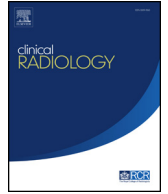




Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Technical Report

Respirators and surgical facemasks for COVID-19: implications for MRI



O.M. Murray^{a,1}, J.M. Bisset^a, P.J. Gilligan^a, M.M. Hannan^b, J.G. Murray^{a,*}

^aDepartment of Radiology, Mater Private Hospital, Eccles Street, Dublin 7, Ireland

^bDepartment of Microbiology, Mater Private Hospital, Eccles Street, Dublin 7, Ireland

ARTICLE INFORMATION

Article history:

Received 24 March 2020

Accepted 30 March 2020

Introduction

COVID-19 was declared a pandemic by the World Health Organization on 11 March 2020.¹ It is a disease spread by aerosol droplets from the airway of infected patients.² Tens of thousands of affected patients are presenting worldwide for medical care. A small percentage of these patients may require magnetic resonance imaging (MRI) for comorbidities. The European Centre for Disease Control recommends healthcare workers use a class 2 or 3 filtering face piece respirator (FFP2 or FFP3), and the Centers for Disease Control and Prevention recommend an N95 respirator (equivalent to FFP2 and FFP3), or facemask if a respirator is not available, when managing a suspected or confirmed case of COVID-19 infection.^{3,4} As a result, staff accompanying patients with suspected or confirmed COVID-19 are likely to be wearing respirators when they arrive at the MRI room. MRI staff may also be wearing a respirator as part of their personal protective equipment when dealing with these patients. These staff members may not be aware that respirators and facemasks do not have MRI safety documentation and as such require testing.⁵ The purpose of this study was to assess a range of currently available respirators

and a facemask for the presence of ferromagnetic properties.

Materials and methods

This was a prospective quality-improvement study with no patient involvement, which does not require ethics committee approval in the authors' institution. Four commonly available respirators and one facemask were tested. These consisted of a 3M Aura respirator FFP3 1863 (Texas, USA), two Kolmi respirators; FFP2 and FFP3 (Angers, France), a Halyard Technology respirator FFP2 (Georgia, USA), and a Dahlhausen surgical facemask (Cologne, Germany). The respirators and mask were first tested outside the MRI control area for ferromagnetic attraction using a strong hand-held magnet (>1,000 Gauss).⁵ They were then placed individually, but not secured, on the face of a three-dimensionally printed head phantom outside the MRI room and the phantom was positioned on the imaging table of a 1.5 T MRI unit (Siemens Avanto, Erlangen, Germany). Respirator/mask movement generated by ferromagnetism was recorded. Finally, a gradient-echo sequence was obtained of the head phantom with the respirator or mask

* Guarantor and correspondent: J. G. Murray, Department of Radiology, Mater Private Hospital, Eccles Street, Dublin 7, Ireland. Tel.: +35318858171. E-mail address: jmurray@mater.ie (J.G. Murray).

¹ Present address: Graduate Entry Medical School, University of Limerick, Limerick City, Ireland.

secured using manufacturer guidelines to assess for local image artefact.

Results

The 3M FFP3 1863 respirator is held in place by the presence of four large ferromagnetic staples joining the elastic bands to the respirator itself. When exposed to the handheld magnet it showed strong ferromagnetic attraction such that it was possible to lift the respirator from a flat surface using the magnet. It underwent considerable translational/torque forces when close to the MRI magnet and completely lost contact with the phantom. There was also considerable image artefact on gradient echo imaging (Fig 1a). Both Kolmi FFP2 and FFP3 respirators also showed strong ferromagnetic properties with the hand-held magnet and could be lifted off a flat table by ferromagnetic attraction to the hand-held magnet. Both respirators also completely lost contact with the phantom when close to the MRI magnet and were associated with considerable artefact on the gradient-echo imaging (Fig 1b and c). The Halyard FFP2 respirator did not exhibit evidence of ferromagnetism to the hand-held magnet or when resting on the phantom on the MRI table. There was only minimal artefact on gradient-echo imaging (Fig 1d). The standard

disposable Dalhousie surgical mask showed no signs of ferromagnetism. There is a small aluminium strip present to allow the mask be formed over the nasal bridge. This produced minimal local artefact on gradient-echo imaging and no obvious heating (Fig 1e).

Discussion

A surgical mask is a loose-fitting disposable device that creates a barrier between the mouth and nose of the wearer and potential contaminants in the immediate environment. The mask is intended to help block large particle droplets, splashes, sprays, or splatter that may contain bacteria and viruses, from reaching the users mouth or airway. They also reduce exposure to others of the wearer's saliva and respiratory secretions.⁴ A FFP2 or FFP3 respirator (equivalent to USA N95 respirator) is a respiratory device designed to achieve a very close facial fit and very efficient filtration of airborne particles.⁴ They are designed to form a seal around the nose and mouth. They must be fit tested, and a proper fit cannot be achieved on men with beards.⁴

Patients with suspected or proven COVID-19 in whom MRI is required should wear a surgical facemask.⁴ This study has shown it may not be necessary to remove the metal nosepiece from the Dahlhausen surgical mask as it is

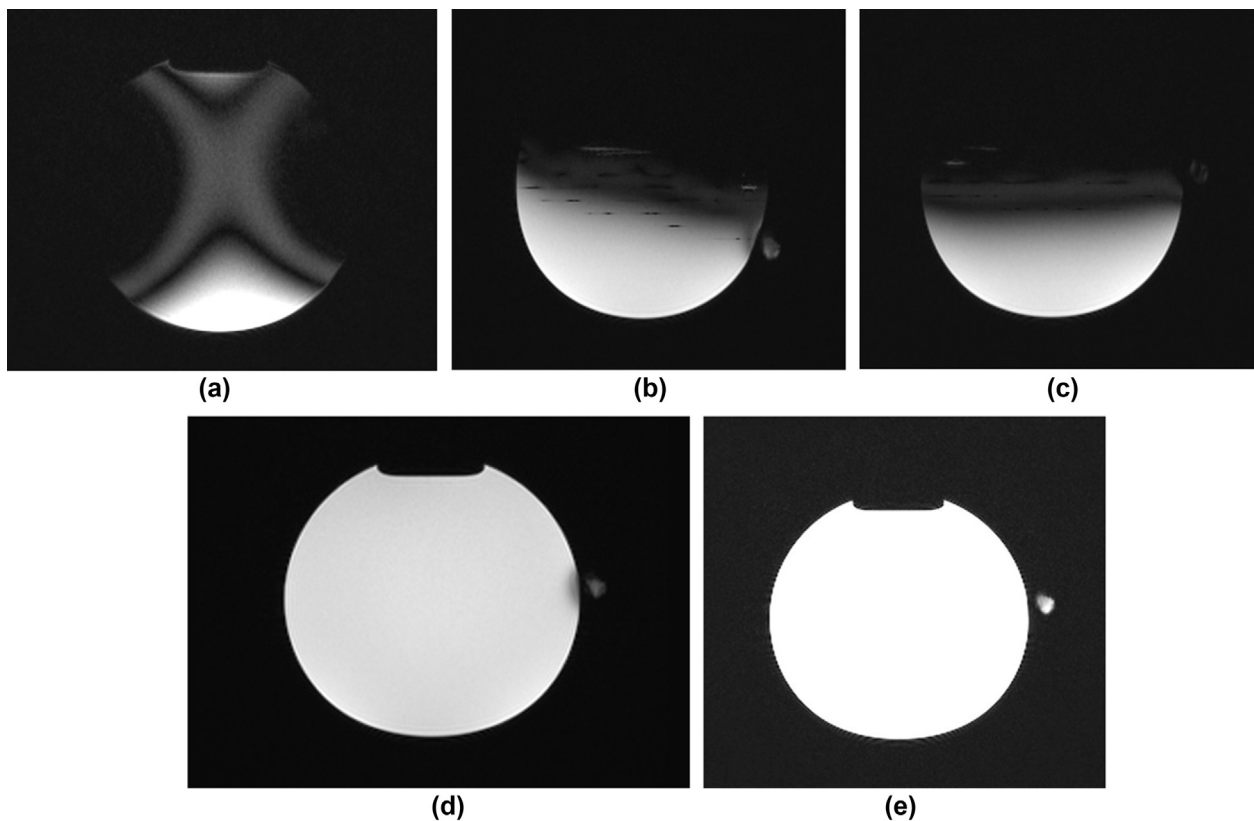


Figure 1 Gradient-echo images (197 ms repetition time, 4.76 ms echo time, 70° flip angle) showing artefacts on images of a phantom due to respirators and a facemask. (a) 3M Aura Respirator 1863. Extensive bilateral artefact from the ferromagnetic staples on the retaining straps. (b) Kolmi Respirator FFP2. Extensive anterior artefact from the ferromagnetic components of the respirator. (c) Kolmi Respirator FFP3. Extensive anterior artefact from the ferromagnetic components of the respirator. (d) Halyard Respirator FFP2. Minimal anterior artefact on the phantom. (e) Dahlhausen Surgical Mask. Minimal anterior artefact from the aluminium nose bridge.

not ferromagnetic. Removal would reduce the seal at the nose bridge and risk contamination. Although aluminium is not ferromagnetic, induced currents could possibly cause local heating if using higher specific absorption rate (SAR) sequences, differing field strengths, or coil configurations. A local risk benefit analysis should be carried out by MRI physics, infection control experts and clinical team for imaging parameters and facemasks available.

Staff who enter the MRI room can use a respirator or facemask. There is a worldwide shortage of respirators, and model availability varies considerably. This study has shown that several commercially available respirators contain ferromagnetic components, and are thus regarded as “MRI unsafe”.⁵ As such, the use of these respirators by staff in the MRI room is contraindicated, both for MRI safety reasons and because they may offer suboptimal protection against COVID-19 due to torque causing a break in the seal at mask user interface.

A limitation of the present study is the fact that a larger number of respirators were not assessed. This is because respirators are not currently freely available given the COVID-19 pandemic. All respirators that were available were tested, and given the findings and wide variation in respirators available internationally, the important message from the present study is that respirators may not be MRI safe.

MRI professionals need to be aware of these issues and are advised to test any respirator used locally with a strong >1,000 gauss hand-held magnet as recommended by the American College of Radiology guidance on MRI safe practice.⁵ The World Health Organization recommends a surgical mask as adequate protection for staff caring for suspected or confirmed patients with COVID-19 unless performing aerosol-generating activities, such as intubation or bronchoscopy.⁶ A surgical mask is therefore a safe

alternative for MR staff to the use of respirators in an MRI environment. The WHO recommendation has been adopted locally.

Conflict of interest

The authors declare no conflict of interest.

References

1. World Health Organization. *Virtual press conference on COVID-19*. 11 March 2020. Available at: https://www.who.int/docs/default-source/coronaviruse/transcripts/who-audio-emergencies-coronavirus-press-conference-full-and-final-11mar2020.pdf?sfvrsn=cb432bb3_2. [Accessed 16 March 2020].
2. European Centre for Disease Prevention and Control. *Guidance for wearing and removing personal protective equipment in healthcare settings for the care of patients with suspected or confirmed COVID-19*. February 2020. Available at: <https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-guidance-wearing-and-removing-personal-protective-equipment-healthcare-settings-updated.pdf>. [Accessed 18 March 2020].
3. Centers for Disease Control and Prevention. *Interim infection prevention and control recommendations for patients with suspected or confirmed coronavirus disease 2019 (COVID-19) in healthcare settings*. 10 March 2020. Available at: <https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html>. [Accessed 19 March 2020].
4. Food and Drug Administration. *N95 respirators and surgical masks (face masks)*. 11 March 2020. Available at: <https://www.fda.gov/medical-devices/personal-protective-equipment-infection-control/n95-respirators-and-surgical-masks-face-masks>. [Accessed 19 March 2020].
5. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. Expert Panel on MR Safety. *J Magn Reson Imaging* 2013;**37**(3):501–30. <https://doi.org/10.1002/jmri.24011>.
6. World Health Organization. *Advice on the use of masks in the community, during home care and in healthcare settings in the context of the novel coronavirus (2019-nCoV) outbreak*. WHO/nCov/IPC_Masks/2020.1. 29 January 2020. Available at: [https://www.who.int/publications-detail/advice-on-the-use-of-masks-in-the-community-during-home-care-and-in-healthcare-settings-in-the-context-of-the-novel-coronavirus-\(2019-ncov\)-outbreak](https://www.who.int/publications-detail/advice-on-the-use-of-masks-in-the-community-during-home-care-and-in-healthcare-settings-in-the-context-of-the-novel-coronavirus-(2019-ncov)-outbreak). [Accessed 18 March 2020].