

**CADTH RAPID RESPONSE REPORT:  
SUMMARY WITH CRITICAL APPRAISAL**

# **MRI-Compatible Ventilators and Physiological Equipment for Adults Undergoing MRI exams: A Review of Clinical Effectiveness and Guidelines**

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## Abbreviations

ACR	American College of Radiology
ASA	American Society of Anesthesiologists
ASTM	American Society for Testing and Materials
MRI	Magnetic resonance imaging
NHMRC	National Health and Medical Research Council
PICO	Patient, interventions, comparators, outcomes
SMRI	Society for Magnetic Resonance Imaging
RCT	randomized controlled trial

## Context and Policy Issues

Magnetic resonance imaging (MRI) is a commonly used procedure in the diagnosis and evaluation of diseases. MRI uses a strong magnetic field and radio waves to produce a detailed cross-sectional 3-dimensional image of the patient's internal organs and structures.<sup>1</sup> While the relative safety and advantages of MRI over other imaging technologies resulted in its ever increasing use, there are a number of safety issues resulting from patient-related and equipment-related factors. Equipment with ferromagnetic property may pose a serious projectile hazard due to magnetic attraction, and should be permanently fixed or tethered to the floor or the wall.<sup>2</sup> Patients may also suffer from thermal injury resulting from excessive heating of equipment during MRI, particularly with electrical conductive materials.<sup>2</sup> Electromagnetic interference is another major concern that can cause device malfunction or lead to distortions or artefacts in the MRI image, therefore special protective cables or enclosures are used.<sup>2</sup>

MRI "safe" equipment is identified as having no ferromagnetic parts or radiofrequency interference.<sup>3</sup> MRI "unsafe" equipment is comprised of ferromagnetic materials or those that cause radiofrequency interference.<sup>3</sup> MRI "conditional" equipment may contain ferromagnetic parts but can operate properly at a safe distance from the MRI system.<sup>3</sup> Equipment with MRI compatibility is necessary to operate in the MRI environment, which conventional accessories are not designed for.<sup>3</sup> MRI scanners have magnets with different strengths, and compatibility should always be assessed from reliable sources. In addition, proper labeling of all equipment with specifications to operational conditions is mandatory.<sup>1</sup>

The American College of Radiology (ACR) published a guidance document on MR safety practices<sup>1</sup> in which four zones of increasing magnetic sensitivity and barriers to access were described. Zone 1 and 2 constitute the freely accessible area outside the MRI environment and the interface separating the more restricted areas, respectively. Zone III is a restricted area within the MRI suite with strict control on ferromagnetic objects or equipment and should be under supervision of authorized personnel. Zone IV contains the MRI scanner; therefore the highest degree of restriction should be imposed to prevent any magnet-associated hazard.<sup>1</sup>

Monitoring of physiological parameters during an MRI examination is necessary for patients who are sedated or anesthetized, critically ill, or have underlying health issues.<sup>2</sup> The Society for Magnetic Resonance Imaging (SMRI) recommends monitoring of patients at least visually or verbally, and using appropriate physiological monitors for high-risk patients or those unable to respond during MRI.<sup>5</sup> In addition, some patients may require mechanical ventilation, which require the same safety considerations as monitoring.<sup>5</sup> A number of guidelines are available to ensure the safety of patients and healthcare professionals working in an MRI unit.<sup>1,4,6-9</sup> However, evidence for clinical effectiveness of equipment used in MRI settings is limited, particularly for ventilators and physiological monitors.

The objective of this report is to summarize the available evidence regarding the clinical effectiveness and evidence-based guidelines for MRI-compatible ventilators and physiological monitoring equipment for use during MRI in adult patients requiring ventilation.

## Research Questions

1. What is the clinical effectiveness of magnetic resonance imaging (MRI)-compatible ventilators in adult patients requiring ventilation during an MRI exam?
2. What is the clinical effectiveness of physiological monitoring equipment used during a MRI exam in adult patients on a ventilator?
3. What are the evidence-based guidelines associated with the use of MRI-compatible ventilators for adult patients undergoing a MRI exam?
4. What are the evidence-based guidelines associated with the use of physiological monitoring equipment used for ventilated adult patients during an MRI exam?

## Key Findings

No evidence regarding the clinical effectiveness of MRI-compatible ventilators and physiological monitors for ventilated patients during MRI was identified.

No evidence-based guidelines associated with the use of MRI-compatible ventilators and physiological monitoring for ventilated adult patients during MRI exams were found.

## Methods

### Literature Search Methods

A limited literature search was conducted on key resources PubMed, The Cochrane Library, University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and major international health technology agencies, as well as a focused Internet search. Methodological filters were applied to limit the retrieval to health technology assessments, systematic reviews, meta-analyses, randomized controlled trials, non-randomized studies, and guidelines. The search was limited to English language documents published between January 1, 2013 and May 23, 2018.

### Selection Criteria and Methods

One reviewer screened citations and selected studies. In the first level of screening, titles and abstracts were reviewed and potentially relevant articles were retrieved and assessed for inclusion. The final selection of full-text articles was based on the inclusion criteria presented in Table 1.

**Table 1: Selection Criteria**

<b>Population</b>	Q1-3: Adult patients requiring ventilation an MRI exam (any setting) Q2-4: Adult patients requiring physiological monitoring during an MRI exam while on a ventilator (any setting)
<b>Intervention</b>	Q1: MRI compatible ventilators Q2: Physiological monitoring equipment (e.g., heart, breathing, blood pressure monitors) used during an MRI exam on a ventilated patient
<b>Comparator</b>	Q1: Standard of care; Non-ventilation approaches; Q2: Standard of care; No monitoring Q3-4: No comparator

<b>Outcomes</b>	Q1-2: Clinical effectiveness and safety (patient benefits and harms) Q3-4: Guidelines
<b>Study Designs</b>	Health technology assessments, systematic reviews, meta-analyses, randomized controlled trials, nonrandomized studies, evidence-based guidelines

MRI = magnetic resonance imaging

## Exclusion Criteria

Articles were excluded if they did not meet the selection criteria outlined in Table 1, they were duplicate publications, or were published prior to 2013. Guidelines with no information on whether a systematic literature search was performed to collect evidence were also excluded.

## Summary of Evidence

### Quantity of Research Available

A total of 285 citations were identified in the literature search. Following screening of titles and abstracts, 283 citations were excluded and two potentially relevant reports from the electronic search were retrieved for full-text review. In addition, 17 potentially relevant publications were retrieved from the grey literature search for full text review. None of these potentially relevant articles met the inclusion criteria described in Table 1. Appendix 1 presents the PRISMA flowchart of the study selection. Additional references of potential interest are provided in Appendix 5.

### Summary of Findings

*Question 1: What is the clinical effectiveness of MRI-compatible ventilators in adult patients requiring ventilation during an MRI exam?*

No relevant evidence regarding the clinical effectiveness of MRI-compatible ventilators was identified; therefore, no summary can be provided.

*Question 2: What is the clinical effectiveness of physiological monitoring equipment used during a MRI exam in adult patients on a ventilator?*

No relevant evidence regarding the clinical effectiveness of physiological monitoring equipment for ventilated patients during MRI was identified; therefore, no summary can be provided.

*Question 3: What are the evidence-based guidelines associated with the use of MRI-compatible ventilators for adult patients undergoing a MRI exam?*

No relevant evidence-based guidelines associated with the use of MRI-compatible ventilators were identified; therefore, no summary can be provided.

*Question 4: What are the evidence-based guidelines associated with the use of physiological monitoring equipment used for ventilated adult patients during an MRI exam?*

No relevant evidence-based guidelines associated with the use of physiological monitors for ventilated patients during MRI were identified; therefore, no summary can be provided.

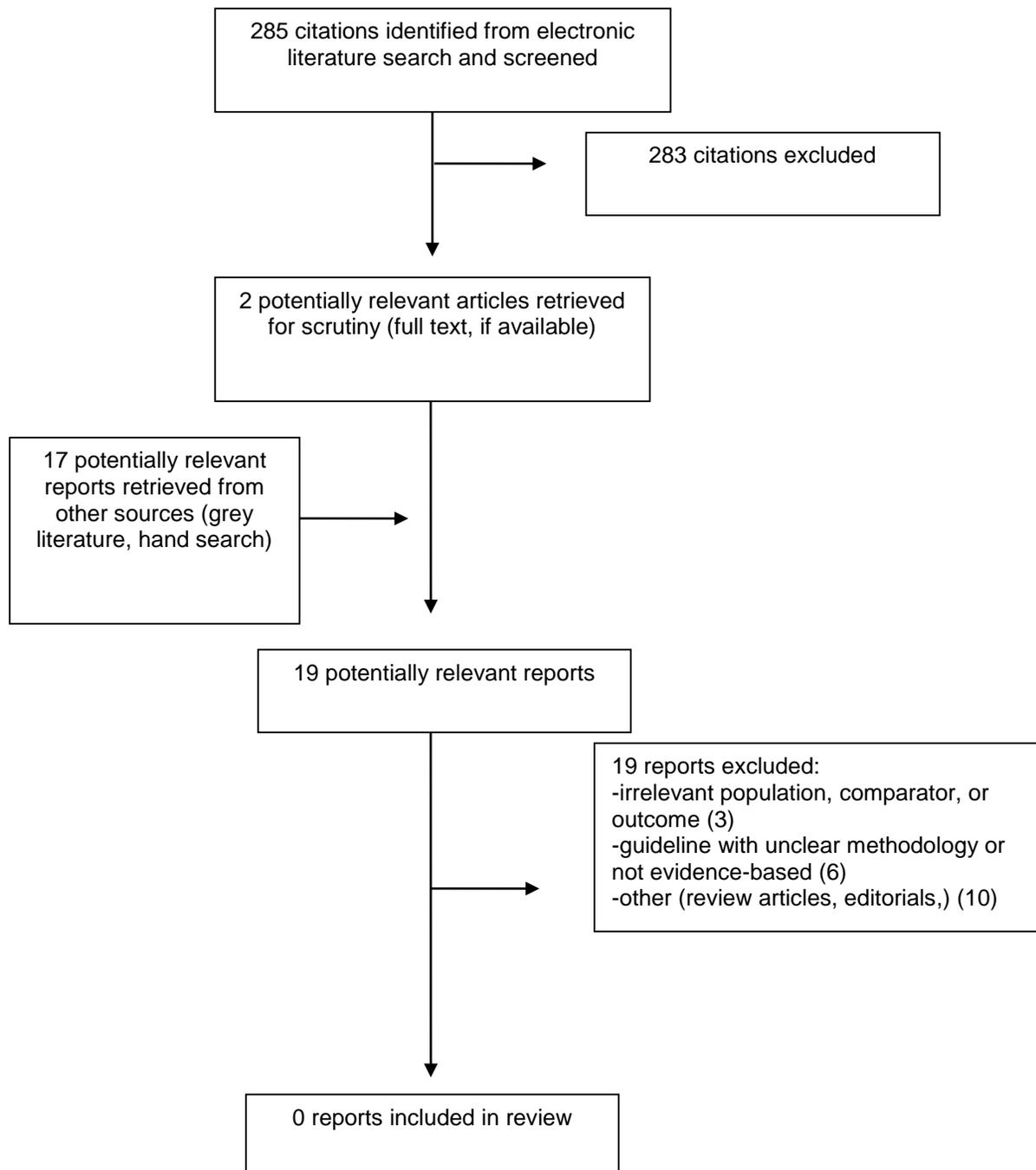
## Conclusions and Implications for Decision or Policy Making

No relevant clinical studies or guidelines were identified from a five-year review of the literature that provided information on the clinical effectiveness, safety and practice guidelines for MRI-compatible ventilators and physiological monitoring among adult patients requiring ventilation during MRI. The paucity in evidence warrants further research in this area. One practice advisory, which did not meet in the inclusion criteria of this review, was primarily targeted towards anesthesiologists to ensure safe practices within an MRI environment and provided information on the safety of physiological monitors.<sup>10</sup> The authors of the advisory indicated that the practice advisory report was not intended as standards or guidelines; instead a set of systematically developed recommendations that may be adopted, modified, or rejected according to the clinical needs and constraints of the local institution. Evidence from several non-comparative observational studies and case reports included in the advisory suggest that monitoring equipment are not associated with serious harms involving the MRI scanner or the individual, other than occasionally evoking a burning sensation or interference with the MRI scan. However, the evidence is not specific to patients on ventilation, and there is significant uncertainty in the quality of the included studies due to a lack of study quality assessment and adequate details. The authors recommended that MRI-compatible ventilators should be available in the unit; however, this appears to be applicable to any equipment used during MRI without any supporting evidence for clinical benefits. The advisory also recommends that anesthesiologists should ensure safety for all personnel within the MRI location, and responsible for inspecting and labeling all equipment for MRI compatibility, communicating with other healthcare professionals in case patients require ventilation, monitoring or other steps, providing anesthetic care, and management of any emergencies. With no recently published comparative data or guidelines on the safety and clinical effectiveness of MRI-compatible ventilators and physiological monitors for ventilated patients, there is a significant dearth in the evidence to inform policy decisions.

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## Appendix 1: Selection of Included Studies



## Appendix 1: Additional References of Potential Interest

### Guideline without the population of interest

Practice advisory on anesthetic care for magnetic resonance imaging: an updated report by the American Society of Anesthesiologists task force on anesthetic care for magnetic resonance imaging. *Anesthesiol.* 2015;122(3):495-520.

<http://anesthesiology.pubs.asahq.org/article.aspx?articleid=2091587>

### Guidelines with unclear methodology, not evidence-based, without information specific to the research questions, or published before 2013

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### Canadian Guidelines/HTA reports

Chakraborty S, Johnson MA, Miller W, Noseworthy MD, Seely J, Dennie C, et al. CAR Standard for magnetic resonance imaging. Ottawa (ON): Canadian Association of Radiologists (CAR); 2011 Apr. <https://car.ca/wp-content/uploads/Magnetic-Resonance-Imaging-2011.pdf> Accessed 2018 Jun 19.

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