

Literature Review: Safety and Quality in Diagnostic Imaging

A report prepared by the Allied Health and Human Performance Unit, University of South Australia

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Acknowledgement

The Australian Commission on Safety and Quality in Health Care acknowledges the Traditional Owners, the Gadigal people of the Eora Nation on whose land the Commission's office is located, and the lands across Australia where those we partner with work. The Commission pays our deep respect to Aboriginal and Torres Strait Islander Elders past, present and emerging

Preface

The Australian Commission on Safety and Quality in Health Care's (the Commission) role is to lead and coordinate national improvements in health care safety and quality. The Commission works in partnership with the Australian Government, state and territory governments and the private sector to achieve a safe, high-quality, sustainable health system. In doing so, the Commission also works closely with patients, carers, clinicians, managers, policymakers and healthcare organisations. The Commission is responsible under the *National Health Reform Act 2011* for formulating standards relating to health care safety and quality matters and for formulating and coordinating national accreditation models for health service organisations.

In July 2021, responsibility for the coordination of the Diagnostic Imaging Accreditation Scheme was contracted to the Commission. Included on the work plan for DIAS was the review of the Diagnostic Imaging Standards.

As part of the review of standards, the Commission contracted the Allied Health and Human Performance Unit, of the University of South Australia to complete a literature review. The literature review sought to address the following questions:

1. What are the main patient safety and quality care risks relevant to diagnostic imaging?
2. What interventions can minimise patient safety and quality risks relevant to diagnostic imaging?
3. What is the evidence for the effectiveness of these interventions?
4. What areas of diagnostic imaging have unwarranted variation?
5. What improvements can address unwarranted variation?
6. What standards operate nationally and internationally for diagnostic imaging, and what do the standards address?

Key Findings

The authors grouped commonly occurring patient safety issues, including:

- **Communication** issues that occur across the continuum of care, arising in the referral, patient identification, examination processes, and during communication between clinicians, which can result in errors on interpretation, reporting and access to timely care.
- **Infection control** issues including hand hygiene, the use of personal protective equipment, and equipment cleaning following examination. Ultrasound has a specific infection risk associated with the gel, and external and internal transducers being transmission agents requiring sterilisation.
- **Radiation safety** has become more important with the increased use of diagnostic imaging. Providing an optimal dose to obtain a useable image and minimise radiation exposure requires careful consideration.
- **Contrast administration** and effect are impacted by the patient's reaction history or pre-existing health conditions. Administration, correct dosing, and effective management of a contrast reaction all present patient risks. In the event of a reaction, responding promptly and appropriately requires training, defined response processes and specific equipment.

- **Diagnostic error** includes an incorrect, delayed, missed, near miss or over-diagnosed disease process due to an examination or treatment within the diagnostic imaging practice.
- **MRI safety issues** include high energy magnets, soft tissue heating associated with the radiofrequency used to image the patient and the acoustic noise associated with gradient coils.

The authors also found multi-faceted strategies addressing individual, situational, environmental, organisational, cultural and communication factors can improve patient safety and quality. While there is a range of strategies with varying levels of evidence, the literature highlights that there is no 'one-size-fits-all' approach. The improvement strategies need to be commensurate with wide-ranging factors contributing to the safety and quality issues. The interventions should include a systems approach to address issues at multiple levels.

Unwarranted variation within diagnostic imaging was considered by the authors in three groups:

- **Low-value care** involves choosing high-cost imaging modalities at the expense of other more affordable, equally accurate modalities. Low-value care can result in an increase in patient and health service's financial burden, patient radiation dose and diagnostic imaging practice workload.
- **Variation from best practice diagnostic or treatment pathways** which may result in incorrect or incomplete diagnosis and an increase in patient radiation dose.
- **Delayed diagnostic imaging accessibility involves** increased waiting times, inequity in access to diagnostic imaging due to geographical differences and workforce shortages.

It was found that interventions to improve unwarranted variations have mixed evidence of effectiveness and can be grouped according to the risk of patient harm. Improvements to address unwarranted variation with a high risk of patient harm include regulation and oversight by professional bodies, availability and use of standards and evidence-based guidelines and strategies to influence the clinician's role. Improvements to address unwarranted variation with a low risk of patient harm include addressing a clinician's belief in imaging or the lack of knowledge on the appropriate use of new radiological technology.

Several national and international standards are available for diagnostic imaging. The standards focus on the practitioner and the practice of diagnostic imaging. Within Australia, the Australian Health Practitioner Regulation Agency sets standards across medical radiation professions. The Diagnostic Imaging Accreditation Scheme (DIAS) ensures safety and quality standards for Australia's diagnostic imaging practices accessing Medicare payments. The Royal Australian and New Zealand College of Radiologists (RANZCR) *Standards of Practice for Clinical Radiology* outlines the standards of practice for clinical radiology.

Internationally, standards assessed in diagnostic imaging services vary in their focus. Common themes include leadership and management, clinical facilities, staffing and workforce, patient experience, safety, technical and quality management, research and innovation.

This literature review will inform the development of standards and resources for diagnostic imaging practices.

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Abbreviations

AANMS	Australasian Association of Nuclear Medicine Specialists
AHPRA	Australian Health Practitioner Regulation Agency
ALARA	As Low As Reasonably Achievable
ASAR	Australian Sonographer Accreditation Registry
ASMIRT	The Australian Society of Medical Imaging and Radiation Therapists
ASUM	The Australasian Society for Ultrasound in Medicine
CT	Computed Tomography
DIAS	Diagnostic Imaging Accreditation Scheme
ESR	European Society of Radiology
MIAP	Medical Imaging Accreditation Program
MRI	Magnetic Resonance Imaging
MRPBA	Medical Radiation Practice Board of Australia
NHMRC	National Health Medical Research Council
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
RANZCR	The Royal Australian and New Zealand College of Radiologists
The Commission	Australian Commission on Safety and Quality in Health Care
UniSA	University of South Australia
US	Ultrasound

Executive Summary

This report summarises contemporary literature on diagnostic imaging patient safety and quality care issues, strategies to improve patient safety and quality care and national and international standards that underpin diagnostic imaging.

Review questions

This review aimed to address the following questions:

1. What are the main patient safety and quality care risks relevant to diagnostic imaging?
2. What interventions can minimise patient safety and quality risks relevant to diagnostic imaging?
3. What is the evidence for the effectiveness of these interventions?
4. What areas of diagnostic imaging have unwarranted variation?
5. What improvements can address unwarranted variation?
6. What standards operate nationally and internationally for diagnostic imaging, and what do the standards address?

Summary of methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) underpinned the literature review. In consultation with the Commission, the UniSA research team developed a review protocol outlining the scope, selection criteria, sources of evidence, search strategy, and methods for data extraction, analysis, and reporting (see Appendix A).

The literature review included commercially produced literature and grey literature that reported on one or more aspects of safety and quality in diagnostic imaging. These included but were not limited to:

- Diagnostic imaging patient risks, harms, or adverse events
- Unwarranted variation in diagnostic imaging
- Methods for management and minimising diagnostic imaging risks, harms, and unwarranted variation
- Common diagnostic imaging standards which aim to protect patients from harm

The targeted diagnostic imaging modalities included ultrasound (US), computed tomography (CT), X-ray, mammography, angiography, fluoroscopy, orthopantomography, magnetic resonance imaging (MRI) and nuclear medicine. The literature included was English only and primarily focused on review types (e.g., narrative, systematic or scoping review) published or produced after 1 January 2010 to prioritise current and best available evidence. Given the nature and the scope of the review, a comprehensive environmental scan or a systematic review was not undertaken.

Key findings

Question 1: What are the main patient safety and quality care risks relevant to diagnostic imaging?

The literature included various patient safety issues and quality care risks from several countries, including the United Kingdom, Europe, Australia, and the United States of America. While the Australian literature is scarce, many patient safety issues and quality care risks are likely shared across jurisdictions. Among the identified studies, various methodologies were used, including a National Specialty report and review papers, including systematic reviews and literature reviews which are more narrative.

Within the reviewed literature, there are common patient safety issues identified that are broadly categorised into the following areas:

Communication

Communication issues occur across the continuum of care, including before, during and after the examination or treatment. In the 'before' category, communication issues may arise as part of the referral process, patient identification and examination process, and communication between clinicians. In the 'during' category, communication issues may arise between clinicians, adversely impacting patient care. In the 'after' category, communication issues may occur between the clinician and the patient, clinician and the referrer, and/or between clinicians that can result in errors in interpretation, reporting and access to timely care.

Infection control

Infection control is essential and includes hand hygiene, personal protective equipment, and cleaning of all equipment following examination. Radiopaque markers and specialised support equipment (such as a chest stand) are infection transmission points unique to diagnostic imaging if not cleaned effectively between patients. Ultrasound has a specific infection risk associated with the gel, and external and internal transducers being transmission agents.

Radiation safety

There is a strong focus on radiation safety in the diagnostic imaging literature. With the increasing use of diagnostic imaging, careful consideration is required about the optimal dose. The literature supports considering the means to keep the dose 'As Low As Reasonably Achievable' (ALARA), which is achieved by carefully considering the examination or treatment justification, images or treatment optimisation and dose limit optimisation. Additional strategies include external shielding and a reduction in repeat images.

Contrast administration

Patient safety issues relating to contrast administration included iodinated and non-iodinated contrast media used in MRI and US. Issues include safe contrast delivery considering the patient's reaction history or pre-existing health condition(s), ensuring the correct dose is administered, and effective management of a contrast reaction. In the event of a reaction, staff are to respond in a timely manner with appropriate resources (such as medication and a resuscitation trolley).

Diagnostic error

Patient safety issues include an incorrect, delayed, missed, near miss or over-diagnosed disease process due to an examination or treatment within the diagnostic imaging practice. While the reasons contributing to these errors are likely to be multifactorial, poor communication and time pressures were identified as common causes.

Safety issues associated with using MRI

MRI safety issues include the use of high energy magnets (such as interactions of the magnetic field with medical devices such as pacemakers), soft tissue heating associated with the radiofrequency used to image the patient and the acoustic noise associated with gradient coils.

Question 2 and 3: What interventions can minimise patient safety and quality risks relevant to diagnostic imaging? What is the evidence for the effectiveness of these interventions?

The commercially produced and grey literature seems to support multi-faceted strategies to address individual, situational, environmental, organisational, cultural and communication factors that impact patient safety and quality. While these factors may present as stand-alone, individual factors, they are complex and inter-related in practice. Addressing one factor without the others may not produce optimal outcomes.

The literature reports a range of strategies, with varying levels of evidence, that suggest how to improve patient safety and reduce quality risks in diagnostic imaging. It highlights that there is no 'one-size-fits-all' approach. The improvement strategies should include multi-component interventions commensurate with wide-ranging factors contributing to the safety and quality issues. The literature recommends underpinning interventions with a systems approach to address issues at multiple levels. However, the literature does not identify the ideal combination of interventions or the parameters underpinning these interventions (type, duration, frequency, mode etc.). This is an important limitation to consider, although this may assist in developing and implementing interventions which consider local context, staffing profile, patient expectations, resources etc.

Commonly reported interventions included:

- Creating a supportive safety culture that is non-punitive with a focus on learning, shared accountability, leadership with stakeholders and supported with adequate infrastructure and resources
- Consistent use of guidelines to inform clinical decision making which can standardise practice and use of key performance indicators
- Standardised and well-documented communication systems, including handoff, use of electronic medical records and ordering systems
- Explicit consideration of patient experiences, expectations, concerns, consent, and patient-mediated interventions
- Engagement with quality improvement activities such as clinical audits, plan-do-study-acts, root cause analysis, error scoring, sentinel events, near-miss events, root cause analysis, lean and six sigma, Radiologic-Surgical and Radiologic-Pathologic Correlation.

- Delivery of and participation in interactive educational sessions and promote learning with various topics (such as training to identify cognitive biases like anchoring, confirmation and availability bias). This may include strategies such as reflective reasoning (meta-cognition), perceptual training and patient safety issues
- Use of peers through activities such as teamwork, double reading/reporting, error/peer review, external review, and peer learning
- Use of checklists and structured reporting
- Implementation of strategies to reduce fatigue and burnout such as adequate staffing, timed breaks, regular exercise, accommodative relaxation
- Addressing environmental factors including but not limited to reading room ambient light, monitor luminance, workstation layout, room temperature and humidity, noise level, and ready access to all necessary tools in the workstation
- Recognising the emergent role of technology such as artificial intelligence, clinical decision support tools, attentional guidance, search strategies, bone subtraction techniques, computer aided detection and electronic medical records

Question 4: What areas of diagnostic imaging have unwarranted variation?

Unwarranted variation within diagnostic imaging can occur across different points of care. It can be grouped into low-value care, deviation from the recommended pathway and access delays. While these themes are presented as stand-alone constructs, in practice, they are likely to be interlinked.

Low-value Care

Low-value care involves choosing high-cost imaging modalities at the expense of other more affordable, equally accurate modalities. Examples include choosing high-cost imaging modalities such as CT, MRI, and contrast studies. Low-value care can result in an increase in the:

- Financial burden for the patient or healthcare service
- Radiation dose for patients having CT and contrast studies
- Workload in a diagnostic imaging practice, which may delay other patients' examinations or treatments that have a higher diagnostic or treatment value

Research highlights the barriers to reducing low-value procedures, include referrer practices and patient expectations.

Variation from recommended diagnostic or treatment pathway

Variation from best practice diagnostic or treatment pathways may result in incorrect or incomplete diagnosis and an increase in patient radiation dose. It is important to have recognised diagnostic or treatment pathways developed based on the available evidence to support the most efficient pathway for the patient through diagnosis and treatment of their disease.

Delayed diagnostic imaging accessibility

This unwarranted variation includes increased waiting times, inequity in access to diagnostic imaging due to geographical differences and workforce shortages.

Question 5: What improvements can address unwarranted variation?

Several improvements have been suggested to address unwarranted variation in diagnostic imaging with mixed evidence of effectiveness. These interventions can be grouped according to the risk of patient harm resulting from unwarranted variation. Examples of unwarranted variation with a high risk of patient harm include inappropriate care resulting in patient death and sexual assault allegations resulting from not clinically necessary, inappropriate behaviour. Improvements to address unwarranted variation that is high risk for patient harm target:

- The process of care through regulation and oversight by professional bodies
- Availability and use of standards and evidence-based guidelines
- Strategies to influence the clinician's role (such as mandatory training, clarity on the scope of practice, compliance with accredited practice, standardisation of referrals, education about reporting obligations and use of algorithms for early clinician notification)

Improvements to address unwarranted variation with a low risk of patient harm (such as inappropriate use of imaging) generally target the clinician's belief in imaging or the lack of knowledge on the appropriate use of new radiological technology. Multi-component interventions that include education and are adapted to the local context are more effective in reducing the use of low-value diagnostic imaging. Appropriateness of diagnostic imaging may be influenced by a myriad of strategies such as education (referrers and imaging specialists' role), use of imaging guidelines including incentives, patient-mediated approaches and use of clinical decision support tools.

The Getting It Right First Time (GIRFT) Programme National Specialty Report highlighted unwarranted variation with purchasing consumables (e.g., different brands), outsourcing reporting services and replacing old equipment. The United Kingdom has a National Health Service (NHS) Spend Comparison Service to help ensure the lowest price consumables are purchased. There is also a framework to manage outsourced reporting services under the NHS Supply Chain procurement.

Question 6: What standards operate nationally and internationally for diagnostic imaging and what do the standards address?

Several national and international standards are available for diagnostic imaging. These standards can be grouped into those used by government regulators and professional organisations. Generally, the government regulators' standards focus on the practitioner and the practice of diagnostic imaging (within the broader medical radiation professions).

Within Australia, the Australian Health Practitioner Regulation Agency (AHPRA) works with the Medical Radiation Board of Australia (MRPBA) to help protect the public and set standards across all medical radiation professions. The MRPBA has published a set of professional capabilities which identify the knowledge, skills and professional attributes needed to safely and competently practice as a medical radiation practitioner. The MRPBA capabilities are divided into five domains: Medical radiation practitioner, Professional and

ethical practitioner, Communicator and collaborator, Evidence-informed practitioner, and Radiation safety and risk manager. The Royal Australian and New Zealand College of Radiologists (RANZCR) has developed the *Clinical Radiology Range of Practice* document which outlines the range of practice that a Fellow of the Royal Australian and New Zealand College of Radiologists may undertake.

The Diagnostic Imaging Accreditation Scheme (DIAS) developed by the Australian Department of Health, ensures safety and quality standards for Australia's diagnostic imaging practices accessing Medicare payments. The DIAS Practice Accreditation Standards address four main areas: Organisational standards, Pre-procedure standards, Procedure standards, and Post-procedure standards. The RANZCR *Standards of Practice for Clinical Radiology* outlines the standards of practice for clinical radiology (both diagnostic imaging and interventional radiology). The RANZCR and the National Association of Testing Authorities deliver the Medical Imaging Accreditation Program (MIAP).

The MRPBA and the Commission are government agencies that maintain public safety and quality standards. The MRPBA ensures a minimum standard for a medical radiation practitioner through professional capabilities, while the Commission maintains practice safety by setting standards and requiring accreditation to ensure appropriate documentation and practice policies are in place.

The standards of practice used by professional organisations vary between individual disciplines. Some of these standards relate to the practice of diagnostic imaging, while others relate to professional practice, or both. They aim to inform and guide their members on ethical principles, the professional and technical skills to maintain safety, reduce risk and improve patient diagnostic outcomes.

International standards on the practice of diagnostic imaging vary in their focus. Common themes across these standards include:

- Leadership/management (organisational structures, referral management guidelines, economic management)
- Clinical facilities (administrative support)
- Staffing and workforce (sufficient skills mix and competence, employee support and training programs, continuing professional development)
- Patient experience (respect, dignity and security, communication, consent and advocacy)
- Safety (radiation, infection prevention and control, management of medicine and contrast, hazardous substances, and risk management)
- Technical (image optimisation, artificial intelligence/ machine learning, information technology, image reporting and unexpected diagnosis), quality management (image reporting policy, equipment management and quality assurance and audit processes)
- Research and innovation (acquisition and dissemination of knowledge, profession advancement and lifelong learning)

Discussion of key findings

Patient safety and quality in diagnostic imaging learnings

This review brings together a diverse body of literature. Eleven core learnings for patient safety and quality in diagnostic imaging were identified. They were:

- Patient safety and quality care risks are complex
- Multifactorial issues contribute to patient safety and quality care risks
- Multicomponent systems approach is required when addressing patient safety and quality care risks
- There is no one-size-fits-all approach for improving patient safety and quality care
- Further robust, high-quality research is required to improve patient safety and quality in diagnostic imaging
- Unwarranted variation can occur across different points of care
- Use a multimodal approach is required to address unwarranted variation
- Potential high-risk unwarranted variation can be improved by adjusting current processes of care
- The workforce requires support and upskilling to address potential low-risk unwarranted variation
- Standards for diagnostic imaging currently rely on overlapping matrices of regulatory and profession led approaches
- Standards for diagnostic imaging are variable but share some similarity.

Conclusion

This review summarised contemporary commercially produced and grey literature on diagnostic imaging patient safety and quality care issues, strategies to improve patient safety and quality care and national and international standards that underpin diagnostic imaging. The synthesis of these findings revealed several learnings on factors contributing to patient safety and quality care in diagnostic imaging. Given the multifactorial nature and complexities that underpin patient safety and quality care in diagnostic imaging, the literature suggests multicomponent interventions with a systems approach. However, the evidence of effectiveness is mixed, and the ideal combination of interventions is unclear. Overall, standards focus on the clinician (in terms of upskilling) and practice (in terms of a process of care). This broad focus is likely to contribute to patient safety and quality care in diagnostic imaging.

Much of the literature is low-level evidence, as identified by the NHMRC Levels of Evidence. Although there is high-level evidence (such as systematic reviews), the evidence is mixed and has knowledge gaps. This highlights the need for ongoing efforts across sectors (health care, research, policy etc) to explore, investigate and implement robust strategies that can improve patient safety and quality in diagnostic imaging.

Introduction

Purpose

This report summarises contemporary literature on diagnostic imaging patient safety and quality care issues, evidence and strategies to improve patient safety and quality care, unwarranted variation in diagnostic imaging, and national and international standards that underpin diagnostic imaging. It will inform the review of Diagnostic Imaging Accreditation Scheme (DIAS) Standards.

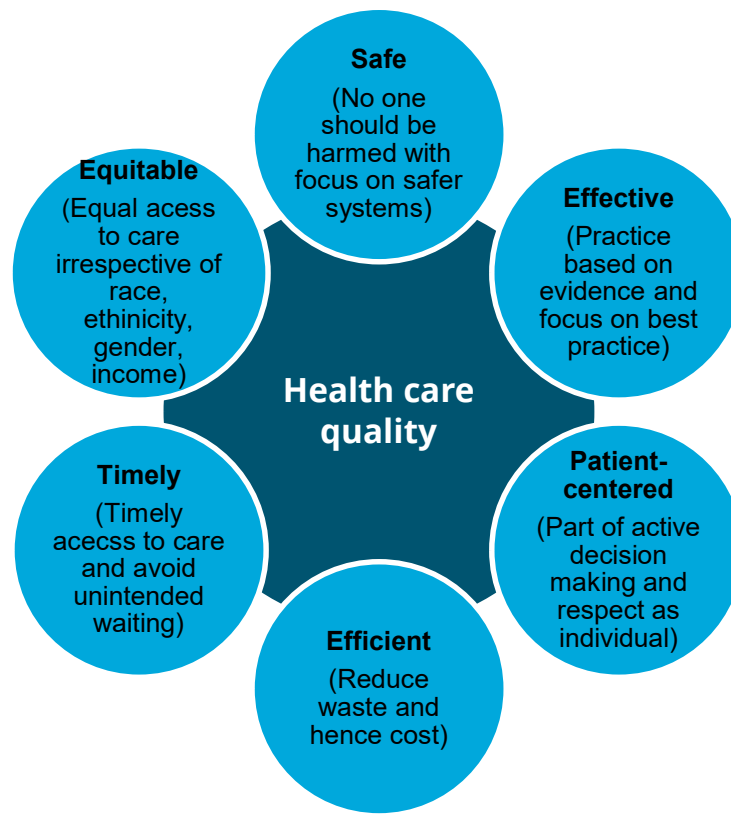
This review aimed to address the following questions:

1. What are the main patient safety and quality care risks relevant to diagnostic imaging?
2. What interventions can minimise patient safety and quality risks relevant to diagnostic imaging?
3. What is the evidence for the effectiveness of these interventions?
4. What areas of diagnostic imaging have unwarranted variation?
5. What improvements can address unwarranted variation?
6. What standards operate nationally and internationally for diagnostic imaging and what do the standards address?

Background

Over the past few decades, since the Institute of Medicine's highly publicised report *To Err is Human: Building a Safer Health System*,¹ there has been renewed focus on the quality and safety of health systems. This report shone a light on medical errors in health care, which likely contributed to several thousand patients losing their lives. This report resulted in a subsequent report by the Institute of Medicine, *Crossing the Quality Chasm: A New Health System for the 21st Century*,² which renewed calls for a health system to be underpinned by six quality principles, namely: safety, effectiveness, patient-centredness, timeliness, efficiency, and equity (Figure 1).

Figure 1: The six health care quality principles



Such seminal works have contributed to increasing awareness of and recognition for patient safety in all fields of health care, including diagnostic imaging. Diagnostic imaging is a critical aspect of health care as it identifies the cause of a patient's signs and symptoms and can inform subsequent health care decisions.³ Yet, its incorrect use can result in patient harm and adverse events. Typical forms of patient harm arising from diagnostic imaging include diagnostic errors, infections, adverse drug events, wrong site, side, procedure or patient, procedural complications, falls and transcriptions errors in reporting.⁴ These errors can be classified into three categories: those involving the patient (identification), diagnostic errors (such as image perception and interpretation, failure to transmit, understand and act on imaging reports and documentation errors) and communication (during times of patient handover and handoff).⁵

It is estimated that 140,000 diagnostic errors occur in Australia each year.³ Despite this, important gaps in our knowledge persist in this area due to the lack of robust data collection mechanisms. As diagnostic imaging is a growth area, it is imperative that strategies are implemented to address patient safety and quality issues. In recognition of this, in recent times, there have been Australian efforts on this topic.^{3, 4, 6-8}

The role of the Commission

The Australian Commission on Safety and Quality in Health Care (the Commission) is a government agency that leads and coordinates national improvements in safety and quality in health care across Australia. From 1st July 2021, the Commission assumed responsibility from the Australian Department of Health for the diagnostic imaging accrediting functions. An

important component of this responsibility is to review and reframe the current DIAS Standards to safety and quality standards.

In June 2007, the Australian Department of Health established DIAS. It links accreditation to the payment of Medicare benefits for diagnostic imaging services. Scheme 1 (introduced in July 2008) commenced with accreditation for diagnostic radiology services only, with Scheme 2 (introduced in July 2010) including practices providing non-radiology services such as cardiac ultrasound and angiography, obstetric and gynaecological ultrasound and nuclear medicine imaging services. Since then, all diagnostic imaging practices intending to render diagnostic services for 'Medicare benefits' must be accredited under DIAS.

On 1st January 2016, the Australian Department of Health implemented modified DIAS Standards. Although no new standards were introduced, the changes addressed and clarified requirements, ambiguities and inconsistencies and improved alignment with the Commission's National Safety and Quality Health Services Standards. Given these standards are now several years old and there have been significant technological advancements in diagnostic imaging, these standards need to be reviewed and refreshed to be consistent and commensurate with the best standards worldwide.

The Commission engaged the Allied Health and Human Performance Unit, University of South Australia (UniSA) to review of the literature on:

- Diagnostic imaging patient safety and quality care issues
- Evidence and strategies to improve patient safety and quality care
- Unwarranted variation
- National and international standards that underpin diagnostic imaging

This report will inform the Commission's role in reviewing and reframing the current Diagnostic Imaging Accreditation Scheme Standards to become safety and quality standards. By doing so, it will improve the safety and quality of diagnostic imaging in Australian health care settings.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR)⁹ underpinned the literature review. In consultation with the Commission the UniSA research team developed a review protocol outlining the scope, selection criteria, sources of evidence, search strategy, and methods for data extraction, analysis and reporting (see Appendix A).

Inclusion criteria

The literature review included commercially produced and grey literature, that reported on one or more aspects of safety and quality in diagnostic imaging. These included but not limited to:

- Diagnostic imaging patient risks, harms or adverse events
- Unwarranted variation in diagnostic imaging
- Methods for management and minimising diagnostic imaging risks, harms and unwarranted variation
- Common diagnostic imaging standards which aim to protect patients from harm

The targeted diagnostic imaging modalities included ultrasound (US), computed tomography (CT), X-ray, mammography, angiography, fluoroscopy, orthopantomography, magnetic resonance imaging (MRI) and nuclear medicine. The literature included was English only and primarily focused on review types (e.g., narrative, systematic or scoping review) that were published or produced after 1 January 2010 to prioritise current and best available evidence.

Broader literature that: focused on medical radiation interventions (e.g., radiation therapy), included non-human subjects (e.g., the role of artificial intelligence in diagnostic testing), were published or produced before 1 January 2010, or were non-English language literature were excluded from this review.

Commercially produced literature

Search and selection of evidence

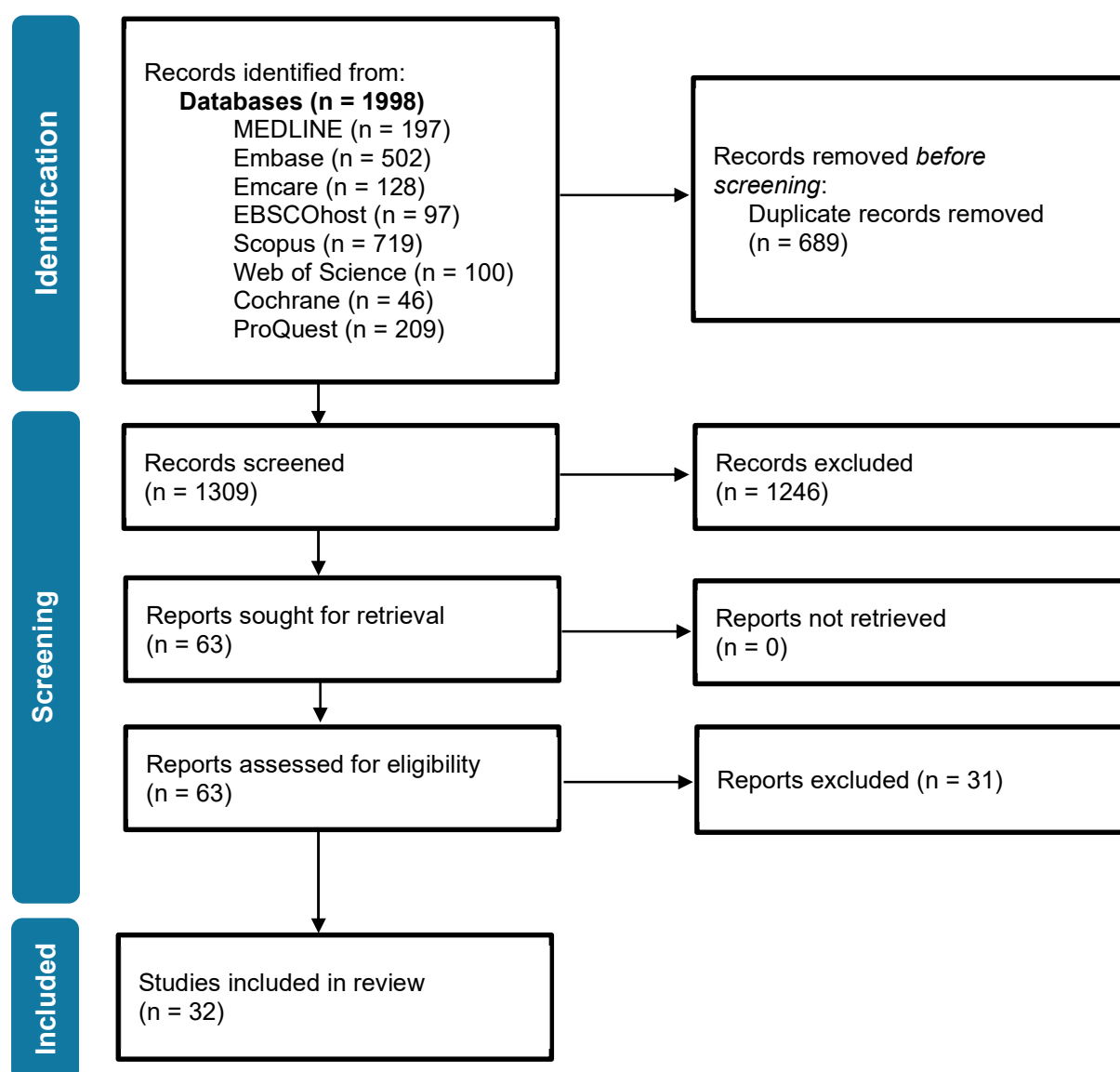
Informed by the review protocol, searches were conducted across MEDLINE, Embase, Emcare, EBSCOhost (CINAHL Complete), Scopus, Web of Science, The Cochrane Library and ProQuest databases.

Duplicate citations were removed using the PRISMA flow diagram for literature selection. After screening the title and abstract for relevance, citations that did not meet the inclusion criteria were excluded. The remaining citations were retrieved for full-text examination. Only literature, which met all the inclusion parameters, was included. The selection process is illustrated in Figure 2.

A total of 32 papers met the inclusion criteria of this review. These papers were assessed according to the National Health Medical Research Council (NHMRC) Levels of Evidence, with level I being high-level evidence and level IV being low-level evidence. The level of evidence and relevance to the review questions (breadth and depth) underpinned paper selection. Once data saturation was achieved (in terms of addressing the review questions),

no further papers were included in the analysis. Appendix C contains the details of the included literature. Appendix D includes a list of relevant literature excluded from the analysis.

Figure 2: PRISMA flow diagram for commercially produced literature selection



Grey literature

The grey literature search sought to complement the search of commercially produced literature to maximise the retrieval of relevant literature on this topic and minimise publication bias for this review.

Search and selection of evidence

The grey literature search was conducted via Google, Google Scholar and a number of key relevant governmental and organisational websites in Australia and internationally.

Publications and Coroner's reports which the Commission provided, were also screened for additional relevant publications. Given the nature of the review, a comprehensive environmental scan was not carried out.

Consistent with the selection process for the commercially produced literature, the level of evidence and relevance to the review questions (breadth and depth) underpinned paper selection. Once data saturation was achieved (in terms of addressing the review questions), no further literature was included in the analysis. Appendix C contains the details of the included literature. Appendix D includes a list of relevant literature excluded from the analysis.

Data extraction, analysis and reporting

Customised data extraction forms were developed specifically for this review to extract pertinent data which addressed the review questions. These included:

- Targeted type(s) of diagnostic imaging modality
- Key issues related to patient safety and quality care in diagnostic imaging
- Identified areas of unwarranted variation in diagnostic imaging
- Types of interventions and strategies for improvement of patient safety and quality care and unwarranted variation
- Evidence for the effectiveness of these interventions and strategies
- Components of national and international standards that underpin diagnostic imaging

The extracted data was narratively summarised and descriptively synthesised for each review question in the 'Findings' section. The findings are presented in tabular or graphical forms. Appendix C contains detailed data extraction tables.

Findings

Question 1: What are the main patient safety and quality care risks relevant to diagnostic imaging?

The literature includes a variety of diagnostic imaging patient safety issues and quality care risks. Many countries worldwide have published on the identification and improvement of these issues. Reviewed literature was from the United Kingdom, Europe, Australia and the United States of America. Publications from Australia were limited in number and were supported by European studies as they are greater in number and more extensive.

Among the identified studies, a variety of methodologies were used including a National Specialty report and review papers, including systematic reviews and literature reviews which are more narrative.

Within the reviewed literature, there are common patient safety issues that can be divided into the following areas:

- Communication
- Infection control
- Radiation safety
- Contrast administration
- Diagnostic error
- Safety issues associated with MRI

Communication

Diagnostic imaging communication consists of communication before, during and after the examination or treatment.^{3, 10} Communication before the examination or treatment includes the initial communication from the referrer to the diagnostic imaging practice. The information contained in the referral is interpreted by both the imaging health professional and the reporting clinician and guides the examination. Incomplete or errors with referrer information can lead to incorrect or incomplete patient examination or treatment.

Before performing the examination or treatment, the healthcare professional communicates with the patient within the diagnostic imaging practice. Incorrect communication at this point could lead to patient identification or examination/treatment errors. Effective communication between the healthcare professional and the patient throughout the examination or treatment process is critical to ensure that errors do not occur. Errors during the examination or treatment process may adversely affect the patient and their healthcare journey.

Infection control

Controlling the spread of infection within the diagnostic imaging practice between patients is a safety issue.¹⁰ The use of hand hygiene, personal protective equipment, and cleaning of all the equipment after completion of the examination or treatment is well-documented¹⁰ to reduce the risk of infection spread. Yet there are issues unique to the diagnostic imaging practice that can provide an infection transmission point such as radiopaque markers, radiolucent sponges, and specialised support equipment such as a chest stand. Ultrasound

has specific infection risks associated with using externally and internally applied transducers and the gel.

Radiation safety

Safety issues relating to radiation in diagnostic imaging are strongly represented in the literature.¹⁰⁻¹³ Special note within the literature is made of the greater risk to paediatric patients and pregnant women. The increasing use of diagnostic imaging and the associated increasing patient doses make the reduction of dose and justification of the radiation dose for each examination important. When considering radiation protection, the literature supports means to keep the dose 'As Low As Reasonably Achievable' (ALARA)¹⁰, which is achieved through carefully considering the examination or treatment justification, images or treatments optimisation and dose limits optimisation. An extension of this includes the appropriate use of external shielding. There are updated guidelines that reflect recent technology improvements and the associated changes to shielding requirements. Consideration of the methods to reduce the number of repeat images undertaken as a means of patient radiation exposure reduction are included within these discussions as one of the key means to reduce exposure.

Contrast administration

Contrast administration and patient safety issues include iodinated and the non-iodinated contrast media used in MRI and US.¹⁰ The safety issues can be further divided into ensuring it is safe to deliver a dose of contrast due to the patient's reaction history or pre-existing health condition, ensuring the correct dose is administered and in the case of a contrast reaction that staff can identify, promptly and appropriately respond to an adverse reaction. A medication and resuscitation trolley needs to be locally available to assist with treating an adverse reaction.

Diagnostic error

Diagnostic error is commonly defined as:

The failure to establish an accurate and timely explanation of a patient's health problem/s or communicate that explanation to the patient.³

Using this definition, the patient safety issues include an incorrect, delayed, missed, near miss or over-diagnosed disease process that occurs due to an examination or treatment within the diagnostic imaging practice.³ A study from the United Kingdom¹⁴ identified that errors could occur before the examination or treatment, during the image acquisition, during the interpretation of the image's content, when an image is reported, and the information is sent through to the referring clinician. While the reasons why such errors occur are likely to be multifactorial, poor communication and time pressures were identified as common causes of these errors. The poor communication could occur at any stage, however, this study highlighted the possibility of errors within the reporting phase, where poor communication of the report's content could lead to misinterpretation of the results by the referring clinician. Time pressures were reported as accounting for some of the errors that impact both the reporting clinicians and those who produce the images.

Safety issues associated with magnetic resonance imaging

Safety issues specifically associated with MRI include the high energy magnet, soft tissue heating associated with the radiofrequency used to image the patient and the acoustic noise associated with the gradient coils.¹⁰ The high energy magnet is the most commonly reported

safety issue in the literature, and it includes interactions of the magnetic field with medical devices such as pacemakers or the potential for projectiles where ferromagnetic objects are inadvertently introduced into the magnetic field.

Table 1 below provides an overview of the included literature.

Table 1: Overview of the included literature on patient safety and quality care issues

Author (Publication year)	Country	Research type (NHMRC Level of Evidence)	Profession	Key findings
Davies, Wathen and Gleeson (2011) ¹¹	United Kingdom	Narrative review (Level IV)	General	<ul style="list-style-type: none"> • Demand for imaging is increasing • Methods to reduce radiation risk discussed particularly for those at greatest risk – children and pregnant women
Docking and Haddock (2021) ³	Australia	Narrative Review/ opinion (Level IV)	General	<ul style="list-style-type: none"> • Definition of errors within the radiology department • Methods to report errors within Australia • Identification of points where errors may occur within the diagnostic imaging examination or procedure • Suggestions of improvement to practice that may avoid some errors
European Society of Radiology (2020) ¹³	Europe	Narrative review (Level IV)	General	<ul style="list-style-type: none"> • Suggested indicators for radiation protection management • Included methods to monitor and improve radiation protection within radiology departments • Identification of audit tool developed by ESR*

Table 2: continued

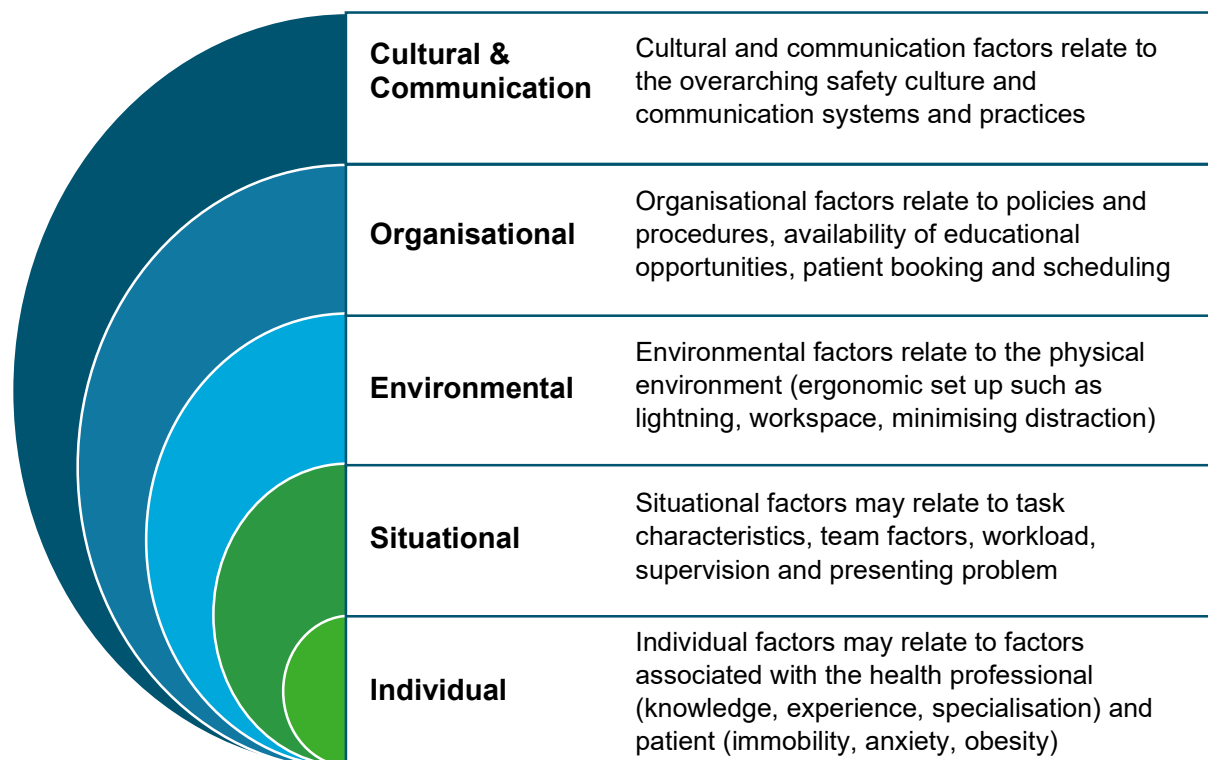
Author (Publication year)	Country	Research type (NHMRC Level of Evidence)	Profession	Key findings
European Society of Radiology and European Federation of Radiographer Societies (2019) ¹⁰	Europe	Narrative review (Level IV)	General	<ul style="list-style-type: none"> • Overview of patient safety issues within medical imaging including specific examples to support explanations. • Covered radiation protection, contrast media, patient handling, information, advocacy, capacity and children. MRI safety, infection control, ultrasound infection control, data security, appropriate professionals, interventional radiology, children and other vulnerable patients and communication. Quality improvement, CPD*, peer review, clinical audit, fatigue and burnout and training in patient safety issues
Hiles et al (2021) ¹²	Europe	Consensus statement (Level IV)	General	Radiation protection devices; their use, effectiveness and support for the development of a European consensus.

*CPD = continuing professional development; ESR = European Society of Radiology

Question 2 and 3: What interventions can minimise patient safety and quality risks relevant to diagnostic imaging? What is the evidence for the effectiveness of these interventions?

The need for improved patient safety and reducing quality risks in diagnostic imaging have been extensively discussed in the literature. It recognises that a systems focus is required given that issues which contribute to poor safety and quality of diagnostic imaging services are often multifactorial. This review identified varied frameworks that recognised this complexity and proposed understanding where, how and why patient safety and quality risks occur and what factors contribute. By understanding these factors, interventions can be implemented to target different factors. Figure 3 below provides a conceptual framework of these factors.

Figure 3: Conceptual framework of factors that contribute to patient safety and quality care in diagnostic imaging



Commercially produced and grey literature was assessed to identify interventions to improve patient safety and reduce quality risks in diagnostic imaging. Collectively, literature seems to support multi-faceted strategies which address factors at the individual, situational, environmental, organisational, cultural and communication levels. While these factors may be present as stand-alone, individual factors, in practice, they are complex and interrelated. Addressing one without others may not produce optimal outcomes.

Much of the literature which informed these questions were narrative reviews (as such, classified as low-level evidence (level IV)), although there were a handful of systematic reviews (level I). While some of these interventions were targeted at diagnostic imaging professions (such as double reading), other interventions were 'borrowed' from other jurisdictions (some were specific to health care such as journal clubs, while others such as checklist and structured reporting were from other industries). Table 2 provides an overview of a selection of the included literature.

Table 3: Overview of the included literature on interventions for improvement of patient safety and quality care in diagnostic imaging

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
Al-hihi et al. (2022) ¹⁵	United States of America	Mixed methods quality improvement project (Level IV)	General	Multicomponent, CDS*-enabled intervention which included educational interventions, awareness of imaging criteria, evidence-informed order panel, denial of imaging requests when not in compliance with indicators. Improvement in the overall rate of appropriate imaging although not sustained without ongoing intervention (e.g., alerts).
Brady (2017) ¹⁴	Ireland	Narrative review (Level IV)	General	Summarised findings for a range of strategies. Some were specific to diagnostic imaging (such as error scoring), while others were generic to health care (such as quality improvement activities). Collectively, there appears to be mixed evidence for these interventions.
Bruno and Nagy (2014) ¹⁶	United States of America	Narrative review (Level IV)	General	Had a particular focus on culture and communication with a range of strategies reported (importance of organisational culture, building a team, using key performance indicators, PDSA* cycle, sentinel events etc). Some evidence to support these strategies in specific contexts.
Bruno (2017) ¹⁷	United States of America	Narrative review (Level IV)	General	Focused on strategies for 'de- biasing', including training to identify cognitive biases (such as anchoring, confirmation and availability biases), computer-aided detection, quality improvement strategies and double reading. Some evidence to support these strategies in specific contexts.
Collins et al (2021) ¹⁸	Australia	Narrative review (Level IV)	Ultrasound - transvaginal ultra- sonography	Focused on informed consent, physical examination following best practice, recognising patient experiences and presence of a chaperone. However, evidence of effectiveness not reported.

Table 4: continued

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
Collins et al (2021) ¹⁸	Australia	Narrative review (Level IV)	Ultrasound - transvaginal ultra- sonography	Focused on informed consent, physical examination following best practice, recognising patient experiences and presence of a chaperone. However, evidence of effectiveness not reported.
Davies, Wathen and Gleeson (2011) ¹¹	United Kingdom	Narrative review (Level IV)	General	Importance of guidelines to inform decision making, use of tools for correct dosing, consideration of other imaging techniques, use of standard operating procedures, improving technology resulting in lower doses with signal detection. However, evidence of effectiveness was not reported.
Degnan et al. (2019) ¹⁹	United States of America	Narrative Review (Level IV)	General	Reported a range of strategies mapped across the factors highlighted in Figure 3. Identified strategies to reduce cognitive, informational, and perceptual errors, reduce fatigue and distractions, and improve physiological and environmental factors. Some evidence to support these strategies in specific contexts.
Docking and Haddock (2021) ³	Australia	Narrative review (Level IV)	General	Took a holistic view highlighting the importance of addressing issues at the referral (quality of referrals), decision making (education and clinical decision support tools) stage and implementation. Highlights the role of artificial intelligence in future. Evidence is limited.

Table 5: continued

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
European Society of Radiology (2020) ¹³	Europe	Narrative review (Level IV)	General	Outlined quality improvement strategies such as continuing professional development, peer review, clinical audits, external review, risk management, addressing fatigue and burnout and training. It also provides a range of key performance indicators (such as compliance with appropriateness criteria, retake rate, monitoring, and feedback to patients and staff).
European Society of Radiology and European Federation of Radiographer Societies (2019) ¹⁰				
French et al. (2010) ²⁰	Australia	Systematic review (Level I)	General	<p>A systematic review which identified some evidence of effectiveness for targeted interventions for specific health diagnoses. For osteoporosis, patient mediated (these interventions are directed at the patient with the aim of changing the behaviour of the patient's healthcare provider, for example through patient education (materials or verbal)), and reminders had the largest effect, followed by organisational interventions.</p> <p>Educational interventions had limited evidence for low back pain but not for other musculoskeletal conditions.</p> <p>It is unclear which interventions are most effective or which combination has the largest effect.</p>
Jabin et al. (2022) ⁴	Australia	Systematic review (Level I)	General	<p>A systematic review that reported on a range of interventions that had a positive:</p> <ul style="list-style-type: none"> • Impact on system quality and safety (such as immediate and critical reporting, implementation of guidelines), • Effect on staff (using training and education through simulation and multifaceted educational training) • Effect on staff and patient experiences (through PACS*, audits, workshops, and shared leadership). <p>Mixed evidence of effectiveness though.</p>

Table 6: continued

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
Lee et al (2013) ²¹	United States of America	Narrative review (Level IV)	General	Calls for a multi-level approach that targets different factors through a range of strategies (such as feedback systems, radiology-pathology correlation, peer review, education, information technology, structured reported systems, computer-aided detection, addressing workload fatigue etc). Some evidence to support these strategies in specific contexts.
Pow, Mello-Thomas and Brennan (2016) ²²	Australia	Narrative review (Level IV)	General	This review evaluated the evidence regarding the effect of double reporting on diagnostic efficacy. Double reading was mostly investigated in mammography. Positive outcomes in terms of reduction in recall rates, increased sensitivity, and cancer detection rates but unclear about cost effectiveness. For neuroradiology, thoracic, trauma, gastrointestinal imaging, and oncology only small-scale studies but encouraging findings.
Thompson et al. (2021) ²³	United States of America	Multiple methods including scoping review (Level IV)	General	This research included a scoping review reported on PROD* research. Much of the literature focuses on mammography and MRI* screening and is mostly related to cancer screening. From a patient's point of view, key domains identified were information or knowledge yielded from the diagnostic procedure, physical impact, emotional outcomes, and test burden. It highlighted a range of issues that may modify PCOs* related to imaging tests including individual patient characteristics, test type (screening, diagnostic, monitoring), clinical situation, clinician and healthcare team, physical environment of the imaging suite and communication of test results.

Table 7: continued

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
Waite et al. (2017a) ²⁴ Waite et al. (2017b) ²⁵	United States of America	Narrative review (Level IV)	General	<p>It proposed two categories of solutions:</p> <ul style="list-style-type: none"> • <i>Non-technological solutions</i> including structured reports, ergonomics, interruptions reduction, double reading, peer review and quality improvement. • <i>Technological solutions</i> including perceptual feedback, attentional guidance, search strategies, bone subtraction techniques, computer aided detection. <p>Some evidence to support these solutions in specific contexts.</p> <p>It proposed strategies for pre-procedure phase errors (such as guidelines for imaging appropriateness, clinicians involved in choosing examination protocol, CPOE* and CDS*), procedure phase errors (time out, checklists, communication and coordination) and post-procedure phase errors (double reading, a culture of support and non-punitive approach, use of guidelines for communication, audits etc.).</p> <p>Some evidence to support these strategies in specific contexts.</p>
Wang et al. (2018) ²⁶	United States of America	Pre-Post (Level IV)	General	<p>Implemented two educational sessions using video and audio formats across three clinics of one-hour duration. Content derived from ACR* Appropriateness Criteria and non-radiological societies. Encouraging findings as this strategy resulted in a reduction in MRI* orders, longer times before MRI was undertaken. Some encouraging findings although limited evidence.</p>

*ACR = American College of Radiology; CDS = clinical decision support; CPOE = computerised physician order entry; MRI = magnetic resonance imaging; PACS = picture archiving and communication system; PDSA = plan-do-study-act; PCOs = patient-centred outcomes; PROD = patient reported outcomes of diagnostics

The literature reports a range of strategies, with varying levels of evidence, that have been suggested to improve patient safety and reduce quality risks in diagnostic imaging. This highlights that there is no 'one-size-fits-all' approach and strategies should include multi-component interventions, commensurate with wide-ranging factors that contribute to safety and quality issues. Therefore, the literature calls for interventions to be underpinned by a systems approach that can address these issues at multiple levels. However, the literature does not identify the ideal combination of interventions or parameters underpinning these

interventions (type, duration, frequency, mode etc.). This is an important limitation to consider, although this may assist in developing and implementing interventions that consider local context, staffing profile, patient expectations, resources etc.

Commonly reported interventions included:

- Creating a supportive safety culture that is non-punitive with a focus on learning and shared accountability and leadership with stakeholders and supported with adequate infrastructure and resources.^{5, 10, 14, 16, 19, 20, 27-30}
- Consistent use of guidelines to inform clinical decision making which can standardise practice and use of key performance indicators.^{3-5, 10, 11, 25, 31-34}
- Standardised and well-documented communication systems, including handoff, use of electronic medical records and ordering systems.^{5, 25, 28, 32, 35, 36}
- Explicit consideration of patient experiences, expectations, concerns, consent and patient-mediated interventions.^{18, 20, 23, 25, 27, 30, 32}
- Engagement with quality improvement activities such as clinical audits, plan-do-study-acts, root cause analysis, error scoring, sentinel events, near-miss events, root cause analysis, lean and six sigma, radiologic-surgical and radiologic-pathologic correlation.^{4, 10, 14, 16, 17, 19, 21, 24, 25, 27, 28}
- Delivery of and participation in interactive educational sessions and promote learning with a range of topics (such as training to identify cognitive biases such as anchoring bias, confirmation bias and availability bias). This may include strategies such as reflective reasoning (meta-cognition), perceptual training and patient safety issues.^{3, 4, 10, 17, 19, 21, 26-28, 30, 34, 37}
- Use of peers through activities such as teamwork, double reading/reporting, error/peer review, external review, and peer learning.^{5, 10, 17, 19, 21, 22, 24, 27, 28}
- Use of checklists and structured reporting.^{4, 14, 19, 21, 24, 25, 38}
- Implementation of strategies to reduce fatigue and burnout such as adequate staffing, timed breaks, regular exercise, and accommodative relaxation.^{5, 10, 14, 19, 21, 24}
- Addressing environmental factors, which may include but are not limited to reading room ambient light, monitor luminance, workstation layout, room temperature and humidity, noise level, and ready access to all necessary tools in the workstation.^{19, 24, 27}
- Recognising the emergent role of technology such as artificial intelligence, clinical decision support tools, attentional guidance, search strategies, bone subtraction techniques, computer-aided detection, and electronic medical records.^{3, 11, 14, 15, 17, 19-21, 24, 25, 27, 39}

Question 4: What areas of diagnostic imaging have unwarranted variation?

The included literature associated with unwarranted variation was from the United Kingdom and Europe, encompassing a narrative review, a systematic review, and practice audits. Whilst studies within this area are somewhat limited in number, common themes emerged. While the following themes are presented as stand-alone constructs for report, in practice, they are likely to be interlinked:

- Low-value care
- Variation from recommended diagnostic or treatment pathway
- Delayed diagnostic imaging accessibility

Low-value care

Low-value care is defined as:

An intervention in which evidence suggests it confers not or very little benefit for patients, or risk of harm exceeds probable benefit or, more broadly, the added costs of the intervention do not provide proportional added benefits.⁴⁰

According to the Organisation for Economic Co-operation and Development (OECD), low-value care can represent 10 - 34% of health service spending.⁴⁰ Whilst this is not all associated with diagnostic imaging, low-value imaging is still included in these figures. Examples of low value, more complex examinations in diagnostic imaging include CT, MRI and contrast studies. These examinations are more expensive to perform and may not be available in all areas.⁴¹ By choosing these examinations, referring clinicians may be disregarding simpler, more readily available and affordable imaging examinations that may provide the required information for diagnosis or monitoring. This represents an increased financial burden for the patient or healthcare service and, in the case of CT and contrast studies, an increased radiation dose for the patient.

Kjelle et al.⁴⁰ noted examples of specific general radiographic examinations related to bronchiolitis, pulmonary embolism, minor head injury and low back pain as low-value procedures. They add to the patient dose burden and cost without significantly adding to the diagnostic information to assist the referring clinician and the patient's journey. The authors identified barriers to reducing these low-value procedures, including referrer practices and patient expectations. Low-value examinations add to the workload within the diagnostic imaging practice which may delay other patients' examinations or treatments which may have a higher diagnostic or treatment value.

Variation from recommended diagnostic or treatment pathway

For many disease processes, there should be recognised diagnostic and treatment pathways (e.g., those developed by the Royal Australian and New Zealand College of Radiology (RANZCR) Clinical Radiology recommendations,⁴² or Diagnostic Imaging Pathways from the Government of Western Australia⁴³). These pathways may be developed based on the available evidence to support the most efficient pathway for the patient through diagnosis and treatment of their disease. Should clinicians choose not to follow these pathways, an incorrect or incomplete diagnosis may result and there may be an associated increase in a patient's radiation dose.

Delayed diagnostic imaging accessibility

The literature highlights two areas that may contribute to a delay in the patient receiving a diagnostic imaging examination or treatment. First, there be an increase in waiting times for patients due to the increasing use of diagnostic imaging services.⁴⁴ This is particularly impactful when combined with the low-value and inappropriate use of diagnostic imaging services. Increasing workload without an associated increase in staffing or equipment may result in a decreased capacity for patient services.⁴⁴

Second, an audit was conducted on the availability of diagnostic services by geographic location in England,⁴¹ and it identified significant differences across England geographically in the availability of diagnostic imaging services. Though this audit has not been replicated in Australia, it can be extrapolated to the Australian context. Given the geographic isolation prevalent in Australia, it is expected that this geographic variation would also present across Australia. This lack of service availability could lead to delays in patient examinations. It is often difficult for patients to access more complex examinations and treatments outside of the major population concentrations within Australia. The lack of more specialised examinations in regional and rural areas could be due to both the equipment's expense and lack of specialised staff. Table 3 provides an overview of the included literature.

Table 8: Overview of the included literature on areas of unwarranted variation

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
Halliday et al (2020) ⁴⁴	United Kingdom	Audit (Level IV)	General	<ul style="list-style-type: none"> Identified a lack of available services in radiology despite rising numbers of examinations and treatments. Significant delays in imaging particularly CT* and MRI* and delays in reporting results which delays ongoing treatment.
Kjelle et al (2021) ⁴⁰	Norway	Systematic review (Level I)	General	<ul style="list-style-type: none"> Targeted studies included CT*, MRI* and contrast studies. Non-specified examinations relating to bronchiolitis, pulmonary embolism, head injury and low back pain imaging.
Public Health England (2017) ⁴¹	United Kingdom	Audit (Level IV)	General	Identified variations in available diagnostic services across geographical areas in England.

Table 9: Continued

Author (Publication year)	Country	Type of research (NHMRC Level of Evidence)	Profession	Key findings
Woznitza et al (2021) ⁴⁵	United Kingdom	Narrative review (Level IV)	General	<ul style="list-style-type: none">• Radiographer reporting shortened time to diagnosis.• All clinical reports included identifiers for reporting radiographer• Explained the North Central and East London framework and standards for implementing and maintaining radiographer reporting network.

*CT = computed tomography; MRI = magnetic resonance imaging

Question 5: What improvements can address unwarranted variation?

A guide published by the Commission explains how health service organisations can identify potentially unwarranted variation and implement changes to make improvements.⁴⁶ The guide outlines six steps for clinicians and managers to work collaboratively to determine priority areas to monitor, detect unwarranted variation, and explore reasons that lead to variation before implementing changes to improve the appropriateness of care.

Upon recognising the key areas of unwarranted variation in diagnostic imaging (see Question 4), both commercially produced and grey literature were assessed for improvements that can address unwarranted variation. These can be categorised according to the risk of patient harm resulting from unwarranted variation.

Improvements on unwarranted variation causing high risk of harm to the patient

Of the limited literature on examples of unwarranted variation that are of high risk of harm to patients, there have been reports on sexual assault allegations based on inappropriate behaviour that was not clinically necessary¹⁸ or inappropriate care that resulted in the death of patients.⁴⁷⁻⁴⁹

Improvements to address unwarranted variation that has a relatively high risk of harm to patients target the process of care through:

- Professional regulatory bodies that regulate the profession and outline practice standards, involvement in accreditation and registration of practitioners, such as:
 - The Medical Radiation Practice Board of Australia (MRPBA) works with the Australian Health Practitioner Regulation Agency (AHPRA) that outlines the key capabilities, scope and role of radiologists and medical radiation practitioners⁵⁰

- The Australian Society of Medical Imaging and Radiation Therapy (ASMIRT) outlines the scope of practice for Medical imaging practitioner⁵¹
- The RANZCR outlines the standards of clinical practice for clinical radiology⁵²
- Availability and use of International and Australian standards and evidence-based guidelines. A literature review by Badcock et al.³¹ outlined the importance of regulatory inspection and clinical audit on the uptake and compliance to the guidelines. (See the summarised findings of Question 6 for further information)
- Coroner's reports⁴⁷⁻⁴⁹ that identify unwarranted variation in clinical care and generally led to recommendations to professional agencies to (Table 4):
 - Amend standards and guidelines (e.g., mandatory training requirements)
 - Consider / clarify scope of practise
 - Monitor accredited practice with regards to compliance
 - Standardise referral practice
 - Educate on reporting obligations
 - Develop an algorithm for early clinician notification

Table 10: Overview of unwarranted variation identified in Coroner's reports and associated recommendations

	Summary of unwarranted variation identified in Coroner's	Recommendation on improvement or
Coroners Court of Victoria (2021) ⁴⁸	The patient was referred to complete a privately funded CT scan that was not indicated. The patient had an anaphylactic reaction to the contrast dye that was poorly managed that causally contributed to the patient's death.	<ul style="list-style-type: none"> • Notification to the AHPRA* on the clinician's practice <p><i>Regarding radiologists</i></p> <ul style="list-style-type: none"> • The RANZCR* to implement mandatory training in the recognition and management of severe contrast reactions and anaphylaxis. • The ASCIA* and the ARC* to develop and implement a training and certification programme for radiologists. • The RANZCR to implement a register of severe contrast reactions and their management to monitor the effectiveness of training and implementation of guidelines. • The RANZCR to amend contrast reaction management guideline and their Standard. • The RANZCR to prepare a joint position statement on when screening is an acceptable indicator for imaging procedures. <p><i>Regarding radiographers</i></p> <ul style="list-style-type: none"> • The MRPB* to review and update Professional Capabilities for Medical Radiation Practitioners and their CPD* guideline to ensure training in emergency response to severe reactions and anaphylaxis. • The RANZCR, ASICA, ARC and ASMIRT* to develop and implement a training and certification program on recognition and management of severe contrast reaction and anaphylaxis, CPR* and Basic Life support. • The MRPBA, RANZCR and ASMIRT to consider expanding a radiographer's scope of practice. <p><i>Regarding private diagnostic imaging practices</i></p> <ul style="list-style-type: none"> • Diagnostic imaging accreditation scheme advisory committee to revise standards on policies and procedures for inappropriate requests.

Table 11: continued

Author (Publication year)	Summary of unwarranted variation identified in Coroner's report	Recommendation on improvement or prevention of future unwarranted variation
Coroners Court of Queensland (2020) ⁴⁹	Inappropriate monitoring and management of a deteriorating patient following an epidural injection which contributed to the patient's death.	<ul style="list-style-type: none"> The RANZCR is to amend the standards of practice (monitoring requirement for specific procedures) and require radiologists performing contrast and sedation to hold CPR* certification to provide advanced life support. The clinician involved is not to perform specific procedures relevant to this case until they have completed relevant training. On specific operational procedures: patient monitoring requirement following the procedure, nurse to be present to monitor recovery, availability of defibrillator.
Coroners Court of Victoria (2015) ⁴⁷	Administration of intravenous radiographic contrast (contraindicated due to the patient's pre-existing renal impairment) as a contributing casual factor to the patient's death. The information on the patient's pre-existing renal impairment was missing in the referral.	<p>No report recommendations.</p> <ul style="list-style-type: none"> Mentioned that it is the radiographer's responsibility to obtain sufficient patient information to make a judgement about any risk to the patient. Mentioned that the referring doctor should be more attentive in completing potentially important parts of the referral.

*AHPRA = Australian Health Practitioner Regulation Agency; ARC = Australian Resuscitation Council; ASCIA = Australasian Society of Clinical Immunology and Allergy; ASMIRT = Australian Society of Medical Imaging and Radiation Therapy; CPD = continuing professional development; CPR = cardiopulmonary resuscitation; MRPBA = Medical Radiation Practice Board of Australia; RANZCR = Royal Australian and New Zealand College of Radiologists

Improvements on unwarranted variation causing lower risk of harm to the patient

Inappropriate use of imaging was the most reported unwarranted variation that is relatively low risk to the patient. Understanding the drivers that lead to inappropriate use of imaging can result in targeted strategies or improvements that reduce unwarranted variation.⁵³ The drivers might be related to the clinician's belief in imaging or the lack of knowledge on the appropriate use of new radiological technology.

A recent systematic review by Kjelle et al.⁴⁰ included 95 studies that found guidelines and education used on their own or combined with other measures were the most common interventions used to reduce low-value imaging. Most studies (95%) within the review targeted the intervention towards referrers, although a small number of studies targeted imaging staff, patients or parents. Multi-component interventions that included education and adapted to the local context were more effective in reducing low-valuing imaging than studies that did not have an education component. Studies that found a 30% reduction in low-value imaging examinations included the following intervention components: clinical

decision support system, feedback to referrers, education, guideline implementation, required action from referrers, and hand-outs (see Table 5).

A 2010 Cochrane review²⁰ (reviewed a total of 28 primary studies) focused on interventions for improving the appropriate use of imaging in people with musculoskeletal conditions found a modest improvement inappropriate bone mineral density test ordering in the management of osteoporosis with any interventions compared to no-intervention. The effectiveness of distributing educational materials in low back pain studies and in other musculoskeletal conditions was inconclusive.

More recent literature reviews and reports have proposed the following strategies to improve appropriateness of using imaging:

- Education of referrers^{3, 54}
- Improving the imaging specialist's role as consultant and gatekeeper⁵⁴
- Evidence based and consensus based imaging referral guidelines⁵⁴
- Financial incentives for appropriate imaging⁵⁴
- Involvement of patient in decision-making⁵⁴
- Clinical decision support tools³

Addressing diagnostic imaging accessibility issues due to variations in practice (due to workforce, geographical, funding barriers) will likely require enabling strategies that target several levers (such as policy, funding arrangements, workforce planning etc.) However, there was no literature specific to diagnostic imaging on how these may be effectively achieved.

Table 12: Interventions with more than 30% reduction in use of low-value imaging examination collated by Kjelle et al.

Citations of the selected primary studies from Kjelle et al. ⁴⁰	Country	Type of research (NHMRC Level of Evidence)	Intervention	Intervention outcome
Ashykian et al. (2019)	United States of America	Retrospective review: Pre-post study (Level IV)	Education through presentation to clinicians	50% reduction in knee x-rays
Bailey et al. (2013a)	United States of America	Review of longitudinal data (Level IV)	Health information exchange (share health information across health care organisation)	90% reduction in MRI or CT* of lumbosacral and thoracic spine
Bailey et al. (2013b)	United States of America	Review of longitudinal data (Level IV)	Health information exchange (share health information across health care organisation)	62% lower odds of diagnostic neuroimaging

Table 13: Continued

Citations of the selected primary studies from Kjelle et al. ⁴⁰	Country	Type of research (NHMRC Level of Evidence)	Intervention	Intervention outcome
Baker et al. (2020)	United States of America	Retrospective review: Pre-post study (Level IV)	Education through presentation and information flyers	>30% reduction in CT* cervical spine
Bhatia et al. (2013)	United States of America	Interrupted time series analysis (Level IV)	Education through lecture pocket card and feedback on appropriateness	26% reduction in Transthoracic echocardiography
Bhatia et al. (2014)	United States of America	Randomised Controlled Trial (Level II)	Education through lecture, tips via email and feedback on appropriateness	62% reduction in Transthoracic echocardiography
Hardin et al. (2017)	United States of America	Pre-post test (Level IV)	Complex care map (consultation, root cause analysis written in standardised framework, team review, implementation, flagged in electronic medical record, and annual revision)	62% reduction in CT*
Hui et al. (2014)	United States of America	Pre-post study (Level IV)	Guideline distribution and education through conference	58% reduction in pelvic ultrasound
Ip et al. (2014)	United States of America	Comparative study with no control group (Level III-3)	Clinical decision support system through computerised physician order entry, with mandatory peer to peer consultation and monitoring of practice pattern variation	30.8% relative decrease in use of MRI for low back pain
Judkins et al. (2013)	Australia	Retrospective review (Level IV)	Guideline	2% increase in ultrasound, 32% reduction in MCU* 21% increase in nuclear medicine scans
Kandiah et al. (2020)	Canada	Quality improvement project: Pre-post study (Level IV)	Information package including information on red flags for imaging; physician and patient education	43% decrease in CT use; 0.6% decrease in MRI use

Table 14: Continued

Keveson et al. (2017)	United States of America	Quality improvement project: pre-post test (Level IV)	Education and ICU* rounding checklist	64% reduction in chest x-ray
Lu et al. (2012)	United States of America	Retrospective review (Level IV)	Import images to a system (that allow access to images at all hours at the main hospital and during business hours at satellite hospital)	61% reduction in repeat imaging with CT* or MRI*
Luther et al. (2019)	United States of America	Retrospective review (Level IV)	Standardised treatment algorithm	60% reduction in wrist x-ray
Ostby et al. (2020)	United States of America	Cohort study: Pre-post study (Level IV)	Implement algorithm on CT* use and consultation prior to obtaining a CT	54% reduction in CT
	United States of America	Chart review (Level IV)	Diagnostic algorithm, education through presentation	51% reduction in abdominal CT*
	United States of America	Pre-post study (Level IV)	Computerised clinical decision support – pop-up to alert providers to order a screening PSA* blood test	38% decline in inappropriate use of PSA screening rate
Wu et al. (2020)	United States of America	Quality improvement project: pre-post test (Level IV)	Survey, education through journal club, education through posters and internal web stie and pocket cards, removal of routine chest x-ray order, duplicate chest x-ray alert on electronic medical record, electronic clinical decision support tool	36% reduction in chest x-ray
Xu et al. (2020)	Canada	Retrospective cohort study: Pre-post study (Level IV)	MRI* appropriateness checklist	48% decrease in knee MRI

CT = computed tomography; ICU = intensive care unit; MRI = magnetic resonance imaging; MCU = micturating cystourethrogram; PSA = prostate specific antigen

Source: Kjelle et al.⁴⁰

In addition to unwarranted variation directly related to patient care, the Getting It Right First Time (GIRFT) Programme National Specialty Report⁴⁴ highlighted unwarranted variation in the purchase of consumables (e.g. different brands), outsourced reporting services and replacement of old equipment. The United Kingdom has a National Health Service (NHS) Spend Comparison Service to help ensure the lowest price consumables were purchased.

Similarly, within the NHS, there are different options to ensure the best value for money when replacing equipment through discussion with the NHS Supply Chain model. Finally, there is also a framework to manage outsourced reporting services under the MHS Supply Chain procurement.

Question 6: What standards operate nationally and internationally for diagnostic imaging and what do the standards address?

Various national and international standards exist for diagnostic imaging, with the aim of improving safety and reducing risk to the public. Nationally, these standards can be grouped into government regulators or by professional organisations specific to the discipline of diagnostic imaging.

Australian standards

Within Australia, the AHPRA works with the MRPBA to help protect the public and set standards across all medical radiation professions, including diagnostic imaging practitioners, i.e., diagnostic radiographers and nuclear medicine technologists.⁵⁵ The MRPBA has published a set of professional capabilities which identify the knowledge, skills and professional attributes needed to safely and competently practice as a medical radiation practitioner.⁵⁵ The MRPBA capabilities are divided into five domains: Medical radiation practitioner, Professional and ethical practitioner, Communicator and collaborator, Evidence-informed practitioner, and Radiation safety and risk manager. These professional capabilities represent the minimum or 'threshold' level of professional capability required by a medical radiation practitioner to practice safely within Australia. The MRPBA also functions as a statutory regulator of the profession through the registration of individuals.

Furthermore, under National Law in July 2012, the MPRBA established the Medical Radiation Practice Accreditation Committee, which is responsible for accrediting education providers and medical radiation practice programs of study against the Medical Radiation practice accreditation standards.⁵⁵

For the diagnostic imaging division of Sonography, registration is unregulated. The Australian Sonographer Accreditation Registry (ASAR), conducts accreditation, sets minimum standards of sonographer training and education in Australia and maintains a register of accredited sonographers and student sonographers.⁵⁶

The DIAS, developed by the Australian Department of Health, ensures Australia's safety and quality standards for diagnostic imaging practices.⁵⁷ Diagnostic imaging practices not accredited under DIAS cannot provide Medicare-funded services.⁵⁷ Furthermore, it is an offence under the *Health Insurance Act 1973* to provide a diagnostic imaging service without first informing patients that the practice is not accredited and that Medicare benefits are not payable.⁵⁷ The DIAS Practice Accreditation Standards address four main areas: Organisational standards, Pre-procedure standards, Procedure standards, and Post-procedure standards.⁵⁷ According to the *DIAS User Guide for Practices Applying for Accreditation*, demonstrating that a new practice meets the full suite of standards may be challenging. Therefore, practices can choose to be accredited against the 'entry-level' standards and will be granted two years to demonstrate they can achieve accreditation against the full suite of standards. When applying for entry-level accreditation, a practice only needs to address three standards within the organisational standards (i.e., Standard 1.2

Registration and Licensing, Standard 1.3 Radiation Safety, Standard 1.4 Equipment Inventory).

The RANZCR *Standards of Practice for Clinical Radiology*⁵² is a document created to promote and improve standards of practice for clinical radiology, (both diagnostic imaging and interventional radiology) ensure safety and high-quality diagnostic services for the Australian and New Zealand public. It is a comprehensive document that covers all clinical radiology services. Depending on the scope of the diagnostic imaging service, a practice is expected to meet the generic requirements (Sections 1-9: practice management, facilities, equipment, personnel, professional supervisor, safety, patient management, teleradiology, artificial intelligence) and then any specific modality requirements (Sections 10-17: bone mineral density, computed tomography, general x-ray, interventional radiology, magnetic resonance imaging, mammography, nuclear medicine, ultrasound).

The MRPBA is a government regulator that maintain public safety and quality standards. The MRPBA does this by ensuring a minimum standard for a medical radiation **practitioner** through the professional capabilities, whereas the DIAS maintains **practice** safety by ensuring appropriate documentation and practice policies are in place. Although RANZCR is not a governmental regulator, its *Standards of Practice for Clinical Radiology* outlines standards of **practice** for clinical radiology.

In addition to government regulators, various professional organisations within Australia have published standards or scope of practice documents relevant to specific diagnostic imaging professions. These professional organisations are listed in Table 6 below and indicate their division of diagnostic imaging.

Table 15: Examples of professional organisations in diagnostic imaging that have published standards (or scope) of practice

Organisation	Abbreviation	Targeted profession
The Australian Society of Medical Imaging and Radiation Therapy	ASMIRT	Medical Radiation Practitioner
The Australasian Society for Ultrasound in Medicine	ASUM	Sonography
The Royal Australian and New Zealand College of Radiologists	RANZCR	Clinical Radiologists

The consistent theme of these standards of practice is to inform and guide professional members on ethical principles, professional and technical skills to maintain patient safety, reduce risk and improve diagnostic outcomes for the patient.^{52, 58, 59} However, the content of each practice standard varies as they all serve a different purpose for each division of diagnostic imaging that they represent, as described below:

- The ASMIRT publication *Medical Imaging Practitioner Scope of Practice*⁵¹ was designed to supplement the ASMIRT Professional Practice Standards (PPS)⁵⁸ and further define the role and core clinical responsibilities of the Medical Imaging Practitioner (MIP). ASMIRT PPS addresses seven key areas: Professional and Ethical Practice, Communication, Teamwork and Autonomy, Knowledge and Understanding, Critical Thinking and Evaluation, Service Delivery and Clinical Management, and Lifelong Learning.

- The Australasian Society for Ultrasound in Medicine (ASUM) has published a series of 'standards of practice' documents to advance the clinical practice of medical ultrasound for the highest standards of patient care.⁶⁰ These publications range from specific examinations in sonography to code of conduct and consent.
- The RANZCR's *Clinical Radiology Range of Practice*⁶¹ is a document created to outline the range of practice that a RANZCR Fellow may undertake. The document differentiates, in broad terms, between core clinical radiology practice and advanced clinical radiology practice.

Nationally, codes of conduct have been published by the MRPBA, ASMIRT, ASUM and the Australasian Association of Nuclear Medicine Specialists (AANMS).^{59, 62-64} The MRPBA code of conduct is a generic publication common to health professionals registered under AHPRA. It has been developed to assist and support registered health practitioners to deliver effective regulated health services within an ethical framework.⁶² Furthermore, Appendix A of the MRPBA code of conduct describes the specific provisions for a medical radiation practitioner (i.e., providing good care, effective communication and radiation protection).⁶² The AANMS code of conduct⁶⁴ sets out principles to:

- guide nuclear medicine specialists in the provision of quality medical and imaging services to their patients
- guide the conduct of nuclear medicine specialists' relationships with patients, colleagues and members of the community
- reinforce the importance of maintaining the integrity and good reputation of the profession of nuclear medicine.

Codes of conduct published by the professional associations all exist to guide members on professional and ethical practice,⁵⁹ and ensure a high level of conduct, highest standard of care and act in the best interest of the public.^{59, 63, 64}

Table 7 below summaries the available standards within Australia and what each represents.

Table 16: Summary table of national standards

Organisation	Government Regulated	Professional Organisation	Code of Conduct	Professional Capabilities/Standards (Scope) of Practice	Practice standards
AANMS	X	√	√	X	X
ASAR	X	X	X	X	X
ASMIRT	X	√	√	√	X
ASUM	X	√	√	√	X
DIAS	√	X	X	X	√
MRPBA	√	X	√	√	X
RANZCR	X	√	X	√	√

AANMS = Australasian Association of Nuclear Medicine Specialists; ASAR = Australian Sonographer Accreditation Registry; ASMIRT = Australian Society of Medical Imaging and Radiation Therapy; ASUM = Australasian Society for Ultrasound in Medicine; DIAS = Diagnostic Imaging Accreditation Scheme; MRPBA = Medical Radiation Practice Board of Australia; RANZCR = Royal Australian and New Zealand College of Radiologists

International standards

Various standards for diagnostic imaging exist internationally, with an emphasis on publications from Europe, New Zealand, the United Kingdom, and the United States of America. All international standards aim to promote best practice and maintain standards of care and quality in diagnostic imaging and can be categorised into the following areas:

- Statement papers from diagnostic imaging professional organisations⁶⁵⁻⁶⁸
- Practice standards or guidelines diagnostic imaging professional organisations⁶⁹⁻⁷⁵

International publications address standards that encompass all clinical pathways within the division of diagnostic imaging (i.e., general) or focus on a specific clinical pathway such as Diagnostic Radiography, MRI or US. Within Europe, challenges exist in creating uniform guidelines across diagnostic imaging services for different European member states.^{65, 66} The European Society of Radiology (ESR) is an apolitical, non-profit organisation dedicated to strengthening and unifying European radiology and they have published a number of guidelines and statement papers on the improvement and harmonisation of quality and safety in diagnostic imaging across Europe.⁷⁶

Table 8 demonstrates an overview of the selected standards that focused on general areas of diagnostic imaging. Common themes were drawn from these international standards (leadership/management, clinical facilities, staffing and workforce, patient experience, safety, technical, quality management and research) to facilitate best practice and quality in diagnostic imaging (Figure 4).^{65, 69, 70, 77}

Table 17: International Standards for diagnostic imaging (general)

Author (publication year)	Country	Type of research	Profession	Key findings
European Society of Radiology (2017) ⁶⁵	Europe	Statement paper	General	This paper highlights the increasing difficulties in the economic management and demand on healthcare systems and presents the concept of 'value-based healthcare' instead of volume-based healthcare.

Table 18: Continued

Author (publication year)	Country	Type of research	Profession	Key findings
International Accreditation New Zealand (2020) ⁷⁵	New Zealand	Practice standards (general criteria for accreditation)	Radiology	<p>This Code provides requirements for competence and quality that are particular to radiology services. This Code is for use by radiology services in developing their management systems and assessing their competence, and for use by International Accreditation New Zealand in confirming or recognising the competence of radiology services. Broadly, the Code outlines requirements across two categories: management and technical requirements. Management requirements outline a range of requirements specific to the service or the organisation of which the radiology service is a part of.</p> <p>Technical requirements outline a range of requirements for the technical aspects across the structure, process, and outcomes of care.</p>
Ministry of Health (2018) ⁷⁴	New Zealand	Practice standards (which also includes some practitioner standards)	Diagnostic and Interventional Radiology	<p>This Code of Practice for Diagnostic and Interventional Radiology outlines all activities associated with radiological equipment used for diagnostic radiology and image-guided interventional procedures, radiological equipment used for diagnostic investigations of volunteers participating in programs of medical research and cone beam computed tomography equipment used for dental purposes. Broadly, the code outlines roles and responsibilities across three categories. They are the managing entity, the radiation practitioner, and other parties (referring practitioner, manufacturer/supplier, and servicing engineer).</p>

Table 19: Continued

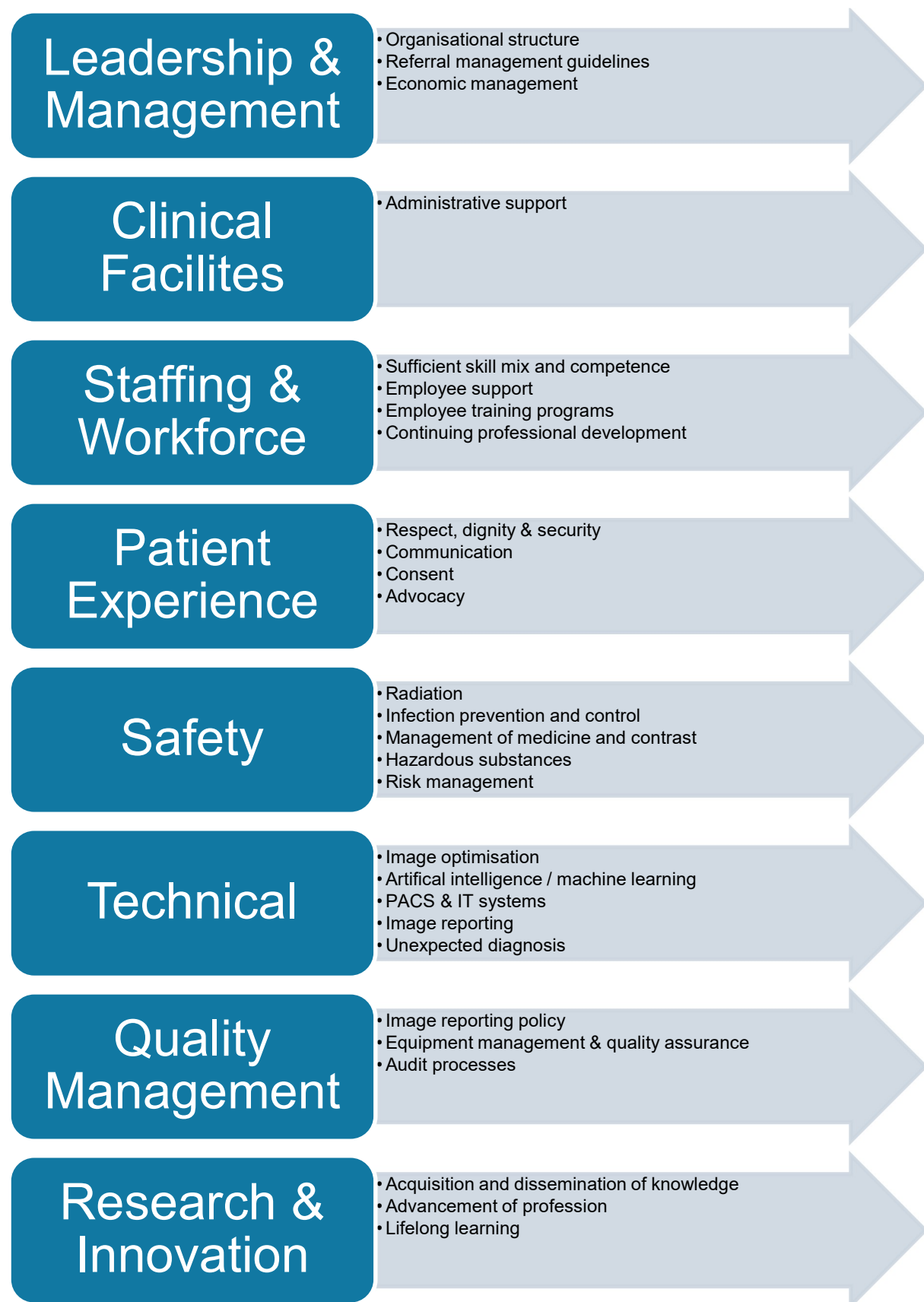
Author (publication year)	Country	Type of research	Profession	Key findings
New Zealand Medical Radiation Technologists Board (2018) ⁷³	New Zealand	Competence standards	Medical Radiation	Competence standards issued by NZMRTB* to ensure patient safety through standards for medical radiation practitioner's education and competence. There are 5 domains within the standards: Professional and Ethical Conduct; Communication and Collaboration; Evidence-Based Practice and Professional Learning; Safety of Practice and Risk Management; Medical Imaging/Radiation Therapy (including the following scope of practice subsets: Medical Imaging Technologist, Nuclear Medicine technologist, Radiation Therapy Technologist, Sonographer, MRI* Technologist).
The American Society of Radiologic Technologists (2021) ⁷⁷	United States of America	Practice standards (which also includes some practitioner standards)	General	Practice standards issued by the ASRT* to guide the medical imaging (and radiation therapy) profession to evaluate the quality of practice service and education provided within the profession. These practice standards detail 13 standards: Assessment; Analysis/Determination; Education; Performance; Evaluation; Implementation; Outcomes Measurement; Documentation; Quality; Self-Assessment; Collaboration and Collegiality; Ethics Research, Innovation and Professional Advocacy.

Table 20: Continued

Author (publication year)	Country	Type of research	Profession	Key findings
The Imaging Services Accreditation Scheme (2017) ⁶⁹	United Kingdom	Standard	Diagnostic Imaging (excludes non-imaging aspects of Nuclear Medicine and asymptomatic breast screening services)	The standards are designed to be a benchmark for quality improvement. It can be used to improve standards outside of the formal accreditation process (by the United Kingdom Accreditation Service) and form the basis for formal accreditation. The standards can be applied to any organisation performing radiological procedures or providing teleradiology. The standards are comprised of the following domains: Leadership and Management; Clinical; Facilities, Resources and Workforce; Patient Experience; and Safety.
The Royal College of Radiographers and the Royal College of Radiologists (2021) ⁷⁰	United Kingdom	Standard	General	The QSI* is designed to be used within a service against which quality improvement, patient experience and patient involvement, and accreditation can be achieved. It aims to improve the quality of care for people attending an imaging service. It sets out best practices to improve patient care and outcomes. It sets a minimum standard, i.e., benchmark. The quality standard is structured to address the generic quality standards applicable to all imaging services. In addition, there are specific additional quality standards for five modalities that must also meet the generic quality statements where applicable (i.e., CT*, interventional radiology, MRI*, nuclear medicine and molecular imaging, ultrasound).

*ASRT = American Society of Radiologic Technologists; CT = computed tomography; MRI = magnetic resonance imaging; NZMRTB = New Zealand Medical Radiation Technologists Board; QSI = quality standard for imaging

Figure 4: High level themes addressed in the international standards in general diagnostic imaging



In addition to the publications on general diagnostic imaging, various international standards address a specific clinical pathway of diagnostic imaging, i.e., diagnostic radiography, MRI and US and outlined in Table 9. Although the focus of each paper was vastly different, common high-level themes were present (i.e. safety, equipment, standardised training), which are all essential elements to ensure the delivery of high-quality standard of care and best practice.

Table 21: International standards for diagnostic imaging (specific clinical pathway)

Author (publication year)	Country	Type of research	Profession	Key findings
Dalili et al (2021) ⁷⁸	United Kingdom	Position Statement	Ultrasound	The Musculoskeletal (MSK) Ultrasound profession has developed significantly over recent years. Many of the duties now undertaken by non-radiologists are tasks that Radiologists previously performed. However, the quality of the service provided to patients remains paramount. Standardised training, practices and competencies must deliver a high-quality MSK ultrasound service (MSKUS). Specific recommendations for action for both MSKUS delivered by a radiologist and non-radiologist.
European Society of Radiology (2019) ⁶⁶	Europe	Statement paper	Diagnostic Radiography	This paper addresses radiation safety in diagnostic and interventional radiology. The ESR* recommends specific reporting criteria for significant events are based on physical quantities and units and not on effective doses or text-based criteria like 'significantly different'. Furthermore, the ESR encourages software vendors to develop affordable dose management systems that meet the basic requirements of the national reporting criteria.
European Society of Radiology (2020) ⁶⁷	Europe	Statement paper	Ultrasound	<p>A consensus statement from the Ultrasound subcommittee of the ESR*, the UEMS* Section of Radiology, and the European Federation of Societies for Ultrasound in Medicine and Biology state:</p> <ul style="list-style-type: none"> • Adequate and continuous training in ultrasound is essential to provide quality examinations • Documentation of ultrasound images in a PACS system must be ensured • Hygienic measures must be implemented in order to prevent contamination.

Table 22: Continued

Author (publication year)	Country	Type of research	Profession	Key findings
Kanal et al (2013) ⁷²	United States of America	Guideline	MRI	<p>These ACR* guidelines are for MRI* facilities to develop an MRI safety program for clinical diagnostic imaging, research, interventional and intraoperative MRI applications. It covers twelve key areas: 1. Establish, Implement, and Maintain Current MRI Safety Policies and Procedures; 2. Static Magnetic Field Issues: Site Access Restriction; 3. MRI Technologist; 4. Pregnancy Related Issues; 5. Pediatric MRI Safety Concerns; 6. Time Varying Gradient Magnetic Field Related Issues: Induced Voltages; 7. Time Varying Radiofrequency Magnetic Field Related Issues: Thermal; 8. Time Varying Gradient Magnetic Field Related Issues: Auditory Considerations; 9. Drug Delivery Patches and Pads; 10. Cryogen-Related Issues; 11. Claustrophobia, Anxiety, Sedation, Analgesia and Anesthesia; 12. Contrast Agent Safety</p>
Nhyssen et al (2017) ⁷⁹	Europe	Guideline	Ultrasound	<p>The paper highlights the importance of infection prevention and control in US*. Decontamination guidelines, regulation and legislation on transducer decontamination, choice of US gel and transducer covers vary throughout Europe. The evidence shows that adequate protocols and staff training can achieve efficient disinfection and contribute to improvements in patient safety. Key findings:</p> <ul style="list-style-type: none">• Transducers must be cleaned/disinfected before first use and after every examination.• Low level disinfection is sufficient for standard US on intact skin.• High level disinfection is mandatory for endo-cavity US and all interventions.• Dedicated transducer covers must be used for endo-cavity US and all interventions.• Sterile gel should be used for all endo-cavity US and all interventions.

Table 23: Continued

Author (publication year)	Country	Type of research	Profession	Key findings
The Society and College of Radiographers and the Royal College of Radiologists (2014) ⁶⁸	United Kingdom	Standard	Ultrasound	This document aims to set standards in key areas essential for delivering high-quality and effective ultrasound imaging services and examinations. The key areas covered are ultrasound equipment, training and education, examination specific standards, ultrasound examination report, auditing of ultrasound practice and report quality and image management.
Watson and Odle (2013) ⁷¹	United States of America	White paper	Diagnostic Radiography	This paper identifies the current challenges associated with the medical imaging profession (i.e., workplace and staffing, technology gaps and workplace culture). It discusses the desired state/best practice regarding the key areas (workplace and staffing, technology gaps and workplace culture).

*ACR = American College of Radiology; ESR = European Society of Radiology; MRI = magnetic resonance imaging; PACS = picture archive and communication system; UMES = European Union of Medical Specialists; US = ultrasound

From the national and international standards, the following conclusions can be drawn:

- National standards for diagnostic imaging are set by both regulatory and professional organisations
- Regulatory bodies maintain public safety and quality standards by ensuring a minimum standard for a medical radiation practitioner (diagnostic radiographer, nuclear medicine technologist) and practice/service safety by ensuring appropriate documentation and policies are in place
- Sonography registration is unregulated. Accreditation is conducted by the ASAR
- International standards vary in their focus however, common themes such as leadership/management, clinical facilities, staffing and workforce, patient experience, safety, technical, quality management and research) are key to achieving best practice and quality in diagnostic imaging.^{65, 69, 70, 77}

Gaps in the evidence

This review identified commercially produced and grey literature that explored patient safety and quality issues associated with diagnostic imaging. Much of the literature was rated as low-level evidence (as per NHMRC Levels of Evidence), highlighting opportunities for further rigorous research.

While there is a handful of high-level research (such as level I evidence and systematic reviews), critical knowledge gaps also persist. For example, the literature on interventions to improve patient safety and quality, while promoting a range of interventions, could not

recommend the ideal combination of interventions nor the parameters that underpin these interventions (type, duration, frequency, mode etc.). While this may assist in developing bespoke and customised intervention strategies which cater to a local context, it may also hinder standardisation, generalisability, and applicability to wider health care settings. Similarly, there is a lack of robust data collection mechanisms to collect accurate and timely data on patient safety and quality issues in diagnostic imaging. As diagnostic imaging is a growth area, it is recommended that this could be complemented by growth in a methodologically sound and robust evidence base.

Discussion

There has been an increasing focus on quality and safety in health care, and the field of diagnostic imaging is no exception. This is evidenced by the growing body of literature, both commercially produced and grey, which informed this review. Collectively, while the literature emphasised the importance of, and recognition for, patient safety and quality in diagnostic imaging, it also acknowledged the complexities underpinning achieving this. Much of the literature is low-level evidence, as identified by the NHMRC levels of evidence. Where there is high-level evidence (such as systematic reviews), the evidence is mixed with knowledge gaps. This highlights the need for ongoing efforts across sectors (health care, research, policy etc.) to explore, investigate and implement robust strategies that can improve patient safety and quality in diagnostic imaging.

Patient safety and quality in diagnostic imaging learnings

The review brought together a diverse body of literature and identified eleven core learnings for patient safety and quality in diagnostic imaging. They are:

Patient safety and quality care risks

The main patient safety and quality care risks can be grouped into communication, infection control, radiation safety, contrast administration, diagnostic error, and safety issues.

Multifactorial issues contribute to patient safety and quality care risks

The issues contributing to patient safety and quality care risks are multifactorial and complex. These factors include issues that occur at the individual, situational, environmental, organisational, cultural and communication levels.

Importance of multicomponent, systems approach

The multifactorial and complex nature of issues that contribute to patient safety and quality risks require multi-component interventions and a systems approach.

There is no 'one-size-fits-all' approach

The literature contains a range of interventions. Some are stand-alone, others are part of a package, and both types have mixed evidence of effectiveness. These include supportive and non-punitive organisational culture, guidelines, standardised communication systems, checklists and structured reporting, patient directed quality improvement activities, educational activities, use of peers, reducing fatigue and burnout, addressing environmental factors and the emergent role of technology.

Further robust high-level research is required

However, the literature does not shed light on the ideal combination of interventions nor the parameters that underpin these interventions (type, duration, frequency, mode etc.). Therefore, ongoing further high-level research is required.

Opportunities for unwarranted variation can occur across different points of care

Unwarranted variation can be grouped into low-value care, variation from the recommended pathways and access delay. Examples of low-value care include choosing high-cost imaging modalities such as CT, MRI and contrast studies at the expense of other more affordable, equally accurate modalities. Variations from recommended pathways (which may be derived from best evidence, consensus, and recommendations), can result in incorrect or incomplete diagnoses and increased patient radiation dose. A delay in access to diagnostic imaging can lead to increased waiting times and inequity in access due to geographical differences and workforce shortages.

Multimodal approach with mixed evidence

Several multimodal improvements (such as education, use of evidence and consensus-based imaging referral guidelines and clinical decision support tools) have been suggested in the literature to address unwarranted variation in diagnostic imaging, albeit with mixed evidence of effectiveness.

Potential high risk unwarranted variation can be improved by adjusting current processes of care

Improvements to address the unwarranted variation of relatively high risk of harm to patients (such as death) target the process of care. Mechanisms to achieve this include regulation, oversight by professional bodies, standards and accreditation schemes, evidence-based guidelines, and targeted strategies to influence the clinician's role (such as mandatory training, clarity on the scope of practice, compliance with accredited practice, standardisation of referrals, education about reporting obligations and use of an algorithm for early clinician notification).

Supporting and upskilling the workforce

Improvements to address the unwarranted variation of relatively low risk of harm to patients (such as inappropriate use of imaging) target a clinician's belief in imaging or are related to the lack of knowledge on the appropriate use of new radiological technology. Multi-component interventions that include education and are adapted to the local context were more effective in reducing the use of low-value diagnostic imaging. Appropriateness of diagnostic imaging may be influenced by a myriad of strategies such as education (role of referrers and imaging specialist's role), imaging guidelines, incentives, patient-mediated approaches and use of clinical decision support tools.

A matrix of standards

Standards are used nationally and internationally to underpin the quality of diagnostic imaging. The diagnostic imaging standards in use are provided by government regulators and professional organisations. Government regulators focus on the practitioner (within the broader medical radiation professions) and diagnostic imaging practice standards.

Professional organisations have standards specific to individual disciplines. While discipline specific, this type of standards aims to inform and guide their members on ethical principles and professional and technical skills to maintain patient safety, reduce risk and improve patient diagnostic outcomes.

Standards vary but share similarities

The focus of national and international standards varies. Common areas in the standards include leadership/management, clinical facilities, staffing and workforce, patient experience, safety, technical, quality management, research, and innovation.

Conclusion

Underpinned by best-practice standards in the conduct and reporting of review (using a modified version of the PRISMA-ScR), this review summarised contemporary literature on:

- Diagnostic imaging patient safety and quality care issues
- Strategies to improve patient safety and quality care
- National and international standards that underpin diagnostic imaging

The review methodology (including the search protocol) was developed and agreed upon before the review.

Commercially produced sources and grey literature which explored patient safety and quality issues with diagnostic imaging were identified from diverse sources. Literature from diverse sources was identified. Much of the literature was rated as low-level evidence (as per NHMRC Levels of Evidence), highlighting opportunities for further rigorous research.

Synthesis of these findings revealed core learnings on factors contributing to patient safety and quality care in diagnostic imaging. The literature suggests multicomponent interventions which have a systems approach to address the multifactorial nature and complexities that underpin, patient safety and quality care. However, the ideal combination of interventions is unclear, and evidence of effectiveness is mixed. Overall, standards that focus on the clinician (in terms of upskilling) and practice (in terms of the process of care) and has broad focus are likely to contribute to patient safety and quality care.

Appendix A

Safety and Quality issues in Diagnostic Imaging: A Literature Review Protocol and Search Strategy

Objectives

This review of the literature aims to identify diagnostic imaging patient safety and quality care issues, evidence and strategies to reduce or prevent adverse events and unwarranted variation in diagnostic imaging and components of diagnostic imaging accreditation standards used to support improvement and quality of care in diagnostic imaging.

Questions

1. What are the main patient safety and quality care risks relevant to diagnostic imaging?
2. What areas of diagnostic imaging have unwarranted variation?
3. What interventions can minimise patient safety and quality risks relevant to diagnostic imaging?
4. What is the evidence for the effectiveness of these interventions?
5. What improvements can address unwarranted variation?
6. What standards operate nationally and internationally for diagnostic imaging and what do the standards address?

Methods

This review will use scoping review methodology underpinned by PRISMA-ScR and will consider:

- The research method and the strengths/limitations of the method
- The parameters of the research, including what the research specifically assessed
- Level of evidence it provides as per the NHMRC Levels of evidence guidelines
- Major relationships or patterns in the research
- Major issues and debates about the topic
- Gaps in the literature

Sources of evidence

A range of commercially produced databases will be searched for peer-reviewed literature:

- OVID (MEDLINE, Embase, Emcare)
- EBSCOhost
- Scopus
- Web of Science

- The Cochrane Library
- ProQuest

To avoid publication bias, reference lists of retrieved articles will also be searched to maximise the retrieval of relevant publications (i.e., pearling). Additionally, grey literature searching will be conducted from the following sources:

- Google and Google Scholar
- Organisational websites (professional associations, government agencies, regulatory authorities)
- Direct contact with experts may also be made to identify any additional literature

Inclusion and exclusion criteria

Table 24: Inclusion and exclusion criteria for literature selection

Concept	Inclusion criteria	Exclusion criteria
Type of participants	Any patient (children and adults) receiving diagnostic imaging	Health care provider / practitioner / clinician
Type of intervention	<ul style="list-style-type: none"> • Any diagnostic imaging modality delivered by health professionals, including: <ul style="list-style-type: none"> – Ultrasound, Computed tomography, X-ray, Mammography, Angiography, Fluoroscopy, Orthopantomography, Magnetic resonance imaging, Nuclear Medicine • Diagnostic imaging standards 	Medical Radiation interventions (radiation therapy)
Type of comparators	Current practice standards	Not applicable
Type of outcomes	Including but not limited to: <ul style="list-style-type: none"> • Diagnostic imaging patient risks, harms or adverse events • Unwarranted variation in diagnostic imaging • Methods for management and minimising diagnostic imaging risks, harms and unwarranted variation • Common diagnostic imaging standards aimed to protect patients from harm 	Medical imaging technical / laboratory data

Table 25: Continued

Concept	• Inclusion criteria	• Exclusion criteria
Type of studies	<ul style="list-style-type: none"> Any publication from commercially produced and grey literature Reviews, including all review types (e.g., narrative, systematic, scoping) involving diagnostic quality and safety issues for imaging modalities Organisational reports, evaluations, professional associations guidelines, frameworks, and policies 	<ul style="list-style-type: none"> Non-English language literature Literature published / produced prior to 1 January 2010 Studies focussing on non-humans (e.g., the role of artificial intelligence in diagnostic testing)

Search terms

A combination of search terms from concepts 1, 2 and 3 (Table 11) will be used to identify potentially relevant publications from the included databases, with the application of appropriate truncation symbols, Boolean operators (AND, OR) and wildcards for relevant databases. Synonymous terms and related Medical Subject Headings (MeSH) will also be used to expand the search as appropriate. A full OVID MEDLINE search syntax has been developed and is presented in Figure 5. This will form the basis of the search for other databases.

Table 26: Search strategy

Concept	Search terms
Concept 1	“patient safety” or adverse or harm or iatrogenic or inappropriate or injury or risk or “unwarranted variation” or “unwarranted clinical variation”
Concept 2	“diagnostic imag*” or “imag*” or ultrasound or x?ray or mammography or angiography or fluoroscopy or orthopantomography or “magnetic resonance imag*” or “nuclear medicine”
Concept 3	“imag* standard*” or “imag* guideline*” or “imag* rule*”

Figure 5: OVID MEDLINE search syntax

<input type="checkbox"/>	# ▲	Searches	Results	Type	Actions	Annotations
<input type="checkbox"/>	1	("patient safety" or adverse or harm or iatrogenic or inappropriate or injury or risk or "unwarranted variation" or "unwarranted clinical variation").mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	5336043	Advanced	Display Results More ▼	
<input type="checkbox"/>	2	limit 1 to (english language and humans)	3839387	Advanced	Display Results More ▼	
<input type="checkbox"/>	3	patient harm/ or patient safety/	24199	Advanced	Display Results More ▼	
<input type="checkbox"/>	4	limit 3 to (english language and humans)	22224	Advanced	Display Results More ▼	
<input type="checkbox"/>	5	2 or 4	3839387	Advanced	Display Results More ▼	
<input type="checkbox"/>	6	("diagnostic imag*" or imag* or ultrasound or x?ray or mammography or angiography or fluoroscopy or orthopantomography or "magnetic resonance imag*" or "nuclear medicine").mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	2880545	Advanced	Display Results More ▼	
<input type="checkbox"/>	7	limit 6 to (english language and humans)	1933297	Advanced	Display Results More ▼	
<input type="checkbox"/>	8	Diagnostic Imaging/ or X-Rays/ or angiography/ or mammography/ or Fluoroscopy/ or Magnetic Resonance Imaging/ or Nuclear Medicine/	625216	Advanced	Display Results More ▼	
<input type="checkbox"/>	9	limit 8 to (english language and humans)	497692	Advanced	Display Results More ▼	
<input type="checkbox"/>	10	7 or 9	1940136	Advanced	Display Results More ▼	
<input type="checkbox"/>	11	("imag* standard*" or "imag* guideline*" or "imag* rule*").mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	922	Advanced	Display Results More ▼	
<input type="checkbox"/>	12	limit 11 to (english language and humans)	685	Advanced	Display Results More ▼	
<input type="checkbox"/>	13	5 and 10 and 12	183	Advanced	Display Results More ▼	
<input type="checkbox"/>	14	limit 13 to yr="2010 -Current"	153	Advanced	Display Results More ▼	

Selection of evidence

Following the search, titles and abstracts will be screened against the inclusion criteria to identify potentially relevant papers. If the titles and abstracts meet the inclusion criteria for this review, they will be initially selected to be part of the review. Full-text copies of eligible articles will be subsequently retrieved for a full examination. Only publications that meet the inclusion parameters will be included in this review. A comprehensive, full systematic review is beyond the scope of this project. Instead, the selection of evidence will be underpinned by those relevant to the review question (in terms of breadth and depth) and level of evidence. Once data saturation is achieved (in terms of addressing the review questions), no further studies will be included in the analysis. An Endnote Library containing both included and additional relevant studies will be provided.

Data extraction and reporting

Customised data extraction forms will be developed specifically for this review and utilised to extract relevant data from the included literature. Given the nature of the review, data will be presented in tabular and graphical forms as appropriate. Data will be narratively summarised and descriptively synthesised (both quantitative and qualitative) to address the review questions.

Reporting

The final report will include a summary of evidence from the literature, ranked using NHMRC Levels of Evidence. This will ensure access to the best available evidence on safety and quality issues in diagnostic imaging.

Appendix B

National Health and Medical Research Council Levels of Evidence

Table 27: NHMRC levels of evidence hierarchy

Level	Intervention	Diagnostic accuracy	Prognosis	Aetiology	Screening intervention
I	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies
II	A randomised controlled trial	A study of test accuracy with an independent, blinded comparison with a valid reference standard, among consecutive persons with a defined clinical presentation	A prospective cohort study	A prospective cohort study	A randomised controlled trial
III-1	A pseudorandomised controlled trial (i.e., alternate allocation or some other method)	A study of test accuracy with an independent, blinded comparison with a valid reference standard, among non-consecutive persons with a defined clinical presentation	All or none	All or none	A pseudorandomised controlled trial (i.e., alternate allocation or some other method)

Table 28: Continued

Level	Intervention	Diagnostic accuracy	Prognosis	Aetiology	Screening intervention
III-2	<p>A comparative study with concurrent controls:</p> <ul style="list-style-type: none"> • Non-randomised, experimental trial • Cohort study • Case-control study • Interrupted time series with a control group 	<p>A comparison with reference standard that does not meet the criteria required for Level II and III-1 evidence</p>	<p>Analysis of prognostic factors amongst persons in a single arm of a randomised controlled trial</p>	<p>A retrospective cohort study</p>	<p>A comparative study with concurrent controls:</p> <ul style="list-style-type: none"> • Non-randomised, experimental trial • Cohort study • Case-control study
III-3	<p>A comparative study without concurrent controls:</p> <ul style="list-style-type: none"> • Historical control study • Two or more single arm study • Interrupted time series without a parallel control group 	<p>Diagnostic case-control study</p>	<p>A retrospective cohort study</p>	<p>A case-control study</p>	<p>A comparative study without concurrent controls:</p> <ul style="list-style-type: none"> • Historical control study • Two or more single arm study
IV	<p>Case series with either post-test or pre-test/post-test outcomes</p>	<p>Study of diagnostic yield (no reference standard)</p>	<p>Case series, or cohort study of persons at different stages of disease</p>	<p>A cross-sectional study or case series</p>	<p>Case series</p>

Appendix C

Overview of Included Literature

Question 1: What are the main patient safety and quality care risks relevant to diagnostic imaging?

Table 29: Data extraction table for Question 1

Study / Document	Country	Type of research	Profession	Key findings
Brady (2017) Title: 'Error and Discrepancy in radiology: inevitable or avoidable?'	Ireland	Narrative review	General	<ul style="list-style-type: none">• Radiology reports are not expected to be definitive or incontrovertible they are opinions bringing together relevant information.• Error definition is not clear and is inevitable <p>Contributing factors</p> <ul style="list-style-type: none">• Technical factors• System issues• Workload issues <p>Strategies for minimising errors</p> <ul style="list-style-type: none">• Identify and learn from errors by reducing the blame culture• Employ quality management and improvement processes• Define quality metrics• Structured reporting• Computer-aided detection• Double reporting with disagreement discussed. Adjustment of radiologists working conditions has a negligible effect on error rate.

Table 30: Continued

Study / Document	Country	Type of research	Profession	Key findings
Carrizales and Clark (2015) Title: 'Implementing Protocols to Improve Patient Safety in the Medical Imaging Department'	United States of America	Narrative with some evidence of literature searching	General	<p>Major changes were driven by changing the funding model to include patient safety factors.</p> <p>Identified areas of improvement:</p> <ul style="list-style-type: none"> • Handoff communication: passing complete and accurate patient-specific information from one caregiver to another • Computer-based order or referral systems: the ordering of examinations and medication by computer without written documentation of the order • Proper patient identification: Name, date of birth, address, any other information specific to that patient • Adequate medication contrast media administration: iodine-based and gadolinium <ul style="list-style-type: none"> – Contrast induced nephropathy <ul style="list-style-type: none"> ○ Kidney damage by contrast administration ○ Associated with cardiovascular complications, extended hospital stays, stage 4-5 renal disease ○ Risk factors – Diabetes mellitus, dehydration, age, contrast administration, choice of contrast, number of studies within time frame ○ Means to reduce risk ○ Increase hydration ○ Medication administration prior to examination ○ Reduce time of fluid restriction prior to examination ○ Sodium bicarbonate prior to contrast studies – Nephrogenic systemic fibrosis

-
- Associated with gadolinium-based contrast agents used in magnetic resonance imaging
 - Once considered 'safe' for stage 4- kidney failure now stage 5 at greatest risk
 - Stage 3 did not develop this condition post gadolinium
 - Other risk factors include: >60, diabetes, lupus, history of renal disease, multiple myeloma
 - Implementation of patient screening prior to administration of contrast media
 - Estimated glomerular filtration rate established prior to administration of gadolinium
-

Table 31: Continued

Study / Document	Country	Type of research	Profession	Key findings
Davies, Wathen and Gleeson (2011) Title: 'The risks of radiation exposure related to diagnostic imaging and how to minimise them'	United Kingdom	Narrative with some evidence of literature searching	General	<i>Demand for imaging increasing</i> <ul style="list-style-type: none">• Reasons offered for increase <i>Highest risk populations</i> <ul style="list-style-type: none">• Pregnant women• Children <i>Reducing radiation risk</i> <ul style="list-style-type: none">• Utilise national guidelines calculate dose before examination• Reduce computed tomography exams<ul style="list-style-type: none">– Choose alternative (magnetic resonance imaging, ultrasound)– Use newer technologies/protocols which reduce dose (computed tomography)– Protocols for examinations to reduce dose variation• Not usual to tell patient of risks and dose of examination• Consider all examination implications prior to referring patient• Explain clearly to the patient and/or carers implications of procedure including dose.

Table 32: Continued

Study / Document	Country	Type of research	Profession	Key findings
Docking and Haddock (2021) Title: 'Reducing diagnostic errors related to medical imaging'	Australia	Narrative Review	General	<p>Definitions of</p> <ul style="list-style-type: none"> • Diagnostic process • Diagnostic error • Delayed diagnosis • Wrong diagnosis • Missed diagnosis • Near misses • Overdiagnosis <p>Methods to report diagnostic error in Australia</p> <ul style="list-style-type: none"> • Medical indemnity claims • Public reporting of diagnostic errors <p>Three phases of diagnostic error</p> <ul style="list-style-type: none"> • Pre-analytic: Follows the clinical history <ul style="list-style-type: none"> – Inappropriate imaging – not clinically indicated, incorrect modality/exam ordered • Analytic: Image acquisition and interpretation <ul style="list-style-type: none"> – Image related errors – suboptimal, artefacts – Incorrect protocol – Radiologist – interpretation / cognitive errors – Overdiagnosis of incidental findings • Post-analytic: Diagnostic treatment and decision-making

-
- Over-reliance/over-confidence in diagnostic imaging
 - Communication failures – timeline receiving report, quality of the report
 - Referrer interpretive/cognitive error

Suggestions to improve the use of diagnostic imaging

- Improve the quality of referrals
 - Development and implementation of strategies for appropriate use of diagnostic imaging
 - Encourage uptake of My Health Record
 - Use of structured report templates
-

Table 33: Continued

Study / Document	Country	Type of research	Profession	Key findings
European Society of Radiology and European Federation of Radiographer Societies (2019) Title: 'Patient Safety in Medical Imaging: a joint paper of the European Society of Radiology (ESR) and the European Federation of Radiographer Societies (EFRS)'	The Netherlands	Narrative Review	General	<p><i>Radiation protection</i></p> <ul style="list-style-type: none"> • Three fundamentals: <ul style="list-style-type: none"> – Justification – Optimisation – Application of doses 'As Low As Reasonably Achievable' <p><i>Drug and contrast issues</i></p> <ul style="list-style-type: none"> • Contrast agents – Iodinated and gadolinium contrast media as well as microbubbles for ultrasound • Hypersensitivity reactions: <ul style="list-style-type: none"> – Be prepared and trained (resuscitation trolley, emergency numbers available) – Question patient for previous reactions, the grade and symptoms – Nephrotoxicity of iodinated contrast media • Consider risk factors: <ul style="list-style-type: none"> – >70, reduced renal function, large doses and multiple contrast injections within 48 – 72 hours – Iodinated contrast induced thyrotoxicosis • Nephrogenic systemic fibrosis – Linear gadolinium chelates (magnetic resonance imaging contrast) recently withdrawn from the EU market • Patient handling: Safe patient handling is defined as any activity requiring force to push, pull, lift, lower, transfer or in some way move or support a person or body part • Issues for the patient and/or healthcare professional

Patient information: informed consent and explanatory information for patients

European Society of Radiology requires all communication with and about people to be – effective, timely, inclusive and personalised.

- Advocacy – Patients access to the right support to make a decision. This can include someone ‘speaking on their behalf.
- Shared decision making
- Capacity – Everyone has right to make a decision and it is assumed they can do this.
- Children – Competence laws are different for <16 as opposed to >16
- Use of chaperones – For intimate examinations
- Emergency imaging – Exception if consent not able to be gained - save patient’s life, prevent deterioration of life

Magnetic resonance imaging safety

- The behaviour of ferro-magnetic objects within a strong magnetic field
- Effect on medical devices
- Radiofrequency risks
- Acoustic noise
- The American College of Radiology Guidance Document on MRI Safe Practices: 2013
- Many other documents relating to this area.

Prevention of infection, decontamination, hospital acquired infections

- General precautions and specific precautions should be employed depending on available information,
 - General: Hand hygiene and personal protective equipment
 - Specific: example of isolation patients
 - Safe injection procedures
-

Ultrasound infection protection

- Unique due to direct contact with equipment
- The gel can be a transmission point
- Ultrasound Working Group of European Society of Radiology published recommendations in 2017 related to transducer decontamination and the use of transducer covers

Data security and IT developments

- Responsibility for patient information, privacy and confidentiality
- Radiology interacts with Hospital Information Systems, Radiology Information Systems and Picture Archiving and Communication System
- Artificial Intelligence and Deep Learning are different challenges not yet fully understood.

Appropriate professionals

- Formal qualifications for both radiologist and radiographer. Clear Scopes of Practice
- Minimum of a formal report

Interventional radiology

- Additional risks relating to potential complications or negative outcomes are explained to the patient

Children and other vulnerable patients

- The onus to protect rights of a child
- Mandated reporters of suspected physical abuse or non-accidental injury

Communication

- Involve patient in their healthcare process and explain the whole procedure or examination in a structured way.
- Accurate communication between healthcare professionals

Quality improvement

- Always possible
- Become part of daily practice
- Every effort to avoid errors
- No-blame culture
- Learning from discrepancies meetings

Continuing Professional Development

- Constant change
- Updating skills and knowledge

Peer review

- Blame-free environment

Clinical audit

- EU mandate since 1997
- Evaluate current practices and opportunities to change practices when appropriate
- Measured against standard where appropriate

External review

- In some countries, these are legal requirements

Risk management

- Responsibility of professionals

Fatigue/burnout

- State of mental weariness within the workplace. Progressive loss of energy and enthusiasm
- Decrease in productivity, effectiveness, reduced commitment and negative effects on homelife

Training in patient safety issues

- Greater focus on formal training and post-qualification
 - European Society of Radiology has published on this matter
-

Table 34: Continued

Study / Document	Country	Type of research	Profession	Key findings
European Society of Radiology (2020) Title: 'Performance indicators for radiation protection management: suggestions for the European Society of Radiology'	Austria	Narrative Review	General	<i>Performance indicators</i> <ul style="list-style-type: none">• Radiation safety is not often included• Patient safety• Personnel safety• Image quality• Clinical outcome• Include all stakeholders• Results obtained for individual investigations used for:<ul style="list-style-type: none">– risk assessment– calculating quality/safety index• Questions in radiology:<ul style="list-style-type: none">– re-take range– incorrect patient imaged– adverse effects of contrast administration– radiation dose events• Care when selecting key performance indicators (KPIs)• Separate key performance indicators (KPIs) for dose• Monitoring as free as possible from manual input

Requirements for performance indicators

- Automatisations – less error
- Availability –representative and meaningful results
- Consistency –clear which data collected and documented
- Sufficiency of events for statistical analysis –meaningful results
- Impact - relevant topics for patient and staff safety
- Reproducibility and stability – suitable indicators
- Usability – easy to capture and unambiguous

Overview of performance indicators for radiation protection

- Templates available for data
- Justification - quality and appropriateness of referral
- Retake rate – relevant quality feature
- Artefacts – limit and linked to repeat rate
- Protective devices – availability and use of protective equipment
- Indicators for personalised feedback – able to link to individual users
- Indicators for patient feedback – information on radiation protection available to patients.

Key performance indicator suggestions included

- Patient-centred key performance indicators
 - Informing the patient about the quantity of exposure and available alternatives
 - Local dose registry
 - Benchmarking with regional or similar registries
 - Timely and regular analysis of accidental/unintended exposures
 - Monitoring of radiation doses outside of the radiology department
 - Personnel-centred key performance indicators
-

-
- Online monitoring of eye lens doses

- Staff dosimetry

European Society Radiology clinical audit tool

- Mandated

- Variety of topics

- Internal or external

- Should be: Achievable, Local, Practical, Inexpensive, Non-threatening and Easy
-

Table 35: Continued

Study / Document	Country	Type of research	Profession	Key findings
Halliday et al (2020) Title: 'Radiology GIRFT Programme National Speciality Report'	United Kingdom	Report	General	<p>Demand for radiology services increased in recent years, specifically in magnetic resonance imaging and computed tomography</p> <p>Delays with scanning and reporting</p> <p>National Health Service radiology services were reviewed</p> <p>20 recommendations were made, which can be grouped into:</p> <ul style="list-style-type: none">• Delivering a patient-centred service• Maximising capacity• Making data work harder• Managing increasing demand• Procurement• Litigation

Table 36: Continued

Study / Document	Country	Type of research	Profession	Key findings
Hiles et al (2021) Title: 'European consensus on patient contact shielding'	Europe	Consensus statement	General	<p>Radiation protection devices have been used for many years to protect against adverse radiation effects.</p> <p>The increasing number of position statements and recommendations have raised concerns regarding the use, effectiveness of these devices – the use of contact shielding can provide false reassurance</p> <p>A need for a European consensus</p> <p>It presents multidisciplinary recommendations for shielding.</p> <p>Reviewed evidence on contact shielding for Gonad, Thyroid, Breast, Eye lens, Embryo/foetal and provided recommendations for the use of contact shielding i.e., either:</p> <ul style="list-style-type: none">• Should use• May use• Not recommended to use <p>Adoption will require a change management program. There is a need to review current practices and provide education to health professionals and the public.</p> <p>Review again in 5 years or if new evidence</p>

Table 37: Continued

Study / Document	Country	Type of research	Profession	Key findings
Jabin et al (2022) Title: 'A Mixed-Methods Systematic Review of the Effectiveness and Experiences of Quality Improvement Interventions in Radiology'	Australia	Systematic Review	General	<p>This study aimed to compile and synthesize evidence regarding the effectiveness of quality improvement interventions in radiology and the experiences and perspectives of staff and patients.</p> <p>Quality improvement interventions were:</p> <ul style="list-style-type: none">• health information technology• training and education• immediate and critical reporting• Safety programs• Introduction of mobile radiography <p>Specifically, the review questions were as follows:</p> <ul style="list-style-type: none">• How effective are interventions that target improvements in patient safety and quality in clinical radiology?• What are the experiences and perspectives of staff and patients in relation to these interventions?
Thompson et al (2019) Title: 'A Secondary Analysis to Identify Patient-Centred Outcomes in ACR's Appropriateness Criteria'	United States of America and United Kingdom	Narrative review	General	<p>To identify patient-centred outcomes across a spectrum of clinical topics included in the American College of Radiology's Appropriateness Criteria.</p> <p>Suggestions on methods to incorporate Patient-Centred Outcomes into review of procedures</p>

Table 38: Continued

Study / Document	Country	Type of research	Profession	Key findings
Thompson et al (2021) Title: 'Patient-centred outcomes of imaging tests: recommendations for patients, clinicians and researchers'	United States of America	Multiple methods including scoping review	General	<ul style="list-style-type: none">• Identified Patient-Centred Outcomes• Included psychological and social dimensions of healthcare• The current focus on diagnostic accuracy rather than patient's perspectives of meaningfulness of test methods to include patient-centred outcomes into the review process

Question 2 and 3: What interventions can minimise patient safety and quality risks relevant to diagnostic imaging? What is the evidence for the effectiveness of these interventions?

Table 39: Data extraction table for Question 2 and 3

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Alzen and Benz-Bohm (2011) Title: 'Radiation protection in paediatric radiology'	Germany	Narrative review	X-rays and computed tomography	<p>There are a number of strategies that could be considered for lowering the dose of ionising radiation.</p> <p>For X-rays, these could include:</p> <ul style="list-style-type: none"> • Proper setting of tube voltage • Use of tube filters • Suitable patient positioning and fixation • Variable use of scattered-radiation grid • Modern storage-plate system. <p>For computed tomography, this could include age and indication adapted protocols.</p>	<p>For X-ray, no data was given.</p> <p>For computed tomography, the intervention described can reduce radiation exposure by 95%.</p>

Table 40: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Al-hihi et al. (2022) Title: 'Improving appropriate imaging for non-specific low back pain'	United States of America	Mixed methods quality improvement project	General	<p>A multicomponent, clinical decision support-enabled intervention was trialled in this research. This included:</p> <ul style="list-style-type: none"> educational sessions with key ordering provider groups in internal medicine (e.g., attending physicians, hospitalists and residents) to review clinical practice variabilities and share information from the Choosing Wisely campaign Use of Health Effectiveness Data and Information Set criteria being communicated to providers to improve adherence and documentation development of a new order panel and clinical decision support order sets Practice alerts and reminders were built into the electronic medical record to marry the clinical guidelines with the institution's order entry system. <p>This established a standardised workflow for non-specific low back pain. In addition to these, access to imaging was denied when providers did not document compliance with institutionally approved indications. However, providers could proceed with an override by entering an active acknowledgement for opposing recommendations.</p> <p>Patient focus groups captured their experiences and expectations. The findings were used in educational sessions content and healthcare professional and patient materials.</p>	<p>First six months, 81.7% received appropriate imaging (target 90%)</p> <p>Following termination of intervention, the rate dropped to 72.7% but then picked up again following a health system-wide deployment of practice-based alerts and order sets.</p> <p>Additionally, quality scorecards of appropriate LBP imaging were created and shared with each provider to help set performance targets. Performance targets emphasised appropriate documentation and specific International Classification of Diseases, 10th revision (ICD-10) codes for billing or associated imaging diagnoses to reflect chronicity of back pain or presence of radiculopathy, trauma, or cancer.</p> <p>The overall rate of appropriate imaging during follow up was 88.2%.</p>

Table 41: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Backcock et al (2015) Title: 'Monitoring of clinical imaging guidelines part 3: Norms, standards, and regulations'	Global	Narrative review	General	<ul style="list-style-type: none">• A range of different strategies was reported in this review. These included:• Regulation for monitoring as a driver to improve the use of guidelines• Use of clinical audits in the absence of legal requirements• Access to guidelines (monitored through clinical audits)• Use of guidelines through support and encouragement• Regulatory inspections and administrative mandates• Pragmatic targets• Monitoring guideline uptake and compliance by using audits, patient procedure registries and clinical decision support systems.	Not reported

Table 42: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Brady (2017) Title: 'Error and discrepancy in radiology: inevitable or avoidable?'	Ireland	Narrative review	General	<p>Radiology Quality Improvement programme involved the development and implementation of information technology tools to collect peer review and other quality improvement activities on a countrywide basis through interconnected picture archiving and communication system/radiology information systems and to analyse the data centrally, with a view to establishing national benchmarks of Quality Improvement Metrics.</p> <p>Structured reporting was shown to improve report content, comprehensiveness, and clarity in body computed tomography.</p> <p>Voice recognition dictation – Commonly used but can be problematic if reliant on transcriptions.</p> <p>Computer-aided detection - minimising the likelihood of missing some radiologic abnormalities, especially in mammography and lung nodule detection on computed tomography. It may have increased sensitivity and decreased specificity.</p> <p>Accommodative relaxation (shifting the focal point from near too far, or vice versa). It may be an effective strategy for reducing visual fatigue. Performed at least twice per hour during prolonged radiology reporting.</p> <p>Error scoring - identification and scoring of errors.</p>	<p>QI programme – Evidence of use but unknown effectiveness.</p> <p>Limited evidence and drawbacks (missing unexpected significant findings)</p> <p>Structured reporting – Some evidence in specific areas</p> <p>Voice recognition dictation – Limited evidence</p> <p>Computer-aided detection – Limited evidence due to poor agreement. With RadPeer there has been an overemphasis on scoring and underemphasis on commenting, and low compliance with little feedback. Moving away from scores to fostering shared learning experiences.</p> <p>Error scoring – Limited evidence</p>

<p>Quality Improvement (discrepancy) meeting uses virtual platforms to allow radiologists to review cases and submit feedback. Removes 'point scoring' and may facilitate attendance, participation and, hence learning.</p> <p>Swedish eCare Feedback programme uses extensive double reporting, identification of cases where disagreement occurs, and collective study of those cases for learning points.</p> <p>Root cause analysis is a system-centred approach, focusing on identifying what happened, why it happened, and what can be done to prevent it from happening again.</p> <p>Hybrid/multi-faceted – a combination of the above.</p>	<p>Quality Improvement (discrepancy) meeting – Some evidence in specific areas</p> <p>Swedish eCare Feedback programme – Some evidence in specific areas</p> <p>Root cause analysis – Limited evidence</p>
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Table 43: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Bruno and Nagy (2014) Title: 'Fundamentals of quality and safety in diagnostic radiology'	United States of America	Narrative	General	This review highlighted the fundamentals of quality and safety in diagnostic radiology including <ul style="list-style-type: none"> • Organisational culture • Building a team • Using key performance indicators • Graphical analysis tools • The role of the quality dashboard • Plan-do-study-act cycle • Recording of sentinel and near miss events • The use of investigatory tools such as root cause analysis and lean and six sigma. 	Some evidence in specific areas
Bruno, Walker and Abujudeh (2015) Title: 'Understanding and confronting our mistakes: The epidemiology of error in radiology and strategies for error reduction'	United States of America	Narrative	General	Checklists and Structured Reporting Practice Quality Improvement Information technology solutions and computer-aided detection Fail-safe strategies for harm prevention and risk reduction whereby direct communication with patients	Limited evidence Some evidence in specific areas Limited evidence Unknown effectiveness

Table 44: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Bruno (2017) Title: '256 Shades of grey: uncertainty and diagnostic error in radiology'	United States of America	Narrative	General	<p>In this review, the author suggests a range of strategies for 'de-biasing' including:</p> <ul style="list-style-type: none"> • Training to identify cognitive biases (such as anchoring bias, confirmation bias, and availability bias) • The use of computer aided detection, which may not reduce risk, but with improved technology (such as deep learning, eye-tracking, real-time feedback on visual dwell time) may be beneficial • The role of practice quality improvement, systems and failsafe strategies • The use of double reading of images. 	Some evidence in specific areas
Carrizales and Clark (2015) Title: 'Implementing protocols to improve patient safety in the medical imaging department'	United States of America	Narrative with some evidence of literature searching	General	<p>This review highlights various strategies to improve patient safety in the medical imaging department.</p> <p>Some strategies reported in this review include effective communication via:</p> <ul style="list-style-type: none"> • Handoff communication, which involves passing complete and accurate patient-specific information from one caregiver to another. Handoff communication needs to be simple, effective, and tailored to different personnel. • Use of electronic medical records, a digital version of patient records to aid in practitioner decision making. However, training and support are required. • A computer provider order entry system is used for ordering exams and medications without written documentation. • Proper patient identification can be improved using wrist bands, radiofrequency identification and barcode identification. • Adequate medication and contrast media administration as improper use could result in Contrast Induced Nephropathy and Nephrogenic Systemic Fibrosis. 	Limited evidence

Table 45: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Collins et al (2020) Title: 'Dangers in the dark: Calling for a safer practice of transvaginal ultrasonography'	Australia	Narrative with some evidence of literature searching	Ultrasound - transvaginal ultrasonography	This review highlighted a range of strategies that could be implemented to promote safer practice in transvaginal ultrasonography. These include <ul style="list-style-type: none">• Informed consent, which is underpinned by current standards• A physical examination process which follows best practice• Patient experiences of transvaginal ultrasound examinations that recognise individual patient needs and requirements• The presence of a chaperone (a qualified practitioner such as a nurse, doctor or any other person who is deemed suitable)	Not reported

Table 46: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Care Quality Commission (2018) Title: 'Radiology review: A national review of radiology reporting within the NHS in England'	England	Narrative review	General	<p>In this review, the Care Quality Commission highlighted strategies to promote safe and quality practices in diagnostic imaging by managing reporting workloads. These include issues with:</p> <p>Outsourcing, when images are sent electronically to an external provider (normally independent) to report. This requires a provider who is appropriately trained and registered with relevant regulatory bodies to participate in routine clinical audits and have systems in place to flag urgent and unexpected findings.</p> <p>Auto-reporting has been suggested as a strategy to manage radiology reporting workload. Auto-reporting involves identifying which examinations could be reported on by non-radiology staff. This involves sending a standard response automatically to referrers, informing them that the examination will not receive a formal radiology report and that it is their responsibility to provide one. This strategy may be useful in some circumstances, such as follow up images for patients attending fracture clinics where a radiologist or radiographer reported the initial X-ray, and the subsequent images are to assess the healing process.</p> <p>This strategy does carry risks, especially for chest and abdominal x-rays where less obvious pathologies (such as small or subtle cancers) may be missed due to lack of adequate training. Therefore, this needs to be supported by training, and if requested, radiology consults are available. However, there is no agreement on what constitutes adequate training for non-radiology staff responsible for reporting images that do not receive a formal radiology report.</p>	Not reported

Table 47: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Currie and Hawke (2020) Title: 'Ethical and legal challenges of artificial intelligence in nuclear medicine'	United States of America	Narrative Review	Nuclear Medicine & Molecular Imaging	<p>This review presents an overview of 'Ethical Principles for Artificial Intelligence in Nuclear Medicine' highlighting 16 Principles in Intelligent Imaging Ethics, including:</p> <p>Ethical domain</p> <ul style="list-style-type: none"> • Beneficence • Non-maleficence • Human values • Equity and equality • Autonomy <p>Legal domain</p> <ul style="list-style-type: none"> • Privacy and security • Mitigation of bias • Transparency • Accountability • Governance • Inclusiveness <p>Social domain</p> <ul style="list-style-type: none"> • Fairness and justice • Safety and reliability • Explain ability • Decision making • Collegiality 	Not reported

Table 48: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Davies, Wathen and Gleeson (2011) Title: 'The risks of radiation exposure related to diagnostic imaging and how to minimise them'	United Kingdom	Narrative with some evidence of literature searching	General	<p>This review outlines a range of strategies to minimise risks associated with radiation exposure. These include:</p> <ul style="list-style-type: none">• The use of guidelines• Calculating before you order using online tools (including apps) to help estimate the effective radiation dose• Reduce unnecessary computed tomography examinations using radiological guidelines• Where there is a lack of clarity, clinical decisions are supported by peers• Use other imaging techniques if possible and consider magnetic resonance imaging and ultrasound procedures• Standardise operating procedures for radiological examinations through the implementation of standard operating procedures• Use technological advances to increase safety by lower doses with signal detection.	Not reported

Table 49: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Degnan et al. (2018) Title: 'Perceptual and interpretive error in diagnostic radiology – causes and potential solutions'	United States of America	Narrative Review	General	<p>In this review, the authors highlight a range of solutions to address perceptual and interpretive errors in diagnostic radiology. These include:</p> <ul style="list-style-type: none"> • Mechanisms to Reduce Cognitive Error using cognitive Psychology Approaches – use of meta-cognition (reflective reasoning) in which individuals think about how a thought process occurred and led to a conclusion. • Use of double reading through the presence of a second reader viewing the study. • Use of error review and peer learning in which identifying and analysing errors, usually in individual peer review and group conference formats. • Having a just culture in which an organisational culture where patient safety is emphasized in conjunction with respect for individual physician's personal worth. • Strategies to Reduce Informational Error through improvements in technology and data capture and reporting. • Strategies for Fatigue Reduction included timed breaks to combat fatigue and increase productivity, and exercise and standing to counteract the fatigue and slowed metabolism that occurs during periods of sedentary behaviour. 	Limited evidence

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- **Addressing physiological and environmental factors** such as reading room ambient light, monitor luminance, workstation layout, room temperature and humidity, noise level and other miscellaneous ergonomic factors.
 - **Strategies to reduce distractions** include designated reporting and non-reporting radiologists and having access to a workstation with all tools required.
 - **Strategies to mitigate perceptual errors** including:
 - Error review using peer review
 - Shared quality improvement by sharing lessons learnt through meetings and other information sharing opportunities
 - Use of structured reporting and checklists as structured reporting organises findings into subheadings such as various organs imaged etc.
 - have access to perceptual training as it may improve observer performance on select tasks
 - Use of artificial intelligence to help identify meaningful patterns in imaging that humans cannot perceive.
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Table 50: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Docking and Haddock (2021) Title: 'Reducing diagnostic errors related to medical imaging'	Australia	Narrative review	General	<p>This review highlighted a range of strategies to reduce diagnostic errors related to the quality of medical imaging referrals. This included:</p> <ul style="list-style-type: none">• The inclusion of clinical information and the diagnostic question to be considered• Improving imaging referral appropriateness• Education of clinicians complemented with clinical decision support tools• Use of clinical decision support tools which can aid the appropriate use of imaging by using alerts or reminders to provide case-specific information at the point of care• The emergent role of artificial intelligence which may improve abnormality detection, characterisation of abnormalities, and monitoring abnormality change over time.	Some evidence in specific areas

Table 51: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
European Society of Radiology (2020) Title: 'Performance indicators for radiation protection management: suggestions from the European Society of Radiology'	Austria	Narrative review	General	<p>This paper supports using key performance indicators collected through continuous quality improvement strategies. Key performance indicators for radiation protection may include:</p> <ul style="list-style-type: none">• Compliance with appropriateness criteria - monitoring of the appropriateness rate, at least for high-dose studies, could be useful.• Retake rate – The frequency of retake rate could be a quality indicator.• Monitoring artefacts - detection of such artefacts and the impact in terms of limitation of significance or repetition rate may be a relevant quality indicator.• Monitoring imaging equipment – hardware, software, renewal rates etc.• Monitoring protective tools – availability and use of radiation protection clothing and equipment may also be used.• Indicators for personalised feedback - individualised observation and documentation of workflows are useful to promptly recognise any influences on the individual radiation exposure of equipment users.• Indicators for patient feedback – surveys regarding patients' feedback about availability and clarity of radiation protection information in radiology departments may be important. These surveys can provide information about patient knowledge, expectations and recommendations that may be helpful in reducing patient anxiety about radiation exposure and the management of radiation protection strategies in departments.	Some evidence in specific areas

Table 52: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
European Society of Radiology and European Federation of Radiographer Societies (2019) Title: 'Patient safety in medical imaging: a joint paper of the European Society of Radiology (ESR) and the European Federation of Radiographer Societies (EFRS)'	The Netherlands	Narrative review	General	<p>In this narrative review, the European Society of Radiology & European Federation of Radiographer Societies outlined quality improvement initiatives to promote patient safety in medical imaging.</p> <p>These include:</p> <ul style="list-style-type: none">• No blame culture and review of errors• Ongoing education through personal learning and departmental continuing professional development• Peer review opportunities for learning and promoting two-way communication• Evaluation of current practices and opportunities to change and improve those practices using clinical audits• External review which may optimise performance and safety standards• Risk management which is a group responsibility• Avoidance of fatigue and burnout through:<ul style="list-style-type: none">– Adequate staffing– Reducing stress out-of-hours obligation and isolation– Restoring a sense of control and lifestyle balance– Improving staff efficiency– Reducing,– Developing reasonable expectations and goals– Providing professional help	Some evidence in specific areas

-
- Promoting action by the radiology community and training in patient safety issues through education and training on patient safety.
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Table 53: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
French et al. (2010) Title: 'Interventions for improving the appropriate use of imaging in people with musculoskeletal conditions (Review)'	Australia	Systematic review	General	<p>In this systematic review, a range of interventions was reviewed to explore their effectiveness in improving the appropriate use of imaging in people with musculoskeletal conditions.</p> <p>For osteoporosis, any form of intervention was better than no intervention. When comparing interventions, patient mediated interventions (using patients to achieve change in healthcare) and reminders had the largest effect.</p> <p>Organisational interventions (such as case management and clinical multi-disciplinary team) had some effect.</p> <p>For low back pain, educational materials were reported to have limited evidence. For other musculoskeletal conditions, educational materials, educational meetings, audits and feedback had no evidence.</p>	Unclear which interventions are most effective or which combination has the largest effect.

Table 54: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Hannaford et al. (2013) Title: 'Learning from incident reports in the Australian medical imaging setting: handover and communication errors'	Australia	Narrative review	General	<p>In this narrative review, the authors provide learning from incident reports in medical imaging and highlight opportunities for improvement.</p> <p>First, issues with patient preparation due to inadequate handover of clinical information pertaining to patients and unsafe and inappropriate transfer of patients. This could be addressed through:</p> <ul style="list-style-type: none">• adoption of standards• staff education of standards to improve clinical handover and patient transfer• revision of handover and transfer policies to include the five rights of patient transfer (right time, right patient, right equipment and documentation, right level of supervision and right resources at the receiving end to adequately care for the patient. <p>Second, issues with a request for imaging can occur due to problems with the content of the request form and incorrect or inappropriate tests requested. This could be addressed by forcing functions for critical data to be embedded in all information technology systems and using clinical decision support tools for appropriate imaging.</p> <p>Third, delayed communication of diagnosis or communication of the wrong diagnosis can occur. This could be addressed by organisation-wide tracking systems for timely distribution and receipt of results and up to date policies regarding the release of interim, final and addenda to reports.</p>	Some evidence in specific areas

Table 55: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Itri et al. (2018) Title: 'Fundamentals of diagnostic error in imaging'	United States of America	Narrative review	General	<p>In this narrative review, the authors propose a range of strategies to address diagnostic errors in imaging, including:</p> <ul style="list-style-type: none">• Non-random peer reviews where peers identify cases with errors and share learning through a nonpunitive environment.• Tumour boards and multi-disciplinary conferences are a form of double reading in which another radiologist, often more experienced and with additional clinical information not available to the original interpreting radiologist, essentially reinterprets imaging studies in an interdisciplinary setting with the aim of refining the diagnosis and tailoring treatment/management.• Radiologic-Surgical and Radiologic- Pathologic Correlation• Reference to a standard (pathologic analysis or surgery) that allows identification of errors using a process that is more objective than peer review.• Re-interpretation of outside studies, which is a variation of double reading in which an imaging study performed outside of the institution is submitted for reinterpretation.• Patients and referring physicians can be valuable resources for identifying cases with diagnostic error.• Educational interventions such as educational strategies, missed case conferences, peer learning conferences etc.• Importance of a supportive, non-punitive culture.• Meta-cognition which is thinking about thinking.	Some evidence in specific areas

-
- The use of double reading which may reduce the impact and frequency of diagnostic errors, although evidence is not strongly supportive.
 - The use of deep learning which may be useful for pattern recognition, prediction, and retrospectively to identify diagnostic error for analysis and development of interventions.
 - Access to Infrastructure and support.
 - Information technology needs which can facilitate ready access to information, modifying standard reporting templates etc.
 - Training via access to educational activities such as workshops delivered by professional societies.
 - Shared leadership between hospital administrators and clinicians with the final goal in mind: practice improvement and high-quality patient care.
 - Incentivising participation through support with adequate resourcing and quarantined time.
-

Table 56: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Jabin et al. (2022) Title: 'A mixed-methods systematic review of the effectiveness and experiences of quality improvement interventions in radiology'	Australia	Systematic review	General	<p>In this systematic review, the authors reported on the effectiveness and experiences of quality improvement interventions in radiology. The findings were grouped across different categories, namely:</p> <p>Effect on system quality and safety - immediate and critical reporting resulted in a reduction of interpretive errors and increased compliance with standard protocols (n = 5 studies).</p> <p>Implementation of fall guidelines and a comprehensive patient safety program positively affected on safety culture and safety performance (n = 2 studies).</p> <p>Introduction of mobile radiography, which improved patient satisfaction by reducing the need for unnecessary patient transportation (n = 1 study)</p> <p>Effect on staff - effectiveness of staff training and education (interpersonal skills, simulation, and multifaceted educational training) resulted in improved patient satisfaction with nationally benchmarked indicators, contrast reaction management, teamwork skills, and awareness of hand hygiene (n = 3 studies).</p> <p>Experiences of staff and patients – four studies examined the staff experiences for different interventions: picture archiving and communication systems (mixed), mammography audit reports (customizable and web-based mammography audit reports were recommended), a drama workshop (communication, teamwork, trust, experience and education, self-awareness, and empathy were thought to create a better shared leadership team and to improve professional development), and shared leadership (improved</p>	Some evidence in specific areas

communication and teamwork were found to be the key factors).

The authors conclude by suggesting a range of strategies for further improvement, including:

- Stronger emphasis on existing quality improvement interventions as a basis for further improvements (n = 6 studies)
 - Improvement of staff performance (teamwork skills, task completion skills)
 - System improvement (reduction of infection risks, work improvement, operational efficiency)
 - Improvement in staff attitude and additional training
 - Picture archiving and communication system guidelines
 - Web-based reports
 - Introduction of new ideas.
-

Table 57: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Larson et al. (2015) Title: 'Key concepts of patient safety in radiology'	United States of America	Narrative review	General	<p>This review highlights a range of factors that could be used to improve patient safety in radiology, including:</p> <p>Human factors</p> <ul style="list-style-type: none"> • Maximise bottom-up processing by making displays clear and legible • Minimise visual clutter • Maximise top-down processing by presenting information in a consistent, familiar manner • Minimise the time and difficulty required to access information • When multiple information sources are necessary for a task, display them close together • Use redundancy for critical information • Capitalize on habits by maximising consistency. <p>Systems thinking - focus on overall patient care that recognises that the system operates in the larger environment.</p> <p>Communication - communication is a combination of</p> <ul style="list-style-type: none"> • Conveyance: unidirectional transmission of information from sender to receive • Convergence: bidirectional exchange of information to ensure that shared understanding has been achieved. 	Some evidence in specific areas

Use of guidelines to convey results promptly, support the radiologist's role as a consultant, and minimise the risk of communication error.

Teamwork – the importance of a coordinated teamwork.

Standardisation - standardisation can have a positive impact, although difficult in practice.

Making errors visible – an open acknowledgement of issues and use of visibility boards.

Daily management systems - provide a structure for leaders to assist and coach their teams to successfully solve problems on an ongoing basis, use:

- huddles
 - goals and metrics
 - daily readiness assessment
 - problem management
 - associated accountability.
-

Table 58: *Continued*

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Lee et al (2012) Title: 'Cognitive and system factors contributing to diagnostic errors in radiology'	United States of America	Narrative review	General	<p>This review calls for a multi-dimensional approach which includes a:</p> <p>Feedback system involving radiology-pathology correlation. This can be a useful mechanism to improve diagnostic accuracy</p> <p>Peer review that is continuous, systematic, and critical reflection and evaluation of physician performance using structured procedures. It can be beneficial but needs a strong culture as well</p> <p>Education is an important component with access to training programs, use of simulation and model patients, self-reflection, reasoning processes and formative feedback</p> <p>Information technology such as the use of new technology to track trends, outliers etc</p> <p>Structured reporting systems may improve the organization, content, readability, and usefulness of the radiology report and advance the efficiency and effectiveness of the reporting process</p> <p>Computer aided detection through clinical support decision tools may be useful, although the evidence is unclear</p> <p>Workload/fatigue that can be mitigated by instituting double reads, limiting the length of work shifts, establishing structured breaks, and switching between modalities during the workday.</p>	Some evidence in specific areas

Table 59: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Linnet et al. (2012) Title: 'Cancer risks associated with external radiation from diagnostic imaging procedures'	United States of America	Narrative review	General	<p>This narrative review summarised strategies to reduce radiation exposure. These include:</p> <p>Justification for the diagnostic procedure and that it is expected to do more good than harm.</p> <p>Optimisation whereby images are adequate for diagnosis and treatment while keeping the radiation dose as low as reasonably achievable. This can benefit from a protocol tailored to patient characteristics and diagnostic reference levels.</p> <p>Bringing together stakeholders to develop and share communication and strategies on the importance of reducing unnecessary radiation.</p>	Some evidence in specific areas
Malone et al. (2015) Title: 'Clinical imaging guidelines part 2: Risks, benefits, and solutions'	Global	Narrative review	General	<p>This narrative review had a particular focus on communication, with the authors highlighting:</p> <ul style="list-style-type: none"> • the importance of communicating risks to the patients • development of new protocols on who will give the information • how communication will be done • the need to check communication has been done • the need to invite feedback • the need for a risk-benefit dialogue underpinned by an informed decision-making process rather than mere passive provision of informed consent 	Some evidence in specific areas

Table 60: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Pinto et al. (2012) Title: 'Learning from errors in radiology: A comprehensive review'	Italy	Narrative review	General	<p>This narrative review highlighted learnings from errors in radiology. The authors highlight a range of strategies that could be considered to address this important issue. These include:</p> <p>Communication: Is critical to preventing dissatisfaction, preventing perceived medical errors/adverse outcomes, and dealing with adverse outcomes. Even if errors occur, good communication with patients, , can reduce the risk of litigation. Although how this occurs is unclear, and there is ongoing fear of increased litigation as apologising makes clinicians feel it is an admission of guilt.</p> <p>Assessment of accuracy: The most common frameworks are the conduct of professional audits and peer reviews, surveys, inspections, and risk management programs..</p> <p>Peer review: Is commonly used and nowadays automated with follow up meetings which provide opportunities for discussion and reflection. There is some evidence to indicate that this has a positive impact by reducing error rates.</p> <p>Educational and professional initiatives, including leadership, is important to creating and sustaining a strong safety culture.</p> <p>Implementing new tools such as checklists, clinical history prompts, and perceptual feedback and, more recently technologies such as digitally acquired images and computer-aided detection can assist this. Use of natural language processing and voice recognition software can be used to detect errors and discrepancies.</p> <p>Organisational culture of safety whereby the healthcare organisation is a learning environment to build and maintain a culture of safety.</p> <p>Error and reporting of near misses should be confidential without fear of blame.</p>	Some evidence in specific areas

Table 61: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Pow, Mello-Thomas and Brennan (2016) Title: 'Evaluation of the effect of double reporting on test accuracy in screening and diagnostic imaging studies: A review of the evidence'	Australia	Narrative with some evidence of literature searching	General	<p>This review evaluated the evidence regarding the effect of double reporting on diagnostic efficacy. Double reading was mainly investigated in mammography.</p> <p>This review used a recall rate to measure the effect of double reading. It refers to the percentage of screening studies for which further diagnostic investigation is recommended by the radiologist.</p> <p>The impact of double reporting on recall rate primarily depended on the reporting process. Relative to a single reading, consensus and arbitration policies were associated with a reduction in recall rate; 39–45% relative reductions are observed with consensus recall policies, with not dissimilar reductions being reported with arbitration (25–32%).</p> <p>Double reporting increases sensitivity and cancer detection rates. It improves the sensitivity of screening mammograms and therefore has been supported by several guidelines. It is standard practice in Australia and New Zealand breast cancer screening programs.</p> <p>Regarding cost effectiveness, it is difficult to compare studies due to heterogeneity between countries, target population, treatment strategies and healthcare costs. There is a paucity of paucity of Australian and New Zealand data evaluating the cost-effectiveness of double reporting.</p> <p>Similarly, compared to a diagnostic setting, screening setting might be more cost-effective as there is no formal report</p>	Some evidence in specific areas

required. Double reporting underpinned by consensus or arbitration might be the most cost-effective strategy.

Regarding Neuroradiology, thoracic, trauma, gastrointestinal imaging, and oncology, only small-scale studies were undertaken but findings were generally encouraging.

Double reporting can increase sensitivity and reduce specificity. Hence it is most useful in screening instances. Independent double reporting with arbitration or consensus of discordant reports appears to be the most efficacious and cost-effective strategy. Much of this research, however, has focussed on mammography.

Table 62: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Power et al. (2016) Title: 'Computed tomography and patient risk: facts, perceptions and uncertainties'	Ireland	Narrative review	Computed tomography	<p>This narrative review summarised dose reduction techniques when using computed tomography. These include:</p> <p>Tube current modulation and automatic exposure control: – The tube current should be modulated based on the overall attenuation of the anatomic area being assessed.</p> <p>Automatic exposure control: A relatively new technique that modulates the tube current during an individual scan based on the different attenuations of different anatomic regions. This has the advantage of delivering the optimal dose to achieve the optimal diagnostic image.</p> <p>Noise reduction filters: Can be used to optimise the quality of an acquired image by eliminating noise.</p> <p>Low dose protocols: In some instances, are not inferior to standard dose computed tomography.</p> <p>Spacing of computed tomography slices: By finding a balance between selecting a slice small enough to achieve the optimal diagnostic image and large enough to ensure the radiation dose delivered is acceptable.</p> <p>Maintaining the limits of the radiation field: Within the anatomy of interest by ensuring the field is maintained to only the area of interest to allow for smaller cumulative dosing and potentially improved images via focused imaging.</p> <p>Decision support: At the time of ordering a scan by using automated prompts and advice when ordering imaging can reduce low utility examinations.</p> <p>Split bolus protocols: Can significantly reduce the radiation burden that may arise from multiple image acquisition, especially for abdomino-pelvic computed tomography.</p>	Some evidence in specific areas

Table 63: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Sivarajah, Dinh, Chetlen (2021) Title: 'Errors in breast imaging: how to reduce errors and promote a safety environment'	United States of America	Narrative	General	In this review, the authors suggest that error mitigation tools can be summarized using the acronym SAFE: S – Support the team, A – ask questions, F – focus on task, E – effectively communicate, ensure equipment optimisation and safe environment.	Some evidence in specific areas

Table 64: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Thompson et al. (2021) Title: 'Patient-centred outcomes of imaging tests: recommendations for patients, clinicians and researchers'	United States of America	Multiple methods including scoping review	General	<p>Patient Reported Outcomes of Diagnostics research.</p> <p>This scoping review included 25 qualitative studies describing patient-centred outcomes. The review mainly focused on mammography and magnetic resonance imaging screening, mostly related to cancer screening. Patient-centred outcomes from imaging studies can be grouped within four main domains:</p> <p>Information or knowledge includes finding the cause of symptoms, reducing the probability of a condition that the patient is worried about, the value of knowing or finding out more whatever the outcome, decision making leading to action, false information from test results and incidental or indeterminate findings.</p> <p>Physical impact includes preparation for the test, physical discomfort and tolerability during the test, and longer term physical effects.</p> <p>Emotional outcomes include reassurance and relief, anxiety and worry, claustrophobia and embracement, lack of control, decisional regret, mismatch with expectations.</p> <p>Test burden includes financial costs of tests and disruption to work or social life.</p> <p>Factors that may modify patient-centred outcomes related to imaging tests include individual patient characteristics, test type (screening, diagnostic, monitoring), clinical situation, clinician and healthcare team, the imaging suite's physical environment and test result communication.</p>	Some evidence in specific areas

Table 65: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Waite et al (2017a) Title: 'Interpretive error in radiology'	United States of America	Narrative review	General	<p>This review summarises a range of non-technological and technological solutions for interpretive radiology.</p> <p>Non-technological solutions include</p> <ul style="list-style-type: none"> • structured reporting templates that may reduce inattention related errors • ergonomic optimisation through ergonomic setups such as optimal lighting, • reduction of physical stressors • interruption reduction through access to clinical data at the picture archiving and communication system workstation • caller ID etc. to screen calls • use of double reading, which while useful, can be costly and time consuming • peer review, • a non-punitive approach to quality improvement to promote shared responsibility and positive culture <p>Technological solutions include:</p> <ul style="list-style-type: none"> • perceptual feedback, where feedback on clinicians' dwell time (total fixation time) using eye-tracking technology has improved detection rates 	Some evidence in specific areas

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- attentional guidance, which involves presenting eye movements of one observer (such as an expert) to another observer (such as a novice), may improve performance
 - search strategies on how best to search and interpret images
 - bone subtraction techniques which involve suppressing overlying bone structures, which may increase lesion conspicuity and reduce surrounding anatomic noise
 - computer assisted detection which uses pattern recognition software that flags suspicious features on an image which a clinician then reviews.
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Table 66: *Continued*

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Waite et al. (2017b) Title: 'Systemic error in radiology'	United States of America	Narrative review	General	<p>In this narrative review, the authors suggest strategies to address systemic errors in radiology.</p> <p>Pre-procedure Phase Errors strategies include</p> <ul style="list-style-type: none"> • Implementation of imaging appropriateness criteria • Involvement of Radiologists in Choosing Examination Protocol • The use of computerised physician order entry can improve indication quality and decrease unnecessary duplicate imaging • The use of Clinical decision support systems, which are point-of-order decision aids that provide real-time feedback to providers/ referrers regarding test appropriateness for specific indications <p>Procedure Phase Errors strategies include:</p> <ul style="list-style-type: none"> • Time out procedures • Checklists • Verbally confirming the correct patient, location and procedure • Preventing medication errors in radiology through communication and coordination, documentation review • Risk-benefit analysis • Maintaining image quality by using standards • Quality assurance programs <p>Post-procedure Phase strategies include:</p>	Some evidence in specific areas

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- Adequate staff
 - Updates to technology such as IT systems and support
 - Optimising ergonomics
 - Double reading
 - A culture of support
 - A nonpunitive approach
 - Awareness
 - Proactive procedures
 - Monthly performance audits to address communication issues
 - Guidelines for standards of communication
 - Tools such as failure modes and effects analysis which identifies and addresses potential problems or failures and their resulting effects on the system before an adverse event occurs.
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Table 67: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Wang et al. (2017) Title: 'Reducing inappropriate lumbar spine MRI for low back pain: radiology support, communication and alignment network'	United States of America	Pre-Post	General	<p>This research aimed to evaluate the impact of educational sessions on reducing lumbar spine magnetic resonance imaging inappropriateness for uncomplicated low back pain.</p> <p>As part of the intervention, educational sessions included two sessions using video and audio formats across three clinics of 1 hour duration.</p> <p>The content was derived from ACR Appropriateness Criteria and non-radiological societies, including the Choosing Wisely campaign, the American College of Physicians, and the American Academy of Family Physicians.</p> <p>The presentations consisted of (1) the context and rationale of guideline implementation for low back pain, (2) select evidence from current literature regarding nonspecific low back pain and imaging, (3) guidelines and appropriate instances of LS (lumbar spine) imaging developed by non-radiological societies, and (4) interactive case-based vignettes to apply knowledge in commonly encountered clinical scenarios.</p>	<p>Reduction in the number of monthly magnetic resonance imaging orders from two clinics.</p> <p>Reduction in the combined magnetic resonance imaging ordered per month across all three clinics.</p> <p>The duration of time from when the patient initially saw a provider for low back pain to when the patient ultimately received a lumbar spine magnetic resonance imaging was significantly longer after educational sessions for each clinic.</p> <p>Similar findings were reported when assessing the combined average elapsed time from all three clinics..</p> <p>No difference in the physical therapy referrals or the time when a patient attends a physical therapy appointment.</p> <p>ACR Appropriateness Criteria rating for lumbar spine magnetic resonance imaging ordered by providers according to each clinic before and after educational sessions showed the average rating for magnetic resonance imaging made at clinic B was 5.7 after educational sessions, which was significantly higher than the rating of 4.0 before educational sessions.</p> <p>Findings were similar when combined for all three clinics, although for clinics A or C there was no significant difference.</p>

Table 68: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Weiser et al. (2013) Title: 'Imaging in childhood cancer: A society for paediatric radiology and children's oncology group joint task force report'	United States of America	Narrative review	General	<p>This narrative review summarised strategies for minimising exposure to ionising radiation from paediatric imaging studies. These findings include:</p> <ul style="list-style-type: none">• Checking if computed tomography is the optimal imaging modality (i.e., whether computed tomography is the appropriate modality for taking the image)• Optimise equipment for paediatrics• Adjust exposure settings based on child size and organ(s) being imaged• Scan the smallest necessary area• Question if higher quality/resolution images are necessary• Follow 'as low as reasonably achievable' principles• Review educational materials and quality assurance initiatives.	Some evidence in specific areas

Table 69: Continued

Study / Document	Country	Type	Profession	Intervention (including parameters)	Evidence of effectiveness
Wilson et al. (2019) Title: 'Guidelines for the safe provision of anaesthesia in magnetic resonance units 2019'	United Kingdom	Narrative review	Magnetic Resonance	<p>There is an increase in the number of units providing anaesthesia for magnetic resonance imaging and the type of intervention performed within the magnetic resonance imaging environment. These guidelines inform anaesthetists and the multidisciplinary team about safety aspects and best practices relating to anaesthesia within the magnetic resonance imaging environment.</p> <p>From a service organisation and training point of view, the following strategies were reported:</p> <ul style="list-style-type: none"> • All hospitals providing a service for anaesthesia within the MRI unit should have a lead anaesthetist responsible for the provision of anaesthesia for magnetic resonance imaging. • Training should be provided for all grades of anaesthetists delivering anaesthesia in a magnetic resonance imaging unit, and the anaesthetists should understand the hazards involved in anaesthetising a patient in the magnetic resonance imaging unit. • Anaesthesia/sedation for a patient needing a magnetic resonance imaging scan, including intensive care unit patients, should consider the patient's pathophysiological status and the remote location of the magnetic resonance imaging unit. • Whenever possible, anaesthesia in remote sites should be provided by appropriately experienced consultants. • When care is delegated to a trainee or Specialty and Associate Specialist doctor, they should have the appropriate competencies and level of training. • It is not acceptable for inexperienced staff, unfamiliar with the magnetic resonance imaging environment, to manage a patient in this environment, particularly out-of-hours. 	Some evidence in specific areas

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- Patients must be accompanied to the scanner by appropriately trained staff members, and if an anaesthetic machine is used, then the anaesthetist should be supported throughout by an anaesthetic assistant who should be suitably skilled, trained, and familiar with the anaesthetic requirements.

From a Patient and staff safety point of view, the following strategies were reported:

- All patients and staff are screened for the presence of implants and devices that may be a contraindication to a safe scan. The referring team should discuss the safety of the devices with the magnetic resonance imaging Responsible Person and the anaesthetist to plan a suitable management strategy.
 - Anyone remaining in the scanning room is provided with ear protection during scanning.
 - Magnetic resonance imaging for patients is only undertaken when the diagnostic benefit outweighs the risk. This discussion must involve the multidisciplinary team, particularly for a patient in the intensive care unit.
 - The magnetic resonance imaging safety checklists for general anaesthesia, intraoperative magnetic resonance imaging and for transfer of intensive care unit patients should be used in conjunction with the World Health Organization checklist.
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Question 4: What areas of diagnostic imaging have unwarranted variation?

Table 70: Data extraction table for Question 4

Study / Document	Country	Type of research	Profession	Key findings
Halliday et al (2020) Title: 'Radiology GIRFT Programme National Speciality Report'	United Kingdom	Audit	General	Identified a lack of available services in radiology despite rising numbers of examinations and treatments. Significant delays in imaging, particularly computed tomography and magnetic resonance imaging. Delays in reporting results and patient ongoing treatment.
Kjelle et al (2021) Title: 'Interventions to reduce low-value imaging a systematic review of interventions and outcomes'	Norway	Systematic review	General	An estimated 20-50% of imaging is low value. Targeted studies included computed tomography, magnetic resonance imaging and contrast studies. It identified low value examinations related to bronchiolitis, pulmonary embolism, head injury and low back pain imaging.
Public Health England (2017) Title: 'The second Atlas of Variation in NHS Diagnostic Services in England'	United Kingdom	Audit	General	The report identified variations in available diagnostic services in geographic areas across England considered warranted and unwarranted variations in availability.

Table 71: Continued

Woznitza et al (2021) Title: 'Clinical reporting of radiographs by radiographers: Policy and practice guidance for regional imaging networks'	United Kingdom	Narrative review	General	<p>The immediate reporting by radiographers has been shown to improve patient pathways by shortening the time to diagnosis.</p> <p>Across the United Kingdom, 97% of departments have radiographer reporting; however the number and types of examinations vary.</p> <p>Radiographers with correct training are entitled to refer for imaging examinations as part of their scope of practice.</p> <p>All clinical reports include the reporting radiographer's name, job title, and Health and Care Professions Council registration number. It was suggested an email address be included for ease of communication.</p> <p>Preceptorship and peer learning to assist with continuing professional development.</p> <p>Volume and frequency of reporting are important for continuing high standards of reporting.</p> <p>Explains the North Central and East London framework and standards for implementing and maintaining a radiographer reporting network.</p>
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Question 5: What improvements can address unwarranted variation?

Table 72: Data extraction table for Question 5 (commercially produced and grey literature)

Study / Document	Country	Type of research	Profession	Key findings
Badcock et al (2015) Title: 'Monitoring of Clinical Imaging Guidelines Part 3: Norms, Standards, and Regulations'	Multi-country	Narrative review	General	Suggestions for monitoring clinical imaging guidelines <ul style="list-style-type: none"> • Availability of guidelines • Use of guidelines by referring healthcare professional and radiologist and other imagers • Guideline implementation, audit, review and revision
Docking and Haddock (2021) Title: 'Reducing diagnostic errors related to medical imaging'	Australia	Narrative review	General	Recommendations to improve the use of diagnostic imaging <ul style="list-style-type: none"> • Improve quality of referrals • Appropriateness of referral (education, clinical decision support tools) • Electronic health records • Structured imaging reports
French et al (2010) Title: 'Interventions for improving the appropriate use of imaging in people with musculoskeletal conditions (Review)'	Australia	Cochrane review	General	Improving the appropriate use of imaging for musculoskeletal conditions. N = 28 primary studies Most studies evaluated interventions designed to change health professional behaviour, for example, the distribution of educational materials, reminders to health professionals and patient education.

Table 73: Continued

Study / Document	Country	Type of research	Profession	Key findings
Hofman, Andersen and Kjelle (2021) Title: 'Visualizing the Invisible: Invisible Waste in Diagnostic Imaging'	Norway	Narrative review	Diagnostic imaging	<p>Unwarranted variation is wasteful imaging.</p> <p>External drivers of wasteful imaging:</p> <ul style="list-style-type: none">• New radiological technology• People's demands• Clinician's intolerance of uncertainty• Expanded clinical indication• Availability. <p>Internal drivers of wasteful imaging:</p> <ul style="list-style-type: none">• A strong belief that imaging reveals the physical truth• Increased reliance on technological tests• A belief that having an image taken is always a good thing• Patients believe that more testing is better• Being more afraid of ignoring than of overdoing• Protection against litigation.

Table 74: Continued

Study / Document	Country	Type of research	Profession	Key findings
Kjelle 2021 Title: 'Interventions to reduce low-value imaging—a systematic review of interventions and outcomes'	Norway	Systematic review	General	<p>N = 95 primary studies</p> <p>Guidelines (n = 28) and education (n = 28), either alone or combined with other measures, were the most common interventions evaluated to reduce low-value imaging. The outcome measures reported in the included studies varied, with the number or rate of imaging examinations (n = 75) being the most frequently reported primary outcomes. Most studies (n = 61) used a single component intervention and most studies (n = 90) targeted referring physicians.</p> <p>The review provides an overview of:</p> <ul style="list-style-type: none">• Participants exposed to the intervention (referring physicians, imaging staff, patients and/or family members)• Types of interventions• Combinations of components in multi-component interventions
Mendelson (2020) Title: 'Diagnostic imaging: Doing the right thing'	Australia	Narrative review	General	<p>Ways to improve appropriateness:</p> <ul style="list-style-type: none">• Education of referrers• Improving the imaging specialist's role as a consultant and gatekeeper• Evidence and consensus based imaging referral guidelines• Remuneration models for diagnostic imaging• Involvement of patient in decision-making

Table 75: Continued

Study / Document	Country	Type of research	Profession	Key findings
Halliday et al (2020) Title: 'Radiology: GIRFT Programme National Specialty Report'	United Kingdom	Report	General	Unwarranted variation <ul style="list-style-type: none">• Consumables• Outsourced reporting services• Equipment Recommendation Trusts should work with NHS partners to enable improved procurement of services, devices and consumables through cost and pricing transparency, aggregation and consolidation, and by sharing best practice. (specific actions on p.72)
Public Health England (2017) Title: 'Reducing unwarranted variation to improve health outcomes and value'	United Kingdom	Report	General	The report is on reducing unwarranted variation. <ul style="list-style-type: none">• Shift the provision of care closer to patients' homes, and reduce the burden and dependence on secondary and acute care services.• Separate the local acquisition of some images from remote reporting. In this way, a local service can be provided to patients without the necessity for the reporting clinician to be on the same site.

Table 76: Continued

Study / Document	Country	Type of research	Profession	Key findings
The Royal Australian and New Zealand College of Radiologists (2020) Title: 'Standards of Practice for Clinical Radiology'	Australia	Standards of practice	Diagnostic Imaging (general)	<p>Depending on the scope of medical imaging services, a practice is expected to meet the generic requirements (Sections 1 to 9) and any specific modality requirements (Sections 10 to 17).</p> <p>Section 1 – 9:</p> <ul style="list-style-type: none">• Practice Management system• Facilities• Equipment• Personnel• Professional Supervisor• Safety• Patient Management• Teleradiology• Artificial Intelligence <p>Section 10 – 17:</p> <ul style="list-style-type: none">• Bone Mineral Density• Computed Tomography• General X-ray• Interventional radiology• Magnetic resonance imaging• Mammography• Nuclear Medicine• Ultrasound

Table 77: Continued

Study / Document	Country	Type of research	Profession	Key findings
Woznitza et al (2021) Title: 'Clinical reporting of radiographs by radiographers: Policy and practice guidance for regional imaging networks'	United Kingdom	Narrative review	General	Outlined 22 standards to minimise unwarranted variation in radiographer reporting.

Table 78: Data extraction table for Question 5 (Coroner's reports)

Document	Summary of Coroner's report	Outcome / Recommendation in the Coroner's report
Coroners court of Queensland 2020	Report of a patient that deteriorated and died post T12 epidural injection	<p>Inappropriate monitoring and management of a deteriorating patient</p> <p>Findings</p> <ul style="list-style-type: none">• Not compliant with the Royal Australian and New Zealand College of Radiologists standards: Inadequate equipment (no defibrillators or large volumes of intravenous fluids)• Breach code of conduct (Medical Radiation Practice Board of Australia)• The clinician involved is not to perform specific procedures relevant to this case until they have completed relevant training. <p>Recommendations</p> <ul style="list-style-type: none">• The Royal Australian and New Zealand College of Radiologists to amend the standards of practice (require specific monitoring for specific procedures) and require radiologists performing contrast and sedation to hold cardiopulmonary resuscitation certification to provide advanced life support• Implement the following procedures<ul style="list-style-type: none">– A nurse to be present at all times, including during procedures and patient recovery– Purchase and utilise electrocardiogram and pulse oximeter to monitor the patient for 60 minutes in recovery– A nurse to regularly check and stock audits of resuscitation drugs– Availability of defibrillator in the recovery room

Table 79: Continued

Document	Summary of Coroner's report	Outcome / Recommendation in the Coroner's report
Coroners court of Victoria 2021	Report of a patient had a computed tomography (CT) scan that was unindicated, patient had an anaphylactic reaction to the contrast dye that was poorly managed and causally contributed to the patient's death	<p>Substandard clinical judgement from doctors resulted in the patient's death</p> <p>Recommendations</p> <ul style="list-style-type: none"> • Professional bodies to amend standards and guidelines • Implement mandatory requirements for training on severe contract reactions and anaphylaxis • audit all Australian accredited diagnostic imaging practice regards their compliance • Standardise referral practices • Consider the scope of practice of radiographers, including training in the preparation and administration of medication appropriate to their practice.
Coroners court of Victoria 2020	Patient died from ruptured aortic aneurysm	<p>No unwarranted variation identified</p> <p>Recommendation</p> <ul style="list-style-type: none"> • Improve clarity of referral criteria • For the involved private radiology practice to remind their radiologists of their obligations to contact referring doctors directly to discuss any significant unexpected, urgent or critical clinical radiology findings
Coroners court of Victoria 2017	Died from natural causes, being complications of a left tentorial meningioma	<p>No unwarranted variation identified.</p> <p>Recommendation</p> <ul style="list-style-type: none"> • Develop guidelines about incidental meningiomas reporting so that the reporting radiologist is required to make a specific recommendation to the referring doctor regarding appropriate follow up.

Table 80: Continued

Document	Summary of Coroner's report	Outcome / Recommendation in the Coroner's report
Coroners court of Victoria 2016	Found the medial management was reasonable and appropriate	No unwarranted variation identified. Recommendation <ul style="list-style-type: none">• Need to provide clarity about the obligation of a radiologist to report back to the referring doctor
Coroners court of Queensland 2015	4 year old child died following ingesting batteries	Recommendations <ul style="list-style-type: none">• The Royal Australian and New Zealand College of Radiologists develop an algorithm for early clinician notification.• The Australian Health Practitioner Regulation Agency raise awareness of emerging product safety issues.
Coroners court of Victoria 2015	Administration of radiographic contrast contributed to patient's death. Background of acute on chronic renal failure.	Comment: It is the radiographer's responsibility to obtain sufficient information to enable a proper judgement to be made as to any attendant risk to the patient.

Question 6: What standards operate nationally and internationally for diagnostic imaging and what do the standards address?

Table 81: Data extraction table for Question 6 (International standards)

Study / Document	Country	Type of research	Profession	Key findings
American Society of Radiologic Technologists (ASRT) (2021) Title: 'The ASRT Practice Standards for medical imaging and radiation therapy'	United States of America	Practice Standards	General	<p>Practice standards issued by the American Society of Radiologic Technologists to guide the medical imaging (and radiation therapy) profession to evaluate the quality of practice service and education provided within the profession. These practice standards detail 13 standards:</p> <ul style="list-style-type: none"> • Assessment • Analysis/Determination • Education • Performance • Evaluation • Implementation • Outcomes Measurement • Documentation • Quality • Self-Assessment • Collaboration and Collegiality • Ethics • Research, Innovation and Professional Advocacy

Table 82: Continued

Study / Document	Country	Type of research	Profession	Key findings
Canadian association of Medical Radiation Technologists (n.d.)	Canada	Guidelines on <i>patient safety</i> and <i>quality of care</i>	Medical Imaging / Nuclear Medicine	<p>Best Practice Guidelines provide quick reference notes on patient safety and quality of care. These guidelines are categorised into:</p> <ul style="list-style-type: none">• Core guidelines apply to all disciplines of medical radiation and those that are discipline specific.• Patient safety guidelines address general safety, radiation safety, magnetic resonance imaging safety and patient safety incidents.• Quality of care guidelines address appropriate care, adapting care, complex patients, and quality assurance.
Chawla et al (2019) Title: 'Canadian Association of Radiologists (CAR) position statement on point-of-care ultrasound'	Canada	Position Statement	Ultrasound	<p>To ensure patient safety and promote the appropriate use of imaging technology, the Canadian Association of Radiologists position is that patients must have access to appropriate, high-quality ultrasound services delivered by providers who have received training commensurate with existing jurisdictional regulations.</p> <p>Ultrasound is highly operator dependent; experience plays a critical role in the developing the interpretive and examination performance skills. If practitioners of point of care ultrasound extend their scanning beyond the scope of their usual practice, there is an increased risk of an adverse outcome for patients.</p> <p>Therefore, it is imperative that the ultrasound training received by a point of care ultrasound imager is equivalent to that of a qualified imaging specialist in their chosen field of expertise.</p>

Table 83: Continued

Study / Document	Country	Type of research	Profession	Key findings
College of Radiographers and Royal College of Radiologists (2021) Title: 'Quality standards for imaging'	United Kingdom	Standard	General (all)	<p>Quality standards for imaging aim to improve the quality of care for people attending an imaging service. It is designed for use within a service to achieve quality improvement, patient experience and involvement, and accreditation.</p> <p>The quality standards for imaging sets out best practices to improve patient care and outcomes and a minimum for the standard, i.e., benchmark. The quality standards are structured to address the generic quality standards that apply to all imaging services. In addition, there are specific additional quality standards for five modalities that must also be met where applicable (i.e. computed tomography, interventional radiology, magnetic resonance imaging, nuclear medicine and molecular imaging, and ultrasound).</p>
Crownover and Bepko (2013) Title: 'Appropriate and safe use of diagnostic imaging'	United States of America	Narrative review	General	<p>This paper highlights the increased use of imaging procedures and increased exposure to ionising radiation resulting in a need for greater awareness and public safety.</p> <p>The authors present information on average effective radiation doses from various medical imaging procedures. In addition, this paper describes the appropriate use of different imaging modalities for specific clinical scenarios.</p>
Dalili et al (2021) Title: 'Musculoskeletal ultrasound imaging standards in the UK: British Society of Skeletal Radiologists (BSSR) position statement'	United Kingdom	Position Statement	Ultrasound	<p>The Musculoskeletal Ultrasound profession has developed significantly over recent years. Many of the duties now undertaken by non-radiologists are tasks that radiologists previously performed.</p> <p>However, the quality of the service provided to patients remains paramount. Standardised training, practices and competencies are required to deliver a high-quality musculoskeletal ultrasound service.</p> <p>The statement has specific recommendations for action for both musculoskeletal ultrasound delivered by a radiologist and a non-radiologist.</p>

Table 84: Continued

Study / Document	Country	Type of research	Profession	Key findings
European Society of Radiology (2017) Title: 'ESR concept paper on value-based radiology'	Europe	Statement paper	General	<p>This paper highlights the increasing difficulties in the economic management and demand on healthcare systems. Factors such as the ageing population, demand for high-quality treatment and ongoing economic crisis threatens the maintenance and support of high-quality healthcare.</p> <p>This paper presents the concept of 'value-based healthcare' instead of volume-based healthcare. Furthermore, the European Society of Radiology has established a working group to develop a definition and conceptual framework for value-based radiology and explore the role of the ESR in supporting value-based radiology in Europe.</p> <p>The European Society of Radiology proposes this will be achieved through evaluation of key areas such as:</p> <ul style="list-style-type: none">• Appropriateness of requests• Attention to radiation protection measures• Characteristics of the reports (correct, complete, well-understandable, structured and properly used)• Relationships between patients and radiology personnel• Continuous professional education, research and innovation.

Table 85: Continued

Study / Document	Country	Type of research	Profession	Key findings
European Society of Radiology (2019) Title: 'How to manage accidental and unintended exposure in radiology: an ESR white paper'	Europe	Statement paper	General	<p>This paper addresses radiation safety in diagnostic and interventional radiology, specifically regarding Directive 2013/59/EURATOM (EU-BSS). Since 2018 all EU member states were required to implement a system to record and analyse all accidental or unintended medical exposures (Article 63). This was a new challenge as many EU member states neither have definitions of accidental and unintended exposures nor recognition of reporting criteria.</p> <p>Through this paper, the European Radiologic Society aims to assist national scientific organisations in advising their national regulators and authorities on how to provide simple and practical information to meet this directive.</p> <p>The European Radiologic Society recommends the reporting criteria for significant events are based on physical quantities and units and not on effective doses or text-based criteria like 'significantly different'. Furthermore, the European Radiologic Society encourages software vendors to develop affordable dose management systems that meet the basic requirements of the national reporting criteria.</p>
European Society of Radiology (2020) Title: 'Position statement and best practice recommendations on the imaging use of ultrasound from the European Society of Radiology ultrasound subcommittee'	Europe	Statement paper	Ultrasound	<p>This document aims to summarise best practice recommendations for using ultrasound in Europe. This paper is a consensus statement from the Ultrasound subcommittee of the European Society of Radiology, the European Union of Medical Specialists Section of Radiology, and the European Federation of Societies for Ultrasound in Medicine and Biology.</p> <p>The key findings of this statement paper are:</p> <ul style="list-style-type: none">• Adequate and continuous training in ultrasound is essential to provide quality examinations.• Documentation of ultrasound images in a picture archive and communication system must be ensured.• Hygienic measures must be implemented to prevent contamination.• Radiologists must take a leading role in training and governance of ultrasound in clinical practice.

Table 86: Continued

Study / Document	Country	Type of research	Profession	Key findings
Imaging Services Accreditation Scheme (2017) Title: 'The Imaging Services Accreditation Scheme Standard: statements, rationales and criteria'	United Kingdom	Standard	Diagnostic Imaging (excludes non-imaging aspects of Nuclear Medicine and asymptomatic breast screening services)	<p>This standard was published by the Joint Accreditation Scheme Committee of the College of Radiographers and The Royal College of Radiologists. The standard is a benchmark against which service delivery can be evaluated to drive quality improvement. It can be used to improve standards outside of the formal accreditation process (by the United Kingdom Accreditation Service) and form the basis for formal accreditation. The standard can be applied to any organisation performing radiological procedures or providing teleradiology.</p> <p>The standard is comprised of the following domains:</p> <ul style="list-style-type: none">• Leadership and Management• Clinical Domain• Facilities, Resources and Workforce Domain• Patient Experience Domain• Safety Domain

Table 87: Continued

Study / Document	Country	Type of research	Profession	Key findings
International Accreditation New Zealand (2020) Title: 'General Criteria for Accreditation: New Zealand Code of Radiology Management Practice'	New Zealand	Practice standards (general criteria for accreditation)	Radiology	<p>This Code provides requirements for competence and quality that are particular to radiology services. This Code is for use by radiology services in developing their management systems and assessing their competence, and for use by International Accreditation New Zealand in confirming or recognising the competence of radiology services. Broadly, the Code outlines requirements across two categories: management and technical requirements. Management requirements outline a range of requirements specific to the service or the organisation of which the radiology service is a part. Management requirements broadly include organisation and management, management system, document control, review of contracts, examination by subcontractor radiology services, external services and supplies, advisory services, resolution of complaints, identification and control of nonconformities, corrective action, preventive action, continual improvement, quality and technical records, internal audits, and management review.</p> <p>Technical requirements outline a range of requirements for the technical aspects across the structure, process, and outcomes of care. Technical requirements broadly include:</p> <ul style="list-style-type: none">• Personnel• accommodation and environmental conditions• radiology equipment• pre-examination procedures• examination procedures• assuring quality of examination procedures• post-examination procedures• reporting of examinations.

Table 88: Continued

Study / Document	Country	Type of research	Profession	Key findings
Kanal et al (2013) Title: 'ACR Guidance Document on MR Safe Practices: 2013'	United States of America	Guideline	Magnetic resonance imaging	<p>Due to the potential safety risks associated with magnetic resonance imaging (MRI), an expert panel was formed to establish and publish guidelines on MRI safety (original guidelines published in 2002).</p> <p>These guidelines have since been reviewed and updated (2004, 2006-2007).</p> <p>These guidelines were issued in 2013 by the American College of Radiology with the purpose of magnetic resonance imaging facilities using them to develop an MRI safety program.</p> <p>The program would consider clinical diagnostic imaging, research, and interventional and intraoperative magnetic resonance imaging applications in the following key areas:</p> <ul style="list-style-type: none">• Establish, implement, and maintain current magnetic resonance imaging safety policies and procedures• Static magnetic field issues: Site access restriction• Magnetic resonance imaging technologist• Pregnancy related issues• Paediatric magnetic resonance imaging safety concerns• Time varying gradient magnetic field related issues:<ul style="list-style-type: none">– Induced voltages– Thermal– Auditory considerations

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- Drug delivery patches and pads
 - Cryogen-related issues
 - Claustrophobia, anxiety, sedation, analgesia and anaesthesia
 - Contrast agent safety
 - Patients in whom there are or may be intracranial aneurysm clips, cardiac pacemakers or implantable cardioverter defibrillators
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Table 89: Continued

Study / Document	Country	Type of research	Profession	Key findings
Nhyssen et al (2017) Title: 'Infection prevention and control in ultrasound – best practice recommendations from the European Society of Radiology Ultrasound Working Group'	Europe	Guideline	Ultrasound	<p>This paper highlights the importance of infection prevention and control in ultrasound.</p> <p>National guidelines, regulations and legislation for decontamination vary throughout Europe, specifically on transducer decontamination, choice of ultrasound gel and transducer covers procedures.</p> <p>The evidence shows that adequate protocols and staff training can achieve efficient disinfection and contribute to improvements in patient safety. Key findings:</p> <ul style="list-style-type: none">• Transducers must be cleaned/disinfected before first use and after every examination.• Low-level disinfection is sufficient for standard ultrasound on intact skin.• High-level disinfection is mandatory for endo-cavity ultrasound and all interventions.• Dedicated transducer covers must be used for endo-cavity ultrasound and all interventions.• Sterile gel should be used for all endo-cavity ultrasound and all interventions.
New Zealand Medical Radiation Technologists Board (2018) Title: 'Policy: Competence standards for medical imaging and radiation therapy practitioners in Aotearoa New Zealand'	New Zealand	Competence standards	Medical Radiation	<p>Competence standards are issued by New Zealand Medical Radiation Technologists Board to ensure patient safety through standards for medical radiation practitioner's education and competence.</p> <p>There are five domains within the standards:</p> <ul style="list-style-type: none">• Professional and Ethical Conduct• Communication and Collaboration• Evidence-Based Practice and Professional Learning• Safety of Practice and Risk Management• Medical Imaging/Radiation Therapy (including the following scope of practice subsets: Medical Imaging Technologist, Nuclear Medicine technologist, Radiation Therapy Technologist, Sonographer, MRI Technologist).

Table 90: Continued

Study / Document	Country	Type of research	Profession	Key findings
Ministry of Health (2018) Title: 'Code of Practice for Diagnostic and Interventional Radiology: ORS C1'	New Zealand	Practice standards (which also includes some practitioner standards)	Diagnostic and Interventional Radiology	<p>This Code of Practice for Diagnostic and Interventional Radiology outlines all activities associated with:</p> <ul style="list-style-type: none">• radiological equipment used for diagnostic radiology and image-guided interventional procedures• radiological equipment used for diagnostic investigations of medical research programs and• cone beam computed tomography equipment used for dental purposes.• Broadly, the code outlines roles and responsibilities across three categories:<ul style="list-style-type: none">– Managing entity, the broad areas of responsibilities include general aspects, safety assessment, facilities, equipment, training and authorization, policies, procedures, and local rules, patient dosimetry, monitoring and measurement, incidents, accidents and emergencies, records, and quality assurance.– Radiation practitioner, the broad areas of responsibilities include general aspects, justification, and optimisation.– Other parties(referring practitioner, manufacturer/supplier, and servicing engineer)., the broad areas of responsibilities include providing sufficient information and cooperation between practitioners (for referring practitioners), supply well-designed, well-manufactured and well-constructed radiological equipment along with sharing of user experience (for manufacturer and supplier) and installing and servicing of equipment competently as well as cooperation and communication with managing entity (for servicing engineer).

Table 91: Continued

Study / Document	Country	Type of research	Profession	Key findings
Royal College of Radiologists and the Society and College of Radiographers (2014) Title: 'Standards for the provision of an ultrasound service'	United Kingdom	Standard	Ultrasound	<p>This document aims to set standards in key areas essential for delivering high-quality and effective ultrasound imaging services and examinations.</p> <p>The key areas covered are:</p> <ul style="list-style-type: none">• ultrasound equipment• training and education• examination specific standards• ultrasound examination report• auditing of ultrasound practice• report quality• image management.

Table 92: Continued

Study / Document	Country	Type of research	Profession	Key findings
Watson and Odle (2013) Title: 'Patient Safety and Quality in Medical Imaging: The Radiologic Technologist's Role'	United States of America	White paper	General	<p>The American Society of Radiologic Technologists recognises that radiologic technologists/medical imaging professionals have a critical role in enhancing patient safety for medical imaging procedures. This paper identifies the current challenges associated with the medical imaging profession and discusses the desired state/best practice regarding these key areas:</p> <ul style="list-style-type: none">• Workplace and Staffing Best practice:<ul style="list-style-type: none">– Medical imaging departments develop staffing policies and procedures that facilitate safe patient care.– Efforts focus on better facilitating radiologist/radiologic technologist collaboration on care, feedback and quality improvement.• Technology Gaps Best practice:<ul style="list-style-type: none">– Medical imaging departments provide effective and efficient applications training for new and upgraded medical imaging equipment.– Recognise that multivendor environments introduce new layers of complexity and require cooperation among vendors and management.• Workplace Culture Best practice:<ul style="list-style-type: none">– Medical imaging departments have quality management processes in place; vendors provide documentation and analysis tools that management uses effectively.– Radiologic technologists are educationally prepared, clinically competent and certified in their respective modalities• Best practice<ul style="list-style-type: none">– Vendors and managers collaboratively develop a detailed training agreement that outlines both parties' expectations before finalizing a medical imaging equipment purchase.

Table 93: Continued

Study / Document	Country	Type of research	Profession	Key findings
Woznitza et al 2021 Title: 'Clinical reporting of radiographs by radiographers: policy and practice guidance for regional imaging networks'	United Kingdom	Narrative Review	General	<p>Recent research estimates that radiographer reporting occurs in 97% of imaging departments. However, there is significant variation in the number of examinations reported by radiographers.</p> <p>Reducing variation improves quality assurance.</p> <p>The purpose and scope of this policy guidance is to:</p> <ul style="list-style-type: none">• Outline consistent clinical governance standards for clinical reporting of radiographs by reporting radiographers for regional imaging networks• Provide a shared framework for implementation within regional healthcare networks (Sustainability and Transformation Partnerships and Integrated Care Systems)• Inform relevant imaging managers, clinical directors, clinical governance leads and others with oversight of best practice in radiographer reporting• Remove unwarranted variation in radiographer reporting practice; improve consistency, provide opportunities to improve quality and patient experience through shared audit and governance processes <p>22 standards were identified to help reduce unwarranted variation.</p>
Zaidi (2010) Title: 'Accreditation standards for medical imaging services'	India	Commentary	General	<p>Rapid changes in the Indian healthcare system have increased the demand for quality healthcare services. The National Accreditation Board for Hospital and Healthcare Providers was set up under the Quality Council of India to establish and operate accreditation programs for healthcare organisations. A basic accreditation program has been introduced in India to assess the quality and safety of imaging services and monitor quality standards.</p>

Table 94: Data extraction table for Question 6 (Australian standards)

Study / Document	Country	Type of research	Profession	Key findings
Australasian Association of Nuclear Medicine Specialists (2019) Title: 'Australasian Association of Nuclear Medicine Specialists: Code of Conduct'	Australia	Code of conduct	Nuclear Medicine	The code of conduct sets out principles to guide nuclear medicine specialists: <ul style="list-style-type: none">• in the provision of quality medical and imaging services to their patients• on how to conduct their relationships with patients, colleagues and members of the community• to reinforce the importance of maintaining the integrity and good reputation of the profession of nuclear medicine.
Department of Health (2016) Title: 'Diagnostic Imaging Accreditation Scheme'	Australia	Practice Accreditation Standards	General	The Diagnostic Imaging Accreditation Scheme ensures safety and quality for diagnostic imaging practices. These standards address four main areas: <ul style="list-style-type: none">• Organisational standards• Pre-procedure standards• Procedure standards• Post-procedure standards

Table 95: Continued

Study / Document	Country	Type of research	Profession	Key findings
Medical Radiation Practice Board; AHPRA (2014) Title: 'For medical radiation practitioners: Code of Conduct'	Australia	Code of conduct	General	<p>The code contains important standards for practitioner behaviour concerning:</p> <ul style="list-style-type: none">• Providing good care, including shared decision making• Working with patients or clients• Working with other practitioners• Working within the healthcare system• Minimising risk• Maintaining professional performance• Professional behaviour and ethical conduct• Ensuring practitioner health• Teaching, supervising and assessing• Research. <p>Appendix A of the Medical Radiation Practice Board of Australia code of conduct describes the specific provisions for medical radiation practitioners grouped under providing good care, effective communication and radiation protection.</p>
Medical Radiation Practice Board; AHPRA (2020) Title: 'Professional capabilities for medical radiation practitioners'	Australia	Professional Capabilities	Medical Imaging, Nuclear Medicine	<p>The professional capabilities document describes minimum/threshold capability requirements to practise safely and competently as a medical radiation practitioner within Australia. The Medical Radiation Practice Board of Australia is a statutory regulator of medical practitioners. This document is also used alongside the Medical Radiation Practice accreditation standards to accredit education providers and medical radiation programs of study.</p>

Table 96: Continued

Study / Document	Country	Type of research	Profession	Key findings
The Royal Australian and New Zealand College of Radiologists (2020) Title: 'Standards of Practice for Clinical Radiology'	Australia	Standards of practice	Diagnostic Imaging (general)	<p>Depending on the scope of medical imaging services, a practice is expected to meet the generic requirements (Sections 1 to 9) and any specific modality requirements (Sections 10 to 17).</p> <p>Section 1 – 9:</p> <ul style="list-style-type: none">• Practice Management system• Facilities• Equipment• Personnel• Professional Supervisor• Safety• Patient Management• Teleradiology• Artificial Intelligence <p>Section 10 – 17:</p> <ul style="list-style-type: none">• Bone Mineral Density• Computed Tomography• General X-ray• Interventional radiology• Magnetic resonance imaging• Mammography• Nuclear Medicine• Ultrasound

Table 97: Continued

Study / Document	Country	Type of research	Profession	Key findings
The Royal Australian and New Zealand College of Radiologists (2021) Title: 'Clinical Radiology range of practice'	Australia	Standards of practice	Diagnostic Imaging (general)	The document outlines the range of practice that a Fellow of the Royal Australian New Zealand College of Radiologists may undertake. The document differentiates between core clinical radiology practice and advanced clinical radiology practice in broad terms.

Appendix D

Further reading: additional relevant literature excluded from the analysis

1. American College of Radiology [Internet]. Reston (US): ACR; c2022. ACR Appropriateness Criteria; [cited 2022 April 14]. Available from: <https://www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria>.
2. Australasian Association of Nuclear Medicine Specialists. Referrer's guide to nuclear medicine & PET procedures. [Internet]. Balmain (AU): AANMS; 2014 [cited 2022 April 22]. Available from: https://aanms.org.au/wp-content/uploads/2020/02/AANMS_REFERRERSGUIDE_2014_PRINT.pdf.
3. Australian Radiation Protection and Nuclear Safety Agency [Internet]. Canberra (AU): ARPANSA; c2022. Radiation Health Series; [cited 2022 April 13]. Available from: <https://www.arpansa.gov.au/regulation-and-licensing/regulatory-publications/radiation-health-series>.
4. Australian Radiation Protection and Nuclear Safety Agency [Internet]. Canberra (AU): ARPANSA; c2022. Radiation Protection Series; [cited 2022 April 13]. Available from: <https://www.arpansa.gov.au/regulation-and-licensing/regulatory-publications/radiation-protection-series>.
5. Bhaludin BN, Shelmerdine SC, Arora S, et al. Delays and errors in abnormal chest radiograph follow-up: a systems approach to promoting patient safety in radiology. *J Eval Clin Pract*. 2014;20: 453-459.
6. Butt FE, Lee EY and Chaturvedi A. Pediatric Musculoskeletal Infections: Imaging Guidelines and Recommendations. *Radiol Clin North Am*. 2022;60: 65-177.
7. Costa PF, Santos A and Testanera G. EANM Benchmark Document on Nuclear Medicine Technologists' Competencies. [Internet]. Vienna (Austria): EANM; 2017 [cited 2022 April 22]. Available from: https://www.eanm.org/content-eanm/uploads/2020/05/EANM_2017_TC_Benchmark.pdf.
8. Costello JE, Shah LM, Peckham ME, et al. Imaging appropriateness for neck pain. *J Am Coll Radiol*. 2020;17: 584-589.
9. Gates RL, Shelton J, Diefenbach KA, et al. Management of the Undescended Testis in Children: An American Pediatric Surgical Association Outcomes and Evidence Based Practice Committee Systematic Review. *J Pediatr Surg*. 2022;17:43.
10. Granata C and Magnano G. Computerized tomography in pediatric oncology. *Eur J Radiol*. 2013;82:1098-1107.
11. Grassi R, Faggian A, Somma F, et al. Application of imaging guidelines in patients with foreign body ingestion or inhalation: literature review. *Semin Ultrasound CT MR*. 2015;36:48-56.
12. Hendee WR, Becker GJ, Borgstede JP, et al. Addressing overutilization in medical imaging. *Radiol Manage*. 2010;257:240-245.
13. Itri JN and Patel SH. Heuristics and cognitive error in medical imaging. *AJR Am J Roentgenol*. 2018;210:1097-1105.
14. Jenkins HJ, Downie AS, Moore CS, et al. Current evidence for spinal X-ray use in the chiropractic profession: a narrative review. *Chiropr Man Therap*. 2018;26:1-11.
15. Jinzaki M, Kitagawa K, Tsai I-C, et al. ASCI 2010 contrast media guideline for cardiac imaging: a report of the Asian Society of Cardiovascular Imaging cardiac computed tomography and cardiac magnetic resonance imaging guideline working group. *Int J Cardiovasc Imaging*. 2010;26:203-212.
16. Kim M-J, Lee S-S, Choi M, et al. Development of an evidence-based clinical imaging diagnostic guideline for implant planning: Joint recommendations of the Korean Academy of Oral and Maxillofacial Radiology and National Evidence-based Healthcare Collaborating Agency. *Imaging Sci Dent*. 2020;50:45-52.

17. Lammi M, Vuolle S, Kiekara T, et al. The use of abdominal imaging studies in children visiting emergency department was variable and unsystematic. *Acta Paediatr.* 2019;108:2089-2094.
18. Lumbreras B, Donat L and Hernández-Aguado I. Incidental findings in imaging diagnostic tests: a systematic review. *Br J Radiol.* 2010;83:276-289.
19. Lurie AG. Doses, benefits, safety, and risks in oral and maxillofacial diagnostic imaging. *Health Phys.* 2019;116:163-169.
20. Makarov DV, Loeb S, Ulmert D, et al. Prostate cancer imaging trends after a nationwide effort to discourage inappropriate prostate cancer imaging. *J Natl Cancer Inst.* 2013;105:1306-1313.
21. Onder O, Yarasir Y, Azizova A, et al. Errors, discrepancies and underlying bias in radiology with case examples: a pictorial review. *Insights Imaging.* 2021;12:1-21.
22. Patenaude Y, Pugash D, Lim K, et al. The use of magnetic resonance imaging in the obstetric patient. *J Obstet Gynaecol Can.* 2014;36:349-355.
23. Pinto A and Brunese L. Spectrum of diagnostic errors in radiology. *World J Radiol.* 2010;2:377.
24. Pomara C, Pascale N, Maglietta F, et al. Use of contrast media in diagnostic imaging: medico-legal considerations. *Radiol Med.* 2015;120:802-809.
25. Rehani MM, Melick ER, Alvi RM, et al. Patients undergoing recurrent CT exams: assessment of patients with non-malignant diseases, reasons for imaging and imaging appropriateness. *Eur Radiol.* 2020;30:1839-1846.
26. Rocha APC, Schawkat K and Morteale KJ. Imaging guidelines for acute pancreatitis: when and when not to image. *Abdom Radiol (NY).* 2020;45:1338-1349.
27. Squillaci E, Bolacchi F, Scaggiante J, et al. Inappropriateness of diagnostic imaging examinations in the inpatient setting: a case study research. *Radiol Med.* 2017;122:221-227.
28. The American College of Obstetricians and Gynecologists. Committee Opinion No. 723: Guidelines for Diagnostic Imaging During Pregnancy and Lactation. *ACOG Comm Opin.* 2017;130:e210-e216.
29. The British Nuclear Medicine Society. BNMS Nuclear Medicine Generic Quality Guidelines for The Provision of Radionuclide Diagnostic Services. [Internet]. Nottingham (UK): BNMS. 2016 [cited 2022 April 14]. Available from: https://cdn.ymaws.com/www.bnms.org.uk/resource/resmgr/guidelines/may_2016_v2_bnms_nuclear_med.pdf.
30. The Royal Australian and New Zealand College of Radiologists. MRI Safety Guidelines Version 3.0. [Internet]. Sydney (AU): RANZCR. 2021 [cited 2022 April 22]. Available from: <https://www.ranzcr.com/college/document-library/ranzcr-mri-safety-guidelines>.
31. The Royal College of Radiologists. IR(ME)R: Implications for clinical practice in diagnostic imaging, international radiology and diagnostic nuclear medicine. [Internet]. London (UK): RCR. 2020 [cited 2022 April 22]. Available from: https://www.rcr.ac.uk/system/files/publication/field_publication_files/irmer-implications-for-clinical-practice-in-diagnostic-imaging-interventional-radiology-and-nuclear-medicine.pdf.
32. The Society of Nuclear Medicine and Molecular Imaging [Internet]. Reston (US): SNMMI; c2022. Clinical Guidelines, <https://www.snmmi.org/ClinicalPractice/content.aspx?ItemNumber=10817&navItemNumber=10786> (accessed 14 April 2022).
33. Venkatesh SK, Welle CL, Miller FH, et al. Reporting standards for primary sclerosing cholangitis using MRI and MR cholangiopancreatography: guidelines from MR Working Group of the International Primary Sclerosing Cholangitis Study Group. *Eur Radiol.* 2021;1-15.
34. Whang JS, Baker SR, Patel R, et al. The causes of medical malpractice suits against radiologists in the United States. *Radiol Manage.* 2013;266:548-554.
35. Young C and Owens CM. Pediatric computed tomography imaging guideline. *Acta Radiol.* 2013;54:998-1006.

36. Zhou Y, Boyd L and Lawson C. Errors in medical imaging and radiography practice: a systematic review. *J Med Imaging Radiat Sci.* 2015;46:435-441.

References

1. Institute of Medicine (US) Committee on Quality of Health Care in America. *To Err is Human: Building a Safer Health System*. Washington (US): National Academies Press, 2000.
2. Institute of Medicine (US) Committee on Quality of Health Care in America. *Crossing the Quality Chasm : A New Health System for the 21st Century*. Washington (US): National Academies Press, 2001.
3. Docking S and Haddock R. *Deeble Issues Brief No 44. Reducing diagnostic errors related to medical imaging*. 2021. Canberra, Australia.
4. Jabin MSR, Schultz T, Mandel C, et al. A mixed-methods systematic review of the effectiveness and experiences of quality improvement interventions in radiology. *J Patient Saf* 2022; 18: e97-e107.
5. Larson DB, Kruskal JB, Krecke KN, et al. Key concepts of patient safety in radiology. *Radiographics* 2015; 35: 1677-1693.
6. Chung L, Kumar S, Oldfield J, et al. The Use of Anatomical Side Markers in General Radiology: A Systematic Review of the Current Literature. *J Patient Saf* 2022; 18: e115-e123. DOI: 10.1097/pts.0000000000000716.
7. Chung L, Kumar S, Oldfield J, et al. A clinical audit of anatomical side marker use in a pediatric medical imaging department: A quantitative and qualitative investigation. *PloS one* 2020; 15: e0242594.
8. Lockie E, Gumm K, Skandarajah A, et al. Poor compliance with imaging guidelines in the pregnant trauma patient remains a challenge. *Trauma* 2021; 23: 80-82. DOI: 10.1177/1460408620943486.
9. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018; 169: 467-473.
10. European Society of Radiology and European Federation of Radiographer Societies. Patient safety in medical imaging: A joint paper of the European Society of Radiology (ESR) and the European Federation of Radiographer Societies (EFRS). *Insights Imaging* 2019; 25: e26-e38.
11. Davies H, Wathen C and Gleeson F. The risks of radiation exposure related to diagnostic imaging and how to minimise them. *BMJ* 2011; 342.
12. Hiles P, Gilligan P, Damilakis J, et al. European consensus on patient contact shielding. *Insights Imaging* 2021; 12: 1-8.
13. European Society of Radiology. Performance indicators for radiation protection management: suggestions from the European Society of Radiology. *Insights Imaging* 2020; 11: 134.
14. Brady AP. Error and discrepancy in radiology: inevitable or avoidable? *Insights Imaging* 2017; 8: 171-182.
15. Al-Hihi E, Gibson C, Lee J, et al. Improving appropriate imaging for non-specific low back pain. *BMJ Open Qual* 2022; 11: e001539.
16. Bruno MA and Nagy P. Fundamentals of quality and safety in diagnostic radiology. *J Am Coll Radiol* 2014; 11: 1115-1120.
17. Bruno MA. 256 shades of gray: uncertainty and diagnostic error in radiology. *Diagnosis* 2017; 4: 149-157.
18. Collins K, Hamlyn T, Bruxner G, et al. Dangers in the dark: Calling for a safer practice of transvaginal ultrasonography. *Australas J Ultrasound Med* 2021; 24: 5-12.
19. Degnan AJ, Ghobadi EH, Hardy P, et al. Perceptual and interpretive error in diagnostic radiology—causes and potential solutions. *Acad Radiol* 2019; 26: 833-845.
20. French SD, Green S, Buchbinder R, et al. Interventions for improving the appropriate use of imaging in people with musculoskeletal conditions. *Cochrane Database Syst Rev* 2010.
21. Lee CS, Nagy PG, Weaver SJ, et al. Cognitive and system factors contributing to diagnostic errors in radiology. *AJR Am J Roentgenol* 2013; 201: 611-617.

22. Pow RE, Mello-Thoms C and Brennan P. Evaluation of the effect of double reporting on test accuracy in screening and diagnostic imaging studies: a review of the evidence. *J Med Imaging Radiat Oncol* 2016; 60: 306-314.
23. Thompson MJ, Suchsland MZ, Hardy V, et al. Patient-centred outcomes of imaging tests: recommendations for patients, clinicians and researchers. *BMJ Qual Saf* 2021.
24. Waite S, Scott J, Gale B, et al. Interpretive error in radiology. *AJR Am J Roentgenol* 2017; 208: 739-749.
25. Waite S, Scott JM, Legasto A, et al. Systemic error in radiology. *AJR Am J Roentgenol* 2017; 209: 629-639.
26. Wang KY, Yen CJ, Chen M, et al. Reducing inappropriate lumbar spine MRI for low back pain: radiology support, communication and alignment network. *J Am Coll Radiol* 2018; 15: 116-122.
27. Itri JN, Tappouni RR, McEachern RO, et al. Fundamentals of diagnostic error in imaging. *Radiographics* 2018; 38: 1845-1865.
28. Pinto A, Caranci F, Romano L, et al. Learning from errors in radiology: a comprehensive review. *Semin Ultrasound CT MR* 2012; 33: 379-382.
29. Sivarajah R, Dinh ML and Chetlun A. Errors in breast imaging: how to reduce errors and promote a safety environment. *J Breast Imaging* 2021; 3: 221-230.
30. Wilson S, Shinde S, Appleby I, et al. Guidelines for the safe provision of anaesthesia in magnetic resonance units 2019: Guidelines from the Association of Anaesthetists and the Neuro Anaesthesia and Critical Care Society of Great Britain and Ireland. *Anaesthesia* 2019; 74: 638-650.
31. Babcock N, Ebdon-Jackson S, Remedios D, et al. Monitoring of clinical imaging guidelines part 3: norms, standards, and regulations. *J Am Coll Radiol* 2015; 12: 290-294.
32. Hannaford N, Mandel C, Crock C, et al. Learning from incident reports in the Australian medical imaging setting: handover and communication errors. *Br J Radiol* 2013; 86: 20120336.
33. Linet MS, Slovis TL, Miller DL, et al. Cancer risks associated with external radiation from diagnostic imaging procedures. *CA Cancer J Clin* 2012; 62: 75-100.
34. Weiser DA, Kaste SC, Siegel MJ, et al. Imaging in childhood cancer: a Society for Pediatric Radiology and Children's oncology group joint task force report. *Pediatr Blood Cancer* 2013; 60: 1253-1260.
35. Carrizales G and Clark KR. Implementing Protocols to Improve Patient Safety in the Medical Imaging Department. *Radiol Manage* 2015; 37: 26-32.
36. Malone J, del Rosario-Perez M, Van Bladel L, et al. Clinical imaging guidelines part 2: Risks, benefits, barriers, and solutions. *J Am Coll Radiol* 2015; 12: 158-165.
37. Care Quality Commission. *Radiology review: a national review of radiology reporting within the NHS in England*. 2018. England: CQC.
38. Bruno MA, Walker EA and Abujudeh HH. Understanding and confronting our mistakes: the epidemiology of error in radiology and strategies for error reduction. *Radiographics* 2015; 35: 1668-1676.
39. Power SP, Moloney F, Twomey M, et al. Computed tomography and patient risk: facts, perceptions and uncertainties. *World J Radiol* 2016; 8: 902.
40. Kjelle E, Andersen ER, Soril LJ, et al. Interventions to reduce low-value imaging – a systematic review of interventions and outcomes. *BMC Health Serv Res* 2021; 21: 1-19.
41. Public Health England. *The 2nd Atlas of Variation in NHS Diagnostic Services in England: Reducing unwarranted variation to improve health outcomes and value*. 2017. London (UK): PHE.
42. Choosing Wisely Australia [Internet]. Surry Hills (AU): CWA; c2022. The Royal Australian and New Zealand College of Radiologists, <https://www.choosingwisely.org.au/recommendations/ranzcr> (accessed 29 April 2022).
43. Government of Western Australia [Internet]. Perth (AU): WA Government; c2022. Diagnostic Imaging Pathways, <http://www.imagingpathways.health.wa.gov.au/index.php> (accessed 24 April 2022).

44. Halliday K, Maskell G, Beeley L, et al. *Radiology GIRFT Programme National Specialty Report*. 2020. NHS.
45. Woznitza N, Steele R, Groombridge H, et al. Clinical reporting of radiographs by radiographers: policy and practice guidance for regional imaging networks. *Radiography* 2021; 27: 645-649.
46. Australian Commission on Safety and Quality in Health Care. *National Safety and Quality Health Service Standards: User guide for the review of clinical variation in health care*. 2021. Sydney (AU): ACSQHC.
47. Coroners Court of Victoria. Inquest into the death of Barbara E Ashton (File No. COR 2012 3220) 2015.
48. Coroners Court of Victoria. Inquest into the death of Peta Hickey (File No. COR 2019 2336). 2021.
49. Coroners Court of Queensland. Inquest into the death of Maria Aurelia Willersdorf (File No. 2015/1475). 2020.
50. Medical Radiation Practice Board of Australia [Internet]. Melbourne (AU): AHPRA; c2022. Our Standards, <https://www.medicalradiationpracticeboard.gov.au/Registration-Standards.aspx> (accessed Mar 31 2022).
51. The Australian Society of Medical Imaging and Radiation Therapy. *Policies & Procedures Manual: Medical Imaging Practitioner Scope of Practice*. 2020. Melbourne (AU): ASMIRT.
52. The Royal Australian and New Zealand College of Radiologists. *Standards of Practice for Clinical Radiology, Version 11.2*. 2020. Sydney (AU): RANZCR.
53. Hofmann B, Andersen ER and Kjelle E. Visualizing the Invisible: Invisible Waste in Diagnostic Imaging. *Healthcare* 2021; 9: 1693.
54. Mendelson RM. Diagnostic imaging: doing the right thing. *J Med Imaging Radiat Oncol* 2020; 64: 353-360.
55. Medical Radiation Practice Board of Australia. *Professional capabilities for medical radiation practitioners* Internet. 2020. Sydney (AU): AHPRA.
56. Australian Sonographer Accreditation Registry [Internet]. Welland (AU): ASAR; c2022. About ASAR, <https://www.asar.com.au/about-asar/about-asar/> (accessed 31 Mar 2022).
57. Australian Government Department of Health. *Diagnostic Imaging Accreditation Scheme*. 2016. Canberra (AU): DoH.
58. The Australian Society of Medical Imaging and Radiation Therapy. *Professional Practice Standards*. 2018. Melbourne (AU): ASMIRT.
59. The Australasian Society for Ultrasound in Medicine. *Guidelines, Policies and Statements: Code of Conduct*. 2018. Chatswood (AU): ASUM.
60. The Australasian Society for Ultrasound in Medicine [Internet]. Chatswood (AU): ASUM; c2022. Standards of Practice, <https://www.asum.com.au/standards-of-practice/> (accessed 1 April 2022).
61. The Royal Australian and New Zealand College of Radiologists. *Clinical Radiology Range of Practice*. 2021. Sydney (AU): RANZCR.
62. Medical Radiation Practice Board of Australia. *For medical radiation practitioners: code of conduct* 2014. Sydney (AU): AHPRA.
63. The Australian Society of Medical Imaging and Radiation Therapy. *Code of Professional Conduct and Ethics for Medical Radiation Practitioners*. 2022. Sydney (AU): ASMIRT.
64. Australasian Association of Nuclear Medicine Specialists. *Code of Conduct*. 2019. Balmain (AU): AANMS.
65. European Society of Radiology. ESR concept paper on value-based radiology. *Insights Imaging* 2017; 8: 447-454.
66. European Society of Radiology. How to manage accidental and unintended exposure in radiology: an ESR white paper. *Insights Imaging* 2019; 10: 23.

67. European Society of Radiology. Position statement and best practice recommendations on the imaging use of ultrasound from the European Society of Radiology ultrasound subcommittee. *Insights Imaging* 2020; 11: 115.
68. The Society and College of Radiographers and The Royal College of Radiologists. *Standards for the provision of an ultrasound service*. 2014. UK: SCoR and RCR.
69. The Imaging Services Accreditation Scheme. *The Imaging Services Accreditation Scheme Standard: statements, rationales, and criteria, ISAS Standard v3.0*. 2017. UK: ISAS.
70. The Royal College of Radiographers and The Royal College of Radiologists. *Quality Standard for Imaging*. 2021. UK: CoR and RCR.
71. Watson L and Odle T. *Patient safety and quality in medical imaging: The radiologic Technologist's role*. 2013. Albuquerque (USA): ASRT.
72. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging* 2013; 37: 501-530.
73. New Zealand Medical Radiation Technologists Board. *Policy: Competence Standards for Medical Imaging and Radiation Therapy Practitioners in Aotearoa New Zealand*. 2018. Wellington (NZ): NZMRTB.
74. Ministry of Health. *Code of Practice for Diagnostic and Interventional Radiology: ORS C1*. 2018. Wellington (NZ): Ministry of Health.
75. International Accreditation New Zealand. *General Criteria for Accreditation: New Zealand Code of Radiology Management Practice*. 2020. Auckland (NZ): IANZ.
76. European Society of Radiology [Internet]. Vienna (Austria): ESR; c2022. Quality & Safety, <https://www.myesr.org/quality-safety> (accessed 1 April 2022).
77. The American Society of Radiologic Technologists. *The ASRT Practice Standards for Medical Imaging and Radiation Therapy* 2021. Albuquerque (USA): ASRT.
78. Dalili D, Carne A, MacKay J, et al. Musculoskeletal ultrasound imaging standards in the UK: British Society of Skeletal Radiologists (BSSR) position statement. *Br J Radiol* 2021; 94: 20210198.
79. Nyhsen CM, Humphreys H, Koerner RJ, et al. Infection prevention and control in ultrasound-best practice recommendations from the European Society of Radiology Ultrasound Working Group. *Insights Imaging* 2017; 8: 523-535.

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