ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

www.surgicalneurologyint.com

Surgical Neurology International

Editor-in-Chief: Nancy E. Epstein, MD, Clinical Professor of Neurological Surgery, School of Medicine, State U. of NY at Stony Brook.

SNI: Unique Case Observations

Editor
S. Ather Enam, MD, PhD
Aga Khan University, Karachi, Sindh, Pakistan

SNI
Open Access

Case Report

Utilization of an ultra-low-field, portable magnetic resonance imaging for brain tumor assessment in lower middle-income countries

Ahmed Altaf[1], Muhammad Waqas Saeed Baqai[2], Faiza Urooj[1], Muhammad Sami Alam[3], Hafiza Fatima Aziz[1], Fatima Mubarak[4], Edmond A. Knopp[5], Khan M. Siddiqui[5], Syed Ather Enam[1]

[1]Department of Neurosurgery, Aga Khan University Hospital, Karachi, Sindh, Pakistan, [2]Department of Neurosurgery, Southmead Hospital, North Bristol, United Kingdom, [3]Department of Radiology, National Medical Centre, [4]Department of Radiology, The Aga Khan University Hospital, Karachi, Sindh, Pakistan, [5]Department of Radiology, Hyperfine, Guilford, Connecticut, United States.

E-mail: Ahmed Altaf - ahmedaltafgagan@gmail.com; Muhammad Waqas Saeed Baqai - waqassaeedbaqai@gmail.com; Faiza Urooj - faizaurooj056@gmail.com; Muhammad Sami Alam - msamialam@gmail.com; Hafiza Fatima Aziz - hafiza.fatima@aku.edu; Fatima Mubarak - fatima.mubarak@aku.edu; Edmond A. Knopp - eknopp@hyperfine.io; Khan M. Siddiqui - khan@siddiqui.md; *Syed Ather Enam - ather.enam@aku.edu

***Corresponding author:**
Syed Ather Enam,
Department of Neurosurgery,
Aga Khan University Hospital,
Karachi, Sindh, Pakistan.

ather.enam@aku.edu

Received : 06 February 2023
Accepted : 04 May 2023
Published : 28 July 2023

DOI
10.25259/SNI_123_2023

Quick Response Code:

ABSTRACT

Background: Access to neuroimaging is limited in low-middle-income countries (LMICs) due to financial and resource constraints. A new, ultra-low-field, low-cost, and portable magnetic resonance imaging (pMRI) device could potentially increase access to imaging in LMICs.

Case Description: We have presented the first brain tumor case scanned using an Ultra-low-field pMRI at Aga Khan University Hospital in Karachi, Pakistan.

Conclusion: The imaging results suggest that the pMRI device can aid in neuroradiological diagnosis in resource-constrained settings. Further, research is needed to assess its compatibility for imaging other neurological disorders and compare its results with conventional MRI results.

Keywords: Brain tumors, Low-middle-income countries, Neuroimaging, Point-of-care, Portable magnetic resonance imaging, Ultra-low-field magnetic resonance imaging

INTRODUCTION

Magnetic resonance imaging (MRI) is essential for diagnosing brain tumors.[13] Although traditional MRIs have a high-field strength, their use is challenging in a setup with limited resources, as they require a controlled environment and the supervision of qualified medical personnel. According to the World Health Organization, more than three-quarters of the global population in 2010 lacked access to diagnostic medical imaging.[15] Due to the economic stagnation and increasing population in low-middle-income countries (LMICs), this discrepancy has grown over time. According to one source, Japan reported 90 times more MRI scanners per person than India.[10] An analysis by Hricak *et al.*[7] shows that expanding imaging facilities, irrespective of improvements in cancer treatment and care quality, may prevent millions of cancer deaths worldwide, resulting in increased life expectancy and improved economic outcomes, particularly in LMICs.

The most significant deficit in neurosurgical care exists in Southeast Asia, where nearly 2.5 million cases go undiagnosed.[2,4] In West Africa, just 84 MRI units serve a combined population of more than 300 million people.[11] Lack of equipment, such as an MRI machine, contributes to the inadequacy of diagnosis and essential neurosurgical care, which is why neurosurgical care in LMICs remains a luxury. Given the fast-paced evolution of cutting-edge technology that supports the provision of acute neurological care, the incidence of the diagnostic issues of neurological disorders has been alleviated. With the introduction of Hyperfine's Swoop, a ultra-low-field portable MRI (ULF pMRI) machine, patients now have the convenience of having MRI scans performed right at their bedside, eliminating the need for transportation to an imaging facility.[12] It has been created to increase accessibility and put MRIs within patient reach. This brief report discusses the application of a new, mobile, and rapid neuroimaging modality for bedside evaluation of brain tumor patients at a tertiary care hospital in an LMIC.

OUR EXPERIENCE

We first employed this ULF pMRI machine for a 31-year-old female who presented to the neurosurgery clinic with a history of new-onset seizures for 1 year. The patient underwent high-field MRI (1.5 T MRI) and ULF pMRI (0.064 T) exams preoperatively and postoperatively, which were evaluated and compared by board-certified neuroradiologists. Figure 1 compares both pre and post-operative standard 1.5 T MRI scans against the ULF pMRI scanner.

The high-field MRI scan revealed a right frontal intra-axial lesion which was hypointense on T1 with no contrast enhancement, hyperintense on T2, and had hyperintense foci on fluid-attenuated inversion recovery (FLAIR), along with prominent sulci and ventricles [Figure 1]. The ULF pMRI images were comparable to the findings of the high-field MRI images, and both were suggestive of low-grade glioma. The post-operative MRI scans both showed post-surgical changes and gross total resection of the lesion, with no evidence of intracranial abnormalities. The results indicate that both types of MRI scans yielded comparable quality images.

DISCUSSION

Advantages of pMRI in our experience

With the application of ULF pMRI in our setting, we could scan brain tumor patients at their bedside and in the operating room recovery area. Time is of the essence while identifying neurosurgical pathologies, and the accessibility of a pMRI

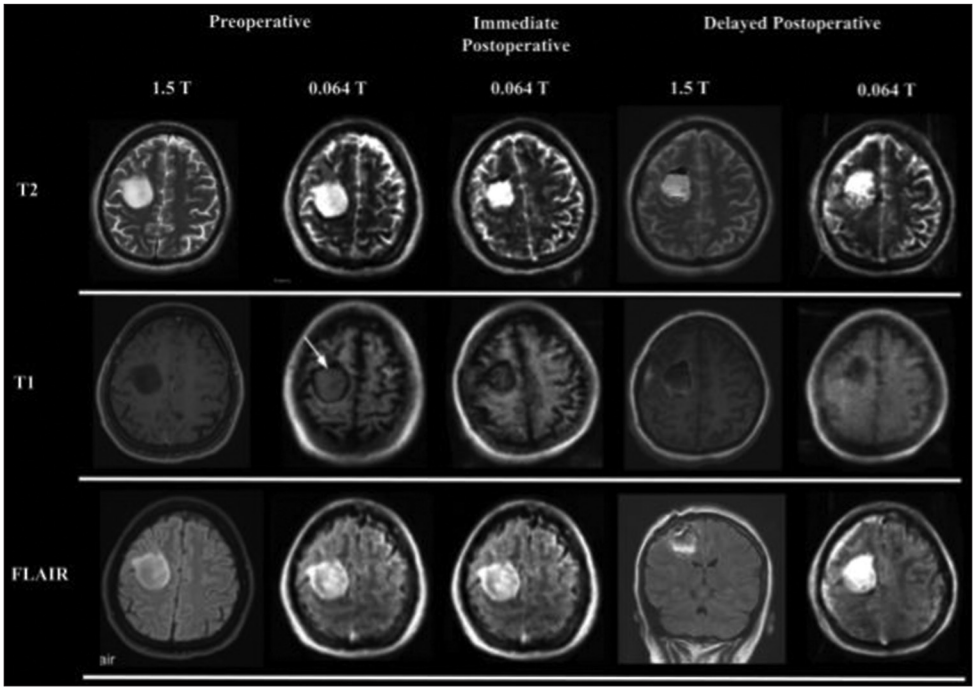

Figure 1: Comparison of standard 1.5 T magnetic resonance imaging (MRI) and ultra-low-field portable MRI (ULF pMRI) Images of a brain tumor. The figure displays the preoperative MRI images of a patient with a brain tumor both obtained using a standard 1.5 T MRI and an ULF pMRI. Initial preoperative images on standard 1.5 T MRI localize a hyperintense lesion on T2 and fluid-attenuated inversion recovery sequences in the right centrum semiovale, involving deep and subcortical white matter with no surrounding edema. ULF pMRI reveals an isointense lesion with a non-specific hypointense rim (white arrow) on T1. The lesion was well-defined with no surrounding edema, or midline shift, nor any pressure effects. These findings were suggestive of low-grade glioma.

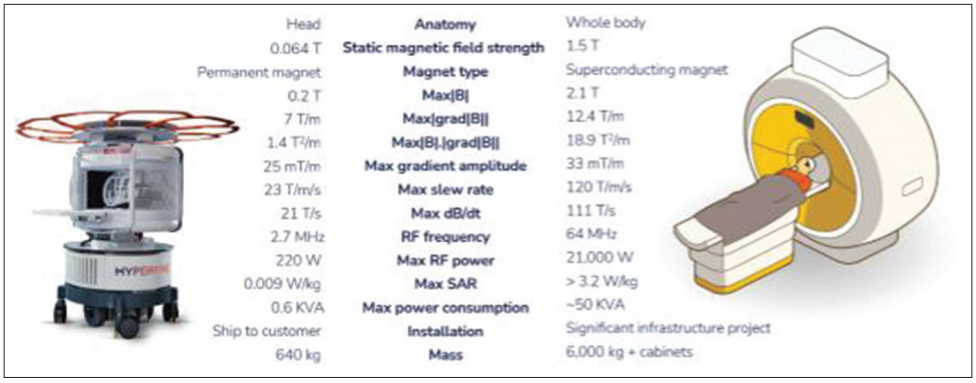

Figure 2: The comparison highlights the capabilities of the portable, ultra-low-field magnetic resonance imaging in providing comparable imaging quality to its conventional counterpart. Radiofrequency (RF), Specific Absorption Rate (SAR), magnetic field gradient (dB/dt), magnitude of the static magnetic field (Max |B|), maximum value of the magnitude of the gradient of the magnetic field (Max |grad|B||), overall strength of the magnetic field used during an MRI scan (Max |B|.|grad|B||)

MRI can expedite emergent medical care. Yuen *et al*.[16] used the pMRI to identify ischemic strokes in patients admitted to the emergency room and those on life support in an intensive care unit. The ULF pMRI exams correctly recapitulated ischemic infarcts in 90% of the patients. Similarly, Mazurek *et al*.,[9] evaluated patients with intracerebral hemorrhage (ICH) at the bedside using a ULF pMRI, with cases being correctly identified with a sensitivity of 80.4%.

The ULF pMRI device is more cost-effective than the conventional MRI, as it does not require a dedicated MRI suite, and the machine is much cheaper ($3 million vs. $50,000).[6] Furthermore, maintenance charges, power consumption, and personnel costs are also diminished.[5] Thanks to its intuitive, easy-to-learn software, we could train clinicians to carry out these scans themselves, reducing the costs. In addition, unlike traditional scanners with a 5 Gauss line extending over 4 m, the 5 Gauss line of this device only extends to a diameter of 158 cm.[12] This feature allows handling metal objects within close proximity without requiring specialized MRI-compatible monitors and transport carts. It also facilitates seamless imaging without requiring patients to disconnect from essential life-saving equipment, such as IV pumps, ventilators, and dialysis machines. Furthermore, patients' families can stay at their bedside, which reduces anxiety and claustrophobia, particularly in pediatric patients. Overall, this device prioritizes the patient's experience, making it the first MRI device to offer patient-centric treatment.

Although it has lower sensitivity, resolution, and signal-to-noise ratio than high-field conventional MRI [Figure 2], this equipment enables us to identify anatomical cerebral landmarks and findings, for example, ICH, mass lesions, and significant post-operative complications.[8] Compared to non-contrast computed tomography, the images provided by ULF pMRI have a better soft-tissue resolution without exposing the patient to harmful radiation.[3]

Challenges that we faced

In our experience, one difference between ULF pMRI and traditional MRI is that the patient's head has to be manually positioned inside the head coil before the scan can begin. Patients who have had neurosurgery require extra precautions during the postoperative period. Placing the patient's head inside the device is a delicate task and requires trained personnel. In addition, since the height of the machine cannot be adjusted; therefore, this requires height-adjustable supports to appropriately place the patient's head inside the pMRI scanner. Furthermore, due to the smaller frame of the ULF pMRI scanner's head coil (261 mm x 205 mm) compared to the opening bore of around 500-600 cm in a traditional bore MRI machine, there is limited headroom for patients. This constraint may potentially heighten the chances of claustrophobia among adults undergoing ULF pMRI scans. Moreover, this ULF pMRI scanner can only perform brain MRIs with standard sequences (including T1, T2, Fluid attenuated inversion recovery, diffusion-weighted imaging, and apparent diffusion coefficient).

Recommendations

One of the changes that emerged as a result of the COVID-19 epidemic was a rapid transition to telemedicine. With the advent of modern mobile devices offering high-speed internet connections, coupled with the widespread availability of free, cutting-edge software for remote video communication there is tremendous potential for live, high-quality online consultations and the global exchange of medical knowledge.[14] We anticipate that the addition of ULF pMRI scanner to these tools will allow patients who lack access to expert neurosurgical care in their native cities to receive better diagnostic imaging.

Although only some centers in an LMIC may be able to acquire this machine, incorporating this ULF pMRI scanner into mobile vans that can bring the imaging device directly to the patient would be a game changer. The geographic and logistics barriers to access essential health services in these regions are well-documented. Many patients are required to travel long distances over difficult terrain to reach the nearest clinic or hospital. In Pakistan, for instance, over half of the patients seeking neurosurgical care are required to travel over 50 km, and nearly, one-fifth are forced to travel 500 km to receive neurosurgical care.[1] By making ULF pMRI scanner more readily available to patients in LMICs, we can deliver effective, patient-centered care, and bring high-quality medical services to those who need them most. Incorporating these units into routine clinical practice can be cost-effective and efficient, helping to address the severe shortage of medical resources in these regions.

However, we must proceed with caution and conduct large-scale studies to fully understand the potential and limitations of ULF pMRI technology in LMICs. There are also significant challenges for conducting larger studies, such as cost, resource availability, and the need for international collaboration across institutions and countries. Despite these challenges, exploring alternative imaging technologies such as ULF pMRI is crucial to address the significant disparities in healthcare access and outcomes between high and low-income countries. Continued research in this area is essential to understand the full potential of ULF pMRI technology and its impact on global health.

CONCLUSION

The utilization of ULF pMRI shows promise in assessing brain tumors in resource-constrained settings, despite the need for improvements in image quality and resolution. Further research is necessary to explore its sensitivity to various neurological conditions and to conduct large-scale comparative studies with conventional MRI.

Declaration of patient consent

The Institutional Review Board (IRB) permission obtained for the study.

Financial support and sponsorship

This research was supported by a grant from Hyperfine Research Inc. to the Pakistan Academy of Neurological Surgery (PANS).

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Bajwa MH, Shah MM, Khalid MU, Khan AA, Zahid N, Anis SB, *et al*. Distance travelled for brain tumour surgery: An low and middle income country's perspective. J Pak Med Assoc 2022;72:S25-33.
2. Branco P, Ayres-Basto M, Portugal P, Ramos I, Seixas D. Brain magnetic resonance imaging: Perception and expectations of neurologists, neurosurgeons and psychiatrists. Neuroradiol J 2014;27:261-7.
3. Brenner DJ, Hricak H. Radiation exposure from medical imaging: Time to regulate? JAMA 2010;304:208-9.
4. Dewan MC, Rattani A, Fieggen G, Arraez MA, Servadei F, Boop FA, *et al*. Global neurosurgery: The current capacity and deficit in the provision of essential neurosurgical care. Executive summary of the global neurosurgery initiative at the program in global surgery and social change. J Neurosurg 2018;130:1055-64.
5. Enderlin M. The Impact of Patient Acuity and Staffing Shortages on Hospitals and Neurocritical Care. Available from: https://hyperfine.io/resources/blog/the-impact-of-patient-acuity-and-staffing-shortages-on-hospitals-and-neurocritical-care [Last accessed on 2023 May 30].
6. FDA Clears 'World's First' Portable, Low-cost MRI Following Positive Clinical Research. Available from: https://healthimaging.com/topics/healthcare-policy/fda-clear-worlds-first-portable-mri [Last accessed on 2022 Sep 23].
7. Hricak H, Abdel-Wahab M, Atun R, Lette MM, Paez D, Brink JA, *et al*. Medical imaging and nuclear medicine: A lancet oncology commission. Lancet Oncol 2021;22:e136-72.
8. Marques JP, Simonis FFJ, Webb AG. Low-field MRI: An MR physics perspective. J Magn Reson Imaging 2019;49:1528-42.
9. Mazurek MH, Cahn BA, Yuen MM, Prabhat AM, Chavva IR, Shah JT, *et al*. Portable, bedside, low-field magnetic resonance imaging for evaluation of intracerebral hemorrhage. Nat Commun 2021;12:5119.
10. MRI NMR Magnetic Resonance Essentials, Introduction, Basic Principles, Facts, History-the Primer of EMRF/TRTF-Facts and Figures: Organ Distribution of MRI Studies-Number of MRI Machines Worldwide-Field Strength of MRI Machines; 2018. Available: https://www.magnetic-resonance.org/ch/21-01.html [Last accessed on 2022 Oct 10].
11. Ogbole GI, Adeyomoye AO, Badu-Peprah A, Mensah Y, Nzeh DA. Survey of magnetic resonance imaging availability in West Africa. Pan Afr Med J 2018;30:240.
12. Prabhat AM, Crawford AL, Mazurek MH, Yuen MM, Chavva IR, Ward A, *et al*. Methodology for low-field, portable magnetic resonance neuroimaging at the bedside. Front Neurol 2021;12:760321.
13. Shetewi SG, Mutairi BS, Bafaraj SM. The role of imaging in examining neurological disorders: Assessing brain, stroke, and neurological disorders using CT and MRI imaging. Adv Comput Tomogr 2020;9:1-11.
14. Szmuda T, Ali S, Słoniewski P, Group NS. Telemedicine in neurosurgery during the novel coronavirus (COVID-19) pandemic. Neurol Neurochir Pol 2020;54:207-8.
15. Welling RD, Azene EM, Kalia V, Pongpirul K, Starikovsky

A, Sydnor R, *et al*. White paper report of the 2010 RAD-AID conference on international radiology for developing countries: Identifying sustainable strategies for imaging services in the developing world. J Am Coll Radiol 2011;8:556-62.
16. Yuen MM, Prabhat AM, Mazurek MH, Chavva IR, Crawford A, Cahn BA, *et al*. Portable, low-field magnetic resonance imaging enables highly accessible and dynamic bedside evaluation of ischemic stroke. Sci Adv 2022;8:eabm3952.

How to cite this article: Altaf A, Baqai MS, Urooj F, Alam M, Aziz HF, Mubarak F, *et al*. Utilization of an ultra-low-field, portable magnetic resonance imaging for brain tumor assessment in lower middle-income countries. Surg Neurol Int 2023;14:260.