**, this equates to **300 additional out-patients** (9,000 minutes divided by 30 minutes per out-patient) that can be scanned in the fixed unit MRI on an annual basis, instead of the ICU patients.

Results

Effect on MRI Wait times

Based on the total combined volumes of patients on the MRI wait-lists at our institutions at the end of 2021 (3922 at KHSC + x at SMH), this equates to **x% reduction in MRI wait times**

This can be achieved by diverting a select number of ICU patients using portable MRI

Results

Effect on CT Wait times

- At our institutions, the average time commitment in the fixed unit CT is typically **30 minutes** per ICU patient.
- For those **838 ICU patients** potentially eligible for Portable MRI and therefore avoiding fixed unit CT (Table 3), **the total time commitment saved on a fixed unit CT on an annual basis at KHSC and SMH is 25,140 minutes.**

This equates to the total time saved on the fixed MRI on an annual basis at the two centres if these ICU patients are scanned using portable MRI rather than being transported to the fixed unit MRI

Results

Effect on CT Wait times

- The average time commitment for an out-patient CT scan on a fixed unit CT is typically **15 minutes**.
- If extrapolated based on the potential fixed unit CT time saved by **diverting 838 ICU patients using portable MRI**, this equates to **1,676 additional out-patients** (25,140 minutes divided by 15 minutes per out-patient) that can be scanned in the fixed unit CT on an annual basis, instead of the ICU patients.

Results

Effect on CT Wait times

Based on the total combined volumes of patients on the MRI wait-lists at our institutions at the end of 2021 (2500 at KHSC + x at SMH), this equates to x%
reduction in CT wait times

This can be achieved by diverting a select number of ICU patients using portable MRI

Discussion

- Portable MRI is a novel imaging modality that can play a vital role in the diagnosis and management of neurological conditions.
- Portable MRI can be applied to a select group of ICU patients.

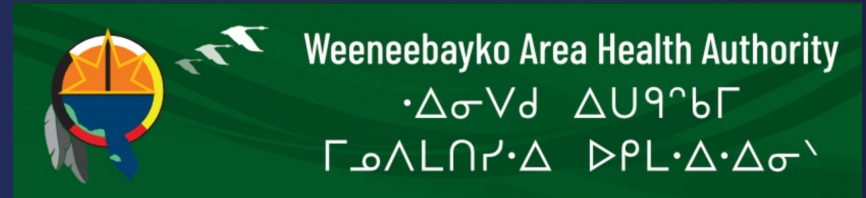


Discussion

- Portable MRI contributes to patient safety and allows increased efficiency in ICU resource utilization by eliminating the need for patient transportation to the radiology department.
- Diverting ICU patients allows time on fixed CT and MRI machines to be freed up for other patients, such as outpatients, thereby reducing wait times.

Discussion

- There is limited experience in Canadian centres for the use of Portable MRI.
- Portable MRI machines are in use in Ontario at St. Michael's Hospital, University of Toronto (since March 2022), and Weeneebayko General Hospital, Weeneebayko Area Health Authority, Moose Factory, Ontario (since November 2021).



Discussion

- The authors have some of the most experience in Portable MRI use of Radiologists in Canada
- O.I., Neuroradiologist, Queen's University, interpreted the first Portable MRI study in Canada.
- A.B. and A.L., Neuroradiologists, University of Toronto, have interpreted the most Portable MRI studies in Canada

Discussion

- 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.

These indications represent:

- 43.9% and 12.4% of fixed unit MRI brain scans at KHSC and SMH respectively, or **100 out of total 407 (24.6%)** of ICU patients.
- 15.8% and 22.6% of fixed unit CT brain scans at KHSC and SMH respectively, or **838 out of 3982 (21.0%)** of ICU patients.

Discussion

- We estimate that **300 additional outpatient MRI scans** and **1676 additional outpatient CT scans** can be potentially performed using the 90 minute time savings per ICU patient on the fixed unit MRI and 30 minute time savings per ICU patient on the fixed unit CT at KHSC and SMH.
- This has a beneficial effect on MRI and CT wait times.
- Applied across Canada, the **%** reduction in MRI and CT wait times can lead to thousands of additional patients being served within the restraints of the existing fixed MRI and CT capacities.

Discussion

- As Portable MRI technology matures, prices decrease, and comfort level with Portable MRI interpretation improves, the clinical indications will likely broaden for Portable MRI use in ICU patients, allowing them to forgo transport for imaging in fixed unit MRI and CT scanners in Radiology departments.
- Therefore, the positive impact of Portable MRI on fixed unit MRI and CT capacity to perform outpatient scans and reduce wait times will only increase.

Discussion

- For example, current slice thickness for diffusion sequences using Portable MRI is 5.8 mm, compared to 3 or 4 mm on typical fixed unit MRI. Using Portable MRI to help exclude small acute strokes will likely become a standard clinical indication, including in the exclusion of posterior fossa strokes, as the technology improves to detect smaller and smaller infarcts.
- Increase in user confidence will improve comfort levels in the distinction of infarcts from blood and other artifacts on Portable MRI images.

Study Limitations

- Some limitations of our analysis include the selection of our proposed clinical indications for Portable MRI. The clinical indications were selected based on our experience and comfort level with interpretation of Portable MRI examinations.
- We chose to limit use to select indications where in our experience Portable MRI may display the greatest most diagnostic utility. However, other users may have different clinical indications for portable MRI application, which will affect the usage.

Study Limitations

- Another variable which will affect the analysis includes time savings on fixed unit MRI and CT based on local clinical practice.
- The 90 minutes and 30 minutes time commitment for ICU patients for fixed unit MRI and CT respectively is based upon long-standing practice at our institutions.
- This time commitment may vary from site to site, leading to different calculations in total time saved if Portable MRI was performed in replacement of fixed unit MRI or CT.

Conclusion

Portable MRI implementation in the ICU setting is feasible for a select range of neurological indications

Based on the developed indications, portable MRI could potentially replace fixed CT in 21% (838) and fixed MRI in 26.5% (108) of ICU patients.

Conclusion

Based on the combined analysis performed at 2 Canadian institutions, a significant number of ICU patients could be diverted from conventional practice of fixed unit MRI and CT to portable MRI

At our 2 institutions, diversion of select ICU patients to portable MRI would result in an increased annual capacity of **300 additional outpatient fixed unit MRI** and **1676 additional outpatient fixed unit CT**

This will have a beneficial effect on wait times at resource constraints sites across Canada

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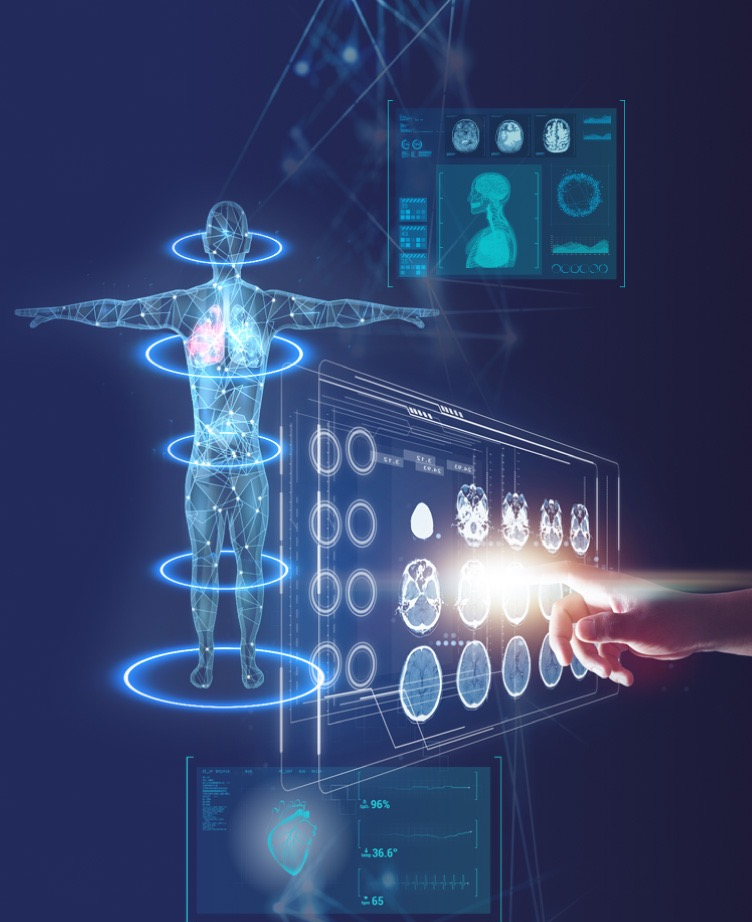
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