1.5 Tesla Magnetic Resonance Imaging Scanners Compared with 3.0 Tesla Magnetic Resonance Imaging Scanners: Systematic Review of Clinical Effectiveness


**Introduction**

Medical technologies are continually changing and magnetic resonance imaging (MRI) is no exception, where increasing the magnet strength has produced more sophisticated device capabilities. Most installed clinical MRI scanners in Canada are built around a 1.5 Tesla (T) magnet, but newer devices include magnets of greater strength at 3.0 T and at 7.0 T. In Canada, between 2008 and 2009, the Canadian Institute for Health Information (CIHI) reported a national average of 41.4 MRI examinations per 1,000 people.1

An MRI scanner works by emitting a strong magnetic field that aligns the nucleic spin orientation of hydrogen atoms at a low energy state in a patient. To manipulate the nucleic spin of hydrogen atoms in another direction (to a higher energy state), MRI emits a radiofrequency into an area in the body. The MRI then captures the energy that is released by hydrogen-bound molecules transitioning from a high to a low energy state. This exchange of energy between spin states is called resonance, hence resonance imaging.

A resonance frequency receiver coil detects the energy emitted from the hydrogen atoms, and a computer displays the different resonance characteristics of various tissue types as an image. The image shows body tissues in various shades of grey.2 The amount of the signal (the strength of the energy emission from induced hydrogen atoms) that is used to compose an image is proportional to the magnetic field strength of the scanner. Signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), spatial resolution, and temporal resolution are common technical terms used to describe MRI image quality.

This report is a review of the evidence comparing the clinical applications of 1.5 T MRI with those of 3.0 T MRI, and aims to provide health care decision-makers such as government purchasers, health care planners, and clinicians with information about the clinical effectiveness of the 1.5 T MRI and the 3.0 T MRI.

**Objective**

The purpose of this review is to evaluate the differences between 1.5 T MRI and 3.0 T MRI scanners. The research questions are:

1. What are the clinical benefits, limitations, and safety considerations for imaging with a 1.5 T MRI scanner compared with a 3.0 T MRI scanner?
2. What are the service delivery, personnel, and structural (renovation, installation) differences between a 1.5 T MRI scanner and a 3.0 T MRI scanner?

**Methods**

A literature search was conducted on health technology assessment (HTA) resources, including MEDLINE, Embase, CINAHL, PubMed, The Cochrane Library (Issue 11, 2010), the University of York Centre for Reviews and Dissemination databases, ECRI (Health Devices Gold), EuroScan, international health technology agencies, and a focused Internet search. The search was limited to English or French language articles that were published between January 1, 2005 and
November 29, 2010. Regular alerts are current to April 27, 2011. Methodological filters were applied to limit the retrieval of articles on 1.5 T MRI or 3.0 T MRI systems to health technology assessments (HTAs), systematic reviews, and meta-analyses. No filters were applied to limit the retrieval by study type for articles that compared 1.5 T MRI and 3.0 T MRI systems. Two independent reviewers screened articles using predefined criteria.

To answer the research question on clinical benefits, limitations, and safety, a systematic review was conducted. The clinical effectiveness of MRI scanners was evaluated by assessing clinically meaningful outcomes including effect on diagnosis, clinical management decisions, or patient outcomes as reported in comparative studies of 1.5 T MRI and of 3.0 T MRI. Studies that reported solely on outcomes specific to technical aspects of imaging were not considered. The included studies had at least 20 patients who were each scanned with 1.5 T MRI and 3.0 T MRI within one week for acute conditions and within one month for chronic conditions. A supplemental, narrative review was conducted to further review MRI and patient safety.

To answer the research question on service delivery, personnel, and structural differences, information was gathered from CIHI, peer-reviewed literature, web-based resources, and experts. In addition, a survey was distributed to the five original equipment manufacturers of MRIs in Canada.

Results

No identified studies examined whether the use of 3.0 T MRI scanners would result in a change in patient outcomes, or a change in clinical management, compared with 1.5 T MRI scanners.

All of the 25 included studies reported on clinical test parameters. The six clinical areas were:

- neurology — mainly multiple sclerosis
- cerebrovascular conditions
- renal artery stenosis
- coronary artery disease (CAD)
- musculoskeletal disorders
- oncology (breast cancer, liver cancer, prostate cancer, endometrial cancer, and cervical cancer).

The authors most commonly reported that 3.0 T MRI was similar to 1.5 T MRI for various outcomes. In a few cases, 1.5 T MRI scanners were found to be better than 3.0 T MRI scanners; for example, regarding tumour delineation of the prostate. And, in some other instances, 3.0 T MRI scanners outperformed 1.5 T MRI scanners. For example, advantages with 3.0 T MRI were seen in:

- lesion detection in multiple sclerosis
- identification of single- or multi-vessel disease in patients with CAD
- identification of disc shape and position for temporomandibular joint (TMJ)
- nerve visibility for brachial plexus
- visibility of anatomic structures in the wrist
- identification of fibrocartilage lesions
- diagnostic accuracy for hepatic metastases
- sensitivity for detecting hepatic metastases.

The sample sizes of the studies ranged from 20 to 65 patients, were prospective, and involved patients who received repeat testing with 1.5 T MRI and 3.0 T MRI within a short time frame. Two or more interpreters (usually radiologists), generally blinded to patient details and magnet size, assessed the images using standardized quantitative measurements and qualitative questionnaires. In some cases, the findings were recorded independently and then compared. In other cases, the findings were agreed to by consensus.

Safety information collected from reviews, not individual studies, indicated that the greater magnetic effect of 3.0 T MRI scanners may make them unsuitable for patients with specific implanted devices; to date, more than 1,000 devices and other objects have not yet been deemed to be safe with the use of the 3.0 T MRI. Increased heat and increased noise with 3.0 T MRI may also be of concern.
One relevant study by Ohba et al.\textsuperscript{3} was identified through the alert process. The study was a non-randomized, prospective comparative study and the results did not affect the conclusions of the systematic review. Ohba et al. provided evidence that 3.0 T MRI and 1.5 T MRI were similar in identifying 58 malignant pulmonary nodules in 76 patients when using diffusion-weighted imaging. The authors also noted that further software developments for 3.0 T MRI would reduce lung artifacts, thus improving the correlation with apparent diffusion coefficient values and the 18F-fluorodeoxyglucose uptake on the positron-emission tomography.

Two original equipment manufacturers responded to the survey, one of which provided substantial information. These survey responses, as well as an interview with an expert and the 2009 medical imaging technology survey by CIHI, provided the information on the research question on service delivery, personnel, and structural differences. As of January 1, 2009,\textsuperscript{1} the CIHI data show that there were 212 MRI installations as of that date, of which eight were 3.0 T (in Alberta, Ontario, and Quebec). The national mean number of examinations per MRI scanner was 5,750. For 2008 to 2009 use, the national mean was 41.4 MRI examinations per 1,000 people, which is below that of the countries in the Organisation for Economic Cooperation and Development, where a mean of 48.5 examinations per 1,000 people was reported. Compared with a 1.5 T MRI, a 3.0 T MRI is a larger and heavier machine, and so a larger room may be required, with additional structural support. The 3.0 T MRI may require upgraded magnetic shielding to confine the 5 Gauss fringe field in the scan room and may require new wave guides (ports through which intravenous tubing or other lines may be passed through into the scan room), as well as increased floor loading at the support feet. The radiofrequency shielding may not need to be replaced.

Limitations

Clinical Benefits, Limitations, and Safety

The main limitation for the systematic review was the lack of evidence linking the clinical test findings for different MRI technologies to an impact on clinically meaningful outcomes; that is, diagnosis, patient management, and clinical outcomes. Although some studies reported that 3.0 T MRI was superior in clinical test parameters (for example, lesion number and lesion location), it was unclear whether this would translate into meaningful differences to patients, and what the magnitude of the differences would be. Studies also tended to be small, generally with 20 patients to 30 patients enrolled. Several articles acknowledged this limitation and suggested that studies would need to be larger, enroll a broader spectrum of patients, and include more extensive patient follow-up to draw clinically valid conclusions. In addition, all the identified studies were observational and thus did not stringently control for potential biases that may result in a higher chance of differences being falsely detected or actual differences not being detected.

The included literature for the systematic review was limited to those studies meeting selection criteria. Therefore, a number of indications for MRI were excluded; for example, brain tumours, epilepsy, breast imaging, and knee and shoulder pathology. Similarly, all included studies involved adult populations; pediatric populations were not studied.

Although the funding source was sought for each included study, 22 of the 25 (88%) included studies did not report whether there was funding or conflicts of interest. Of the remaining three studies, one, each, was funded by the German Research Foundation, Dutch MS Research Foundation, and Pfizer. Regarding industry affiliation, studies reported one author employed by GE, two by Philips, and one by Pfizer.
An issue in the interpretation of the results of these studies is the increasing sophistication and changing performance of MRI devices. Although only recent studies were included (published in 2005 or later), some studies were performed as early as 2003 when 3.0 T MRI was in the early stages of introduction. Current 1.5 T MRI and 3.0 T MRI machines would perform differently from those that were used in the studies, suggesting that the findings from the earlier studies would not be reproducible today.

The MRI literature is limited, in part due to federal regulations that only require device manufacturers to provide proof of safety and technical performance consistency according to specifications (scientific evidence of clinical utility or patient benefit before licensing is unnecessary). This does not provide an impetus for manufacturers to conduct studies that explore the impact of device technology on clinical outcomes.

**Service Delivery, Personnel, and Structural Differences**

Short time lines for report completion, time of year (December and January), and extensiveness of the survey requests limited the information received from original equipment manufacturers. The information that is needed to adequately assess service delivery, personnel, and structural differences is often unpublished, inaccessible, and anecdotal. Similarly, data on utilization were limited to information that was collected in January 2009 (2010 data have been collected but have not yet been released by CIHI). More than with the other sections of this report, the information on service delivery and personnel are not immediately transferable to other jurisdictions.

**Conclusions**

The evidence on clinical test parameters (for example, number of lesions) shows that 3.0 T MRI, in general, performs as well as or better than 1.5 T MRI for the studies included in this review. Study design is, however, limited by factors such as design and sample size. The evidence on clinical test parameters does not indicate whether or not patients will receive different clinical management or experience different health outcomes. That is, the relative clinical effectiveness of 3.0 T MRI compared with 1.5 T MRI cannot be determined. There is a lack of evidence on the safety of using 3.0 T MRI with implanted devices. Other factors to consider with a 3.0 T MRI is the extent to which a facility with a 1.5 T MRI requires renovation to house a 3.0 T MRI, the experience of staff, the need for research applications, and the need for current and future clinical applications.

**References**


Production Notes

CADTH Technology Overviews is produced by:
Canadian Agency for Drugs and Technologies in Health (CADTH)
600-865 Carling Ave.
Ottawa, Ontario, Canada K1S 5S8
Tel.: 613-226-2553
Fax: 613-226-5392
Website: www.cadth.ca

CADTH Technology Overviews contains articles that are based on CADTH Technology Reports and other CADTH reports on health technologies. The information presented in this publication is intended to help Canadian health care decision-makers, health care professionals, health systems leaders, and policy-makers make well-informed decisions and thereby improve the quality of health care services. The information in this publication should not be used as a substitute for the application of clinical judgment in respect to the care of a particular patient or other professional judgment in any decision-making process, nor is it intended to replace professional medical advice.

While CADTH has taken care in the preparation of this publication to ensure that its contents are accurate, complete, and up to date as of the date of publication, CADTH does not make any guarantee to that effect. CADTH is not responsible for any errors or omissions or injury, loss or damage arising from or relating to the use (or misuse) of any information, statements, or conclusions contained in or implied by the information in this publication or in any of the source documentation.

CADTH Technology Overviews and the information it provides is prepared and intended for use in the context of the Canadian health care system. Other health care systems are different; the issues and information related to the subject matter presented in this publication may be different in other jurisdictions and, if used outside of Canada, it is at the user’s risk. This disclaimer and any questions or matters of any nature arising from or relating to the content or use (or misuse) of this publication will be governed by and interpreted in accordance with the laws of the Province of Ontario and the laws of Canada applicable therein, and all proceedings shall be subject to the exclusive jurisdiction of the courts of the Province of Ontario, Canada.

CADTH takes sole responsibility for the final form and content of this publication, subject to the limitations noted above. The statements and conclusions in this publication are those of CADTH and not of its advisory committees and reviewers. The statements, conclusions, and views expressed herein do not necessarily represent the views of Health Canada or any Canadian provincial or territorial government.

Production of CADTH Technology Overviews is made possible by financial contributions from Health Canada and the governments of Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Northwest Territories, Nova Scotia, Nunavut, Prince Edward Island, Saskatchewan, and Yukon.

Copyright © CADTH 2012. You are permitted to reproduce this document for non-commercial purposes, provided it is not modified when reproduced and appropriate credit is given to CADTH. You may not otherwise copy, modify, translate, post on a website, store electronically, republish, or redistribute any content from this document in any form or by any means without the prior written permission of CADTH.

Please contact CADTH’s Vice-President of Corporate Services at corporateservices@cadth.ca with any inquiries about this notice or other legal matters relating to CADTH’s services.

Cite as: Canadian Agency for Drugs and Technologies in Health. CADTH Technology Overviews, 2012; 2(2).

ISSN: 1481-4501 (online)