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Technical Report

SIR HELMET (Safety In Radiology HEalthcare Localised Metrological EnviromenT): a low-cost negative-pressure isolation barrier for shielding MRI frontline workers from COVID-19 exposure

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Introduction

COVID-19 is a highly infective disease caused by a novel coronavirus first identified in Wuhan, China, in December 2019. It has now evolved into a pandemic affecting at least 216 countries. The precise incidence of stroke in COVID-19 patients is unknown but is thought to affect up to 5.7% of severely affected individuals.[1] It is also being recognised as the first clinical presentation of COVID-19, especially in young patients.[2,3] Although computed tomography (CT) is the first line imaging technique to assess patients presenting with acute stroke symptoms, many centres prefer to evaluate further with magnetic resonance imaging (MRI).[4] Hence, more patients with COVID-19 are attending for MRI examinations.

In well-resourced hospitals, infective COVID-19 patients are nursed within negative-pressure rooms. Even within these negative-pressure rooms, research has shown extensive environmental contamination when occupied by infected patients.[5] Although patients can be provided with filtering face piece (FFP) masks to reduce their infectivity, studies have demonstrated high rates (up to 87%) of poor fit of the face masks among untrained non-healthcare professionals.[6]

Most MRI rooms are not built with negative-pressure ventilation systems. In addition, there are limitations to the use of personal protective equipment (PPE) by both patients and staff within the magnetic field of the MRI room. Therefore, each time a patient with COVID-19 undergoes MRI, there is a real risk of MRI room contamination and exposure of both staff and subsequent patients to the virus.

To address the above problem, a low-cost physical barrier was designed and developed for use within the MRI machine that could produce a localised negative-pressure containment area around the patient's head. The barrier

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has been named “SIR HELMET” from Safety In Radiology HEalthcare Localised Metrological EnviromenT. The “helmet” can potentially reduce the spread of pathogens via the patient’s breath. In addition to assessing its functionality, the present study also evaluates the impact of the shield on MRI image quality.

Materials and methods

The SIR HELMET is a dome shaped, re-useable barrier that fits into MRI machines with a bore size of ≥65 cm. It is made of 3 mm clear acrylic with chloroform used as the primary adhesive. The access port on the front of the “helmet” is covered with a 1.5 mm silicone rubber membrane with slits for access and clamped to the main structure with another layer of 3 mm acrylic, held together by plastic screws (Fig 1). The calculated raw volume of the helmet is 139 l with an effective net gas volume of approximately 130 l or less depending on patient position within the barrier shield. Negative pressure within the “helmet” is generated by connecting a standard medical gas wall vacuum using extension tubing via a port in the barrier shield. Continuous air suction is performed with a 5 m connecting tube (Steril Medical, Loyang, Singapore) and either filtered via an underwater seal containing standard chlorine-based disinfectant with at least 4 cm high fluid trap or directly through a Medi-Vac Flex Advantage Flexible Liners fluid and bacteria trap (Cardinal Health, Dublin, OH, USA) before venting. Suction pressure rates of the wall vacuum in the above-described set-up can be regulated via a vacuum regulator (Legacy Vacuum Regulator, Ohio Medical Corporation, Gurnee, IL, USA). An airflow meter (LZQ-7 Flowmeter, Hilitand, Shenzhen, China) was used to measure the effective airflow rates.

For this study, two healthy volunteers were scanned in a 3 T MAGNETOM SKYRA MRI unit (Siemens, Munich, Germany) and a 1.5 T Optima MRI unit (GE Healthcare, Chicago, IL, USA) using standard head and neck sequences (eight sets of examinations in total; four of the head and four of the cervical spine). Each participant was scanned using each machine by the same senior MRI radiographer with and without the “helmet”.

Images were loaded onto a standalone staging picture archiving and retrieval system, Centricity Universal Viewer (GE Healthcare). The eight anonymised sets of images were reviewed on diagnostic-quality monitors by two consultant musculoskeletal radiologists, two consultant neuroradiologists, and two consultant clinical diagnostic radiologists, blinded to the acquisition history of the images. Overall, eight examination sets were read independently by six different readers to provide 48 total sets for scoring. Images were scored on a scale of 1–4 regarding diagnostic quality, structural delineation, and severity of artefacts for each set of images as per Ryu *et al.*[7] with area for free-text comment.

Results

Negative pressure airflow rates of >20 l/min was obtained with the underwater seal filter system and at 40 l/min without. This allowed at least 9.2 full gas exchanges per hour for the underwater seal filtered system and at least 18.5 for the other one.

There was consensus regarding scoring of all eight sets of images among all the readers with full points for diagnostic quality, delineation of structural margins, and complete lack of MRI-related artefacts (Fig 2). Post-scoring, the readers were informed that half of the image sets were performed with the “helmet”, but they were not able to identify these sets from those scanned without the helmet.

Discussion

Although transmission of COVID-19 is predominantly via direct contact or aerosol inhalation, it may also occur via indirect delayed contact, for example, through the use of the same physical seat.[8] Droplet transmission enhanced by air-conditioning airflow creating super spreaders is also documented.[9] Hence, isolation of the most infective

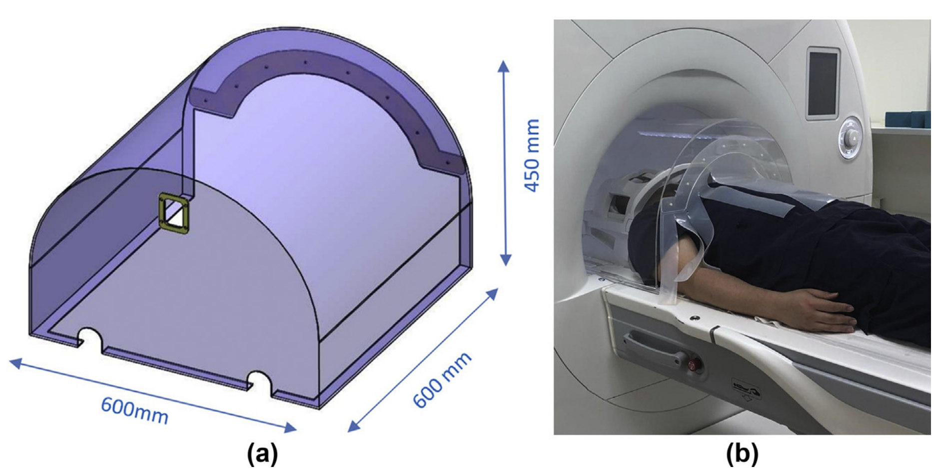

Figure 1 SIR HELMET (Safety In Radiology HEalthcare Localised Metrological EnvironmenT) barrier. (a) Schematic drawing of SIR HELMET. (b) Use of SIR HELMET in a 65 mm-bore MRI machine.

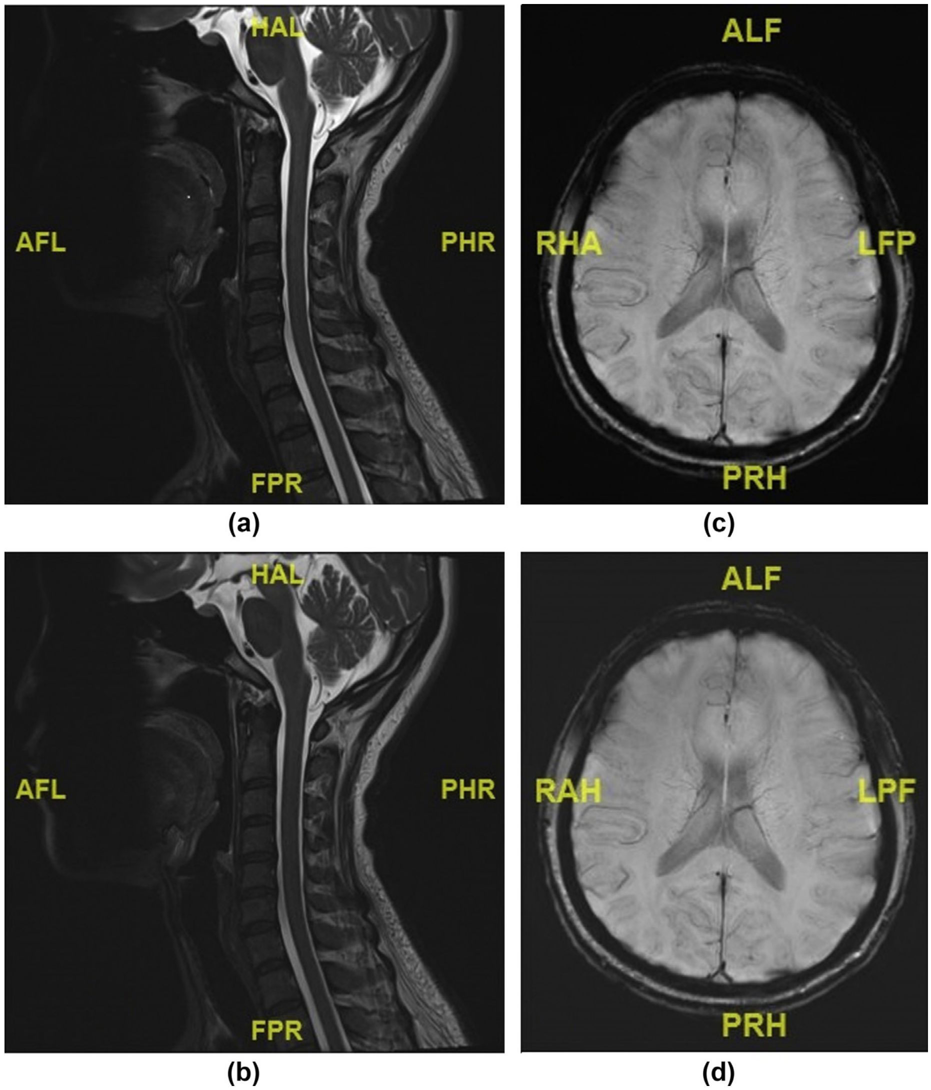

Figure 2 Representative 3-T MRI examination images of a healthy participant with and without the use of SIR HELMET. (a) Sagittal cervical spine image acquired in T2-weighted MRI using turbo spin-echo sequence utilising a head coil without SIR HELMET and (b) the equivalent image obtained with the presence of SIR HELMET. (c) Axial image of the brain acquired in susceptibility-weighted imaging utilising a head coil without SIR HELMET and (d) the equivalent image obtained with the presence of SIR HELMET.

patients is essential.[10] Nevertheless, when an infected patient is brought outside their isolation ward to other clinical areas, such as radiology departments, this "isolation" is interrupted, creating potential opportunities for virus dissemination. As the COVID-19 pandemic continues, there is high likelihood that more coronavirus-infected patients would present with stroke or stroke-like symptoms, thereby increasing the need to perform MRI examinations in these patients. As a limited resource, it may not be possible to reserve an MRI machine exclusively to image COVID-19 patients. Hence, it is essential to explore alternative ways to control the spread of infection from transit of an infected patient through an MRI room.

To reduce environmental transmission, COVID-19-positive patients are usually transferred along dedicated routes within the hospital with at least a surgical or FFP2 mask to capture any aerosolised respiratory secretions; however, this is not possible during MRI examinations, especially during head and neck imaging. Surgical masks and FFP2 masks typically contain a metallic mouldable nose bridge to maintain a good air seal and several different types of FFP2 masks utilise steel clips to secure the elastic straps, which are contraindicated within the scanner bore. At National University Hospital, Singapore, patients and frontline workers remove the metallic mouldable nasal bridge of their masks while working in the MRI room. This compromises the structural integrity of the mask, thereby limiting its capacity in capturing aerosolised respiratory secretions and reducing its ability to provide protection from contaminants in the external environmental.

MRI machines are typically located within shielded rooms with no open windows and a controlled, recirculated airflow system. Within the bore of the magnet, there is directed airflow from the head of the bed towards the feet.

Should a patient cough or sneeze within the bore of the scanner, the droplets would also spread along the same direction. Although terminal cleaning of the floor and couch of the MRI machine is usually performed after scanning an infected patient, it is not routine to perform a complete deep clean inside the bore of the magnet each time. Thorough cleaning inside the bore of the magnet is a strenuous and time-consuming process. Hence, the use of SIR HELMET would be valuable addition as it potentially reduces droplet contamination within the bore of the magnet and across the room. The aerosol can be contained in a closed space within the shield and cleared through air exchange. The effort of thoroughly cleaning the shield between patients is much less than that of cleaning the bore of the MRI machine.

Using the ubiquitous medical gas wall vacuum apparatus, the “helmet” can provide at least 9.2 full gas exchange per hour with the afore-described filtration system or 18.5 full gas exchanges per hour without filtration. This gas exchange rate is similar to or above that of the requirements of a negative-pressure isolation facility, which is usually 10 to 15 exchanges per hour. Hence, use of this helmet would effectively provide frontline healthcare staff and patients with an added layer of protection against airborne pathogens. This can also avoid the cost and time required in installing negative-pressure ventilation systems within an MRI room.

Use of the helmet without suction is not recommended due to concerns regarding carbon dioxide retention during long examinations. In an unvented system, there are also concerns of a high concentration of aerosolised pathogen that the MRI technician would be exposed to, while removing the “helmet” from the patient. The decision to vent the suction via an underwater seal sterilisation scrub or directly to the wall vacuum port would depend on the local hospital infection-control policy and the underlying infrastructure of the vacuum system.

To improve patient comfort and to reduce claustrophobia, the helmet was intentionally fabricated using flame-polished translucent acrylic, using the biggest arc possible to maximise the sense of space. Given the multitude of different scanner and coil configurations, the length of the “helmet” was increased intentionally to fit across all the MRI machines within National University Hospital Singapore. If required, it is possible to customise this shield for individual scanners with shorter lengths to increase the air exchange rates. Acrylic is cheap and can be fabricated quickly, and in addition, is suitable for cleaning with most of the usual disinfectants.

The image quality of MRI examinations was not affected by scanning with the helmet on. The adoption of this or similar barriers would provide frontline healthcare staff and patients with an additional level of protection without prohibitive financial costs to the institution.

Declaration of competing interests

The authors declare no conflict of interest.

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