ORIGINAL ARTICLE

Safety of Face Masks and Hygiene Precautions in MRI During Covid-19 Pandemic

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ABSTRACT

Introduction: During the Covid-19 pandemic, questions have been raised among medical imaging practitioners on the safety and practicality of wearing face masks while undergoing magnetic resonance imaging (MRI). Although asking patients to wear face masks during such procedure is sometimes not feasible, mitigating steps to minimise exposure to Covid-19 infection in an MRI environment is important. An online survey was conducted to find out the practice at government and private institutions in Malaysia. **Materials and methods:** This survey was distributed to MRI radiographers from government and private institutions in Malaysia. Questions were about types of face masks, metal strip removal, the reasons for not using face masks on patients, and procedures for sanitising the MRI machine. **Results:** A total of 61 institutions required patients to wear face masks when undergoing MRI, and 79 offered standard surgical masks for patients. Only two institutions provided the more efficient but costly N95 respirator. However, 61 respondents only said their institutions removed the metallic nose clip before starting the procedure. Most respondents in institutions that did not provide face masks to patients said they did so because it was unsafe. It was also found that the bed and radiofrequency(RF) coils are the most sanitised parts of the MRI machine, while the gantry is the least cleaned. **Conclusion:** MRI administrators should modify their standard operating procedure and workflow to fulfil safety requirements during the pandemic. Other strategies to reduce respiratory droplets in the air, such as installing mechanical ventilation, should be considered for MRI rooms.
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INTRODUCTION

Coronavirus disease 2019 (Covid-19) has caused a major health crisis around the world. With the availability of vaccines, most patients will just develop mild to moderate illness. However, in the early stages of the pandemic, the disease is considered a threat to humanity. After slightly more than a year, it was first reported in Wuhan, China, in December 2019, Covid-19 had claimed the lives of around two million people worldwide (1). In December 2022, the death toll was reported to be more than 6.6 million. Furthermore, those who survived may develop long-term effects known as long Covid (2).

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes the disease, is much more infectious and fatal than the SARS-CoV-1 that caused the Severe Acute Respiratory Syndrome outbreak from 2002 to 2004(3). Mutations in SARS-CoV2 have resulted in the emergence of highly contagious Delta and Omicron variants. These variants have stronger affinity to infect target host cells and may even evade the body's immune system, making vaccines less effective. They can spread through the inhalation of viral particles in respiratory droplets in the air. The coronavirus may also enter the body from the mouth and eyes that come into contact with contaminated hands and utensils (4–6).

The wearing of face masks in indoor public spaces is one of the key measures recommended by the World Health Organisation (WHO) to prevent the transmission of Covid-19(7). The use of face masks reduces the risk

of contamination by limiting the volume and travel distance of respiratory droplets or aerosols when the wearer sneezes, coughs, laughs or speaks. If worn correctly, it can also protect the wearer by preventing respiratory aerosols from entering the body through the mouth and nose. Even though the Malaysian government recently lifted the requirement to wear face masks in most public places, it is still mandatory to be worn in certain places such as healthcare facilities. In high-risk medical procedures, healthcare workers may be required to wear personal protective equipment in addition to face masks (8). But in the case of patients, most hospital protocols only require them to wear face masks at all times within the premises. Despite that, the implementation of this simple measure may become challenging when performing certain procedures like magnetic resonance imaging (MRI).

The MRI machine uses static and time-varying magnetic fields to produce diagnostic images. As the generated static magnetic field is very powerful, typically at 1.5 Tesla or higher, any ferromagnetic object nearby may become a hazard as it becomes strongly attracted to the MRI bore (9). Surgical face masks and N95 respirators contain a metallic clip or wire to fit the mask to the nose. Therefore, the metallic strip on the facemask will be pulled by MRI when the patient is brought into the machine while wearing the facemask. One of the major concerns in MRI safety is that metal objects could cause tissue burning during scanning. There are two types of changing magnetic fields used in MRI - radiofrequency (RF) and gradient fields. These fields are used to generate and spatially encode MRI signals. The amplitude of the RF magnetic field is from 0 to 50 μT, and its frequency is around 64 MHz and 128 Mhz for 1.5T and 3T, respectively. For the gradient field, its amplitude is from 0 to 80 mT m^{-1} and the frequency is from 0 to 10 kHz (9). According to the Maxwell-Faraday equation, a changing magnetic field is always accompanied by an electrical field. When electrically conductive materials such as aluminum, copper and silver are within the magnetic field environment, the electric field will induce a current in the conductor.

Thermal burns and excessive tissue heating during MRI are mainly caused by the RF field (10). During imaging, a highly conductive object such as a metallic wire may act as a 'short circuit' to the electrical potential induced in the body by the RF field. It may cause eddy currents to be induced and flow from the wire to the tissue. When a current flows into a small and high resistance area at the wire-tissue interface, it may generate a great amount of heat and cause burns in tissues (11). RF burns may also occur due to a secondary electric field generated around the wire. This electric field maximises when the wire length is at approximately one-half of the wavelength of the RF field. This resonance length depends on the RF frequency and the medium it passes through. For example, at 64 MHz (1.5 T), the length is 234 cm in air and 26 cm in tissue. While at 128 MHz (3T), it is 117 cm and 13 cm in air and muscles, respectively. At this condition, the coupling between the transmitting coil and the conductor causes a standing wave pattern of voltage and current in the wire. This secondary electric field can be much higher than the transmitted primary incident RF field at certain locations. This scattered field induces electrical current and, when high enough, will cause burn in the tissue (10).

Any devices intended to be used in or near MRI environment such as medical implants, external fixators, and other accessories should be labelled as 'MR Safe', 'MR Unsafe, or ' MR Conditional' (12). 'MR Safe' items mean that they pose no safety hazards in the MR environment. 'MR Unsafe' items should not be brought into the MRI room. Patients with MR Unsafe devices or medical implants should not be scanned. The item labelled with 'MR Conditional' may safely enter the MRI room; however, each item has very specific conditions provided in the labelling. The detail of specific conditions is stated in the ACR guidance document on MR safe practices: 2013 (12). It is very important for patients with medical implants and other devices not to be scanned in MRI unless the items can be positively identified as 'MR Conditional' and confirmed that they are safe to be scanned. These labellings are also applicable to face masks. Some commercial respiratory and surgical masks have been tested for their safety in MRI environments (13,14). Respiratory masks that contain ferromagnetic components, such as nose strips and staples, were classified as 'MR Unsafe'' (13, 14). Masks which do not contain any ferromagnetic and electrically conductive components were deemed 'MR Safe' (14). A respiratory mask has a non-ferromagnetic component of aluminium nose strip was deemed as ' MRI conditional' where it might cause local heating during scanning (14) .

Some fabric masks may also contain nanoparticle strands or coatings made of highly conductive material, such as silver and copper. The United States Food and Drug Administration (FDA) has warned that these masks may cause thermal burns during MRI (15,16). Another possible effect of metallic elements in the masks is the production of susceptible artefacts in images, which may cause misdiagnosis (13). Furthermore, wearing face masks may make it difficult for claustrophobic patients to breathe in the confined space of the MRI machine. Due to these issues, non-Covid patients may have to be exempted from wearing face masks while undergoing MRI. Moreover, MRI is not strictly regulated like ionising radiation-based imaging modalities. Hence, the safety practices may differ from one hospital to another. This survey aims to assess the use of face masks and other precautionary measures for non-Covid patients undergoing routine MRI in healthcare institutions throughout Malaysia.

MATERIALS AND METHODS

An online survey was developed using Google Forms, and it was distributed through email to all government and private institutions providing MRI services in Malaysia. The list of all the institutions was provided by the Ministry of Health, Malaysia. MRI radiographers responsible for performing scans were the targeted respondents in this study. This survey was required to be answered by a representative of MRI radiographers that follow or practice the standard operating procedure (SOP) that has been developed at their facilities. Only one response was accepted from each institution. The information provided was dealt with confidentiality. The survey was conducted from March until July 2021.

The questions in this survey were prepared in English and created based on the guidance on general MRI safety (12), the use of face masks and cleaning procedures for MRI (16) as recommended by the American College of Radiology (ACR). The use of face masks and its safety features for non-Covid-19 patients and sanitisation procedures in MRI were assessed in this survey. Questions about MR-safe face masks and metal strip removal were included, and respondents were asked to answer discreetly (Yes or No). There were also multiple-choice questions on the reasons for not using face masks on patients, types of face masks used, and procedures for sanitising the MRI machine after each scanning. A sample of the survey questions is summarised in the flow chart in Fig. 1. The answers were compiled using MS Excel (Microsoft Corp., WA, USA) . This study was considered as a policy-related survey and involves no more than minimal risk to respondents. The Ministry of Health Malaysia Research Ethics Committee has confirmed that no ethical approval is required (NMRR ID-24-01418-NGO).

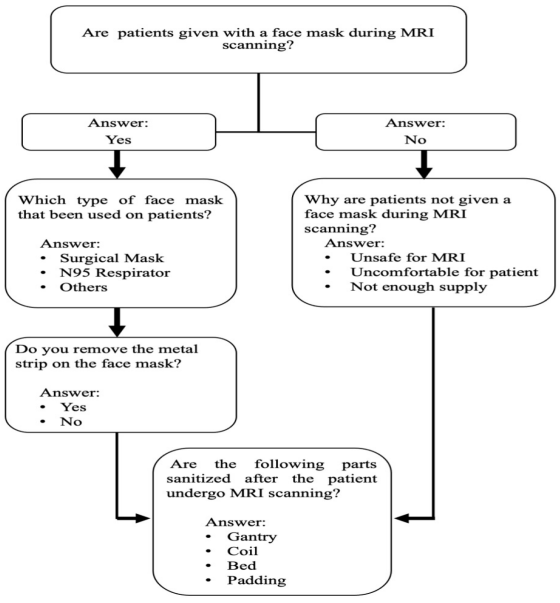

Figure 1: Flowchart showing questions asked in the Google Forms distributed to MRI facilities in Malaysia.

RESULTS

The response rate of this survey was 70 %, where 90 respondents replied within four months. The type of institution, magnetic field strength and number of MRI machines available are shown in Table I.

Table I: The number of MRI machines and their respective field strength at different institutions in Malaysia.

		MRI magnetic field strength		
Institution	**Total**	**3T**	**1.5T**	**< 1T**
Private hospitals	63	6	68	5
Government hospitals	21	1	25	-
University hospitals	4	4	3	1
Research centres	2	1	1	-
Total	90	12	96	6

* One institution may have more than one MRI machine, hence the higher number of total magnetic field strengths

Table II shows the results of the survey regarding face mask usage on patients during MRI scanning. A total of 61 (68 %) respondents said their institutions required patients to wear face masks in routine examinations. However, none of them stated that the face masks used were labelled as MR-safe. A total of 79 (88%) respondents stated that their institutions were providing standard surgical or medical masks, and two (2 %) gave better N95 respirators. Only 61 (68 %) institutions removed the metallic nose clip from the face masks before conducting a scan, while 14 (15 %) did not. Some of the respondents mentioned that the patients also used their own paper or fabric face masks. A total of 28 (31 %) MRI facilities did not provide face masks to patients.

Table II: The usage and types of face masks worn by patients during MRI.

Survey Items	**N**	**Percentage (%)**
Patients must wear face masks during scans	61	68
Type of face mask worn:		
• Standard medical/surgical mask	79	88
• N95 Respirator	2	2
• Others (e.g. Fabric, paper mask)	9	10
Metallic nose clips removed before scanning	61	68

The main reason the facilities did not provide face masks to patients was that they were considered unsafe for MRI (Fig. 2). Another reason was that the patient felt uncomfortable and had difficulty breathing inside the scanner. The respondents also mentioned that the decision to provide a face mask to patients depended on the body part being scanned and the patients' reception.

Fig. 3 shows the parts of the MRI machine sanitised after each procedure. The bed and RF coils were sanitised in most institutions regardless whether the patients wore a face mask. While, the gantry was the least sanitised part in both cases. In general, more institutions sanitised their MRI machines when patients did not wear face masks, except for the RF coil.

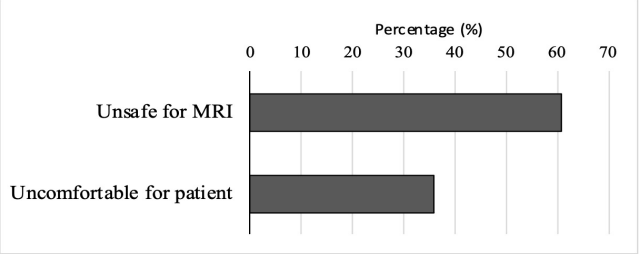

Figure 2: The reasons for not providing face masks to patients during MRI.

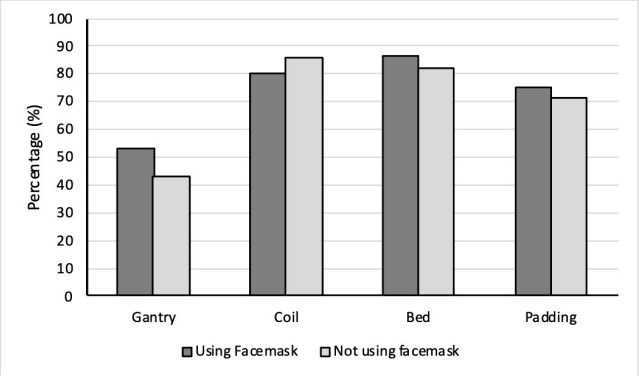

Figure 3: Components of MRI machine sanitised after each scanning of non-Covid patients.

DISCUSSION

The Covid-19 pandemic had caused a health crisis around the world. With the emergence of the Delta and Omicron variants, the number of infected people had dramatically increased (17). Chest computed tomography (CT) (18) was the preferred imaging modality for the diagnosis and management of patients with Covid-19 (19). This preference was due to its excellent capability of producing lung images in high resolution besides a short acquisition time. Even though MRI was not commonly used to diagnose Covid-19 patients, its role in diagnosing other diseases during the pandemic was still crucial. Since infected patients might not show symptoms during the hospital admission screening, every MRI patient could potentially carry the virus. It was reported that asymptomic individuals were a potential source of disease transmission in communities (3,18). Hence, radiographers and other personnel in the MRI suite, who were in close contact with patients, would be at risk if no adequate precautions were implemented. The relatively enclosed space and poor ventilation had been identified as critical factors that allowed respiratory droplets containing the coronavirus to linger in MRI suites and infect staff members and other patients (20) .

From our survey, about one-third of all responding MRI facilities in Malaysia did not require patients to wear face masks during scanning. Safety concerns were the main reason why patients were not required to do so. This was because the metal nose clip of a standard face mask is usually made of ferromagnetic materials, which could be pulled off by the main magnet. Even though the force might not be strong enough to dislocate or remove the masks entirely from the patient, it might loosen its fitting to the nose, which would compromise the functionality of the mask (14).

Another major concern was that the metal clip could cause skin burns in patients (16). The incident of skin burns on patients' face resulted from wearing a facemask during neck scanning with 3T MRI was reported in FDA Safety Communication (15,16) Some studies had suggested that nose clips made of non-ferromagnetic metals such as aluminium might not need to be removed (13). However, it should be noted that aluminium is also an excellent electrical conductor, which could potentially cause heating when exposed to RF energy. Keenan at all suggested to remove the alluminium noses strip from the face mask on the patients when performing MRI on the brain, head and neck particularly when using high specific absorption rate (SAR), high gradient fields and long scanning time sequences (14). The authors also found that all metal components in the tested face masks did not cause a temperature rise of more than 40oC during scanning. However, this study was conducted on a 3D laser-printed head phantom filled with water. Hence, the phantom used may not accurately mimic the dielectric properties of tissues in the human head.

Some of our survey respondents mentioned that there were patients who brought fabric face masks to their MRI facilities. This kind of mask may consist of metal fibres or metallic nanoparticles such as copper and could potentially produce local heating in MRI (16, 21) . This includes fabric face masks labelled with "anti-microbial" or "anti-bacterial". Skin burns during MRI caused by a jogging pant containing metal fibres examination had been reported (22). Another paper reports a second-degree burn on a patient's flank and wrist caused by her undershirt containing antimicrobial silver microfibers from MRI scanning of the brain and spine (23). The burns may occur when the eddy currents are generated within the cloth fibres. The risk is higher when the conductive material forms a closed loop of large diameter. The metallic fibres in the clothing are invisible, and they cannot be detected by standard ferromagnetic detectors. It is recommende that all patients must change to MR-Safe gowns or scrubs supplied by the MRI facility prior to MRI examination in order to avoid this issue (16,23).

Another effect of metallic objects in face masks is the production of susceptibility artefacts, especially if the masks are within or close to the imaging field of view (FOV) (13, 14). The metals distort the static magnetic field and may cause a signal void in surrounding tissues. This artefact also may cause severe distortion in the images. This issue might affect the quality of some brain images. The FDA had recommended that the metal nose clips be removed from face masks to avoid these risks (15, 16). However, this might cause an opening at the nose bridge

where respiratory droplets and aerosols could escape into the air or land on the MRI machine parts. Hence, the application of duct tape across the nose section of the face mask has been recommended to maintain its intended function (16). Another reason for not providing face masks was that it causes discomfort to patients. This issue might lead to breathing difficulty, increased heart rate, panic attacks, increased movement and other distress symptoms that could interfere with a scan (25). As a result, the scan would produce more motion artefacts, leading to delayed or repeated procedures. It was also reported that the amount of inspired CO2 could increase when wearing a face mask during scanning (26). This might cause mild hypercapnia in patients and potentially affect the results in blood oxygenation level-dependent (BOLD) functional MRI (fMRI) studies.

Although sometimes it might not be feasible to ask patients to wear face masks during MRI, mitigating steps to minimise exposure to Covid-19 in an MRI environment is important. Hence, MRI administrators should modify their standard operating procedures and workflows to fulfil safety requirements during the pandemic. Necessary steps should be taken to minimise the risk of Covid-19 infection, especially if patients cannot wear face masks due to unavoidable circumstances. All MRI components in close proximity to patients, including the internal surface of the bore, should be sanitised before or after every scan (16). Cleaning should also be carried out inside the bore. However, it is important to make sure that all cleaning kit components do not contain any ferromagnetic materials before using them to clean the MRI machine.

Another strategy to minimise the spread of Covid-19 is to reduce viral concentration in the air, which could be achieved with mechanical ventilation. The natural ventilation approach, such as opening windows and doors, might not be possible due to the special design and layout of the MRI rooms. MRI machines require a controlled temperature and humidity to operate. Furthermore, to minimise the risks of projectile events, the MRI room doors were always kept closed. Hence, the use of an active mechanical ventilation system fitted with a high-efficiency particulate air (HEPA) filter would be strongly recommended. The MRI administrator should consult hospital engineers and other professionals to assess and optimise the air quality in the MRI suite.

Even though the Covid-19 symptoms were becoming less severe worldwide, the number of cases and deaths reported are still high. Furthermore, the possibility of new contagious and lethal variants of Covid-19 and other airborne infectious diseases emerging would always become a concern among the medical fraternity. The wearing of face masks could be considered a "frontline method" to bring the pandemic under control, besides preventing the spread of other respiratory infections like influenza and tuberculosis. Hence, wearing face masks in public places had become the new normal as people try to adapt to the pandemic. Other methods such as vaccination, physical distancing, hand hygiene, contact tracing and isolation were also important "tools" in preventing the spread of Covid-19.

CONCLUSION

In conclusion, to reduce exposure to SARS-CoV-2 and minimise the spread of Covid-19 in MRI facilities, patients should be asked to wear face masks without metallic elements during scans. Our survey showed that only 68 % of MRI facilities in Malaysia required non-Covid patients to wear face masks during scanning. Safety concerns and patient comfort were the main reasons they were not given face masks. Since Covid-19 was mainly spread by respiratory aerosols, extra precautions should be taken if wearing face masks was not possible during a scan. For example, the MRI gantry and accessories should be properly sanitised in between scans, and adequate mechanical air ventilation and filtering systems should be installed in the MRI room.

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