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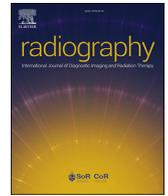
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Managing acoustic noise within MRI: A qualitative interview study among Swedish radiographers



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ABSTRACT

Introduction: Acoustic noise from magnetic resonance imaging (MRI) can cause hearing loss and needs to be mitigated to ensure the safety of patients and personnel. Capturing MR personnel's insights is crucial for guiding the development and future applications of noise-reduction technology. This study aimed to explore how MR radiographers manage acoustic noise in clinical MR settings.

Methods: Using a qualitative design, we conducted semi-structured individual interviews with fifteen MR radiographers from fifteen hospitals around Sweden. We focused on the clinical implications of participants' noise management, using an interpretive description approach. We also identified sociotechnical interactions between *People, Environment, Tools, and Tasks* (PETT) by adopting a Human Factors/Ergonomics framework. Interview data were analyzed inductively with thematic analysis (Braun and Clarke).

Results: The analysis generated three main themes regarding MR radiographers' noise management: (I) Navigating Occupational Noise: Risk Management and Adaptation; (II) Protecting the Patient and Serving the Exam, and (III) Establishing a Safe Healthcare Environment with Organizational Support.

Conclusion: This study offers insights into radiographers' experiences of managing acoustic noise within MRI, and the associated challenges. Radiographers have adopted multiple strategies to protect patients and themselves from adverse noise-related effects. However, they require tools and support to manage this effectively, suggesting a need for organizations to adopt more proactive, holistic approaches to safety initiatives.

Implications for practice: The radiographers stressed the importance of a soundproofed work environment to minimize occupational adverse health effects and preserve work performance. They acknowledge noise as a common contributor to patient distress and discomfort. Providing options like earplugs, headphones, mold putty, software-optimized "quiet" sequences, and patient information were important tools. Fostering a safety culture requires proactive safety efforts and support from colleagues and management.

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Introduction

Acoustic noise is a prominent feature of magnetic resonance imaging (MRI). Scanning typically produces sound pressure levels exceeding 85 decibels (dB), at which there is a risk of hearing loss, and occasionally peaking at 120–130 dB.^{1–4} Consequently, this acoustic noise needs to be mitigated to preserve both patient and

personnel safety. MR-generated noise is also associated with patient discomfort and anxiety, which may intensify claustrophobic reactions and result in preemptively aborted exams.^{5,6} Furthermore, the noise impedes personnel's ability to communicate or verbally support the patient throughout the exam.⁷ Additionally, Swedish MR radiographers report noise as a contributor to increased workload and stress.⁸

Modern MRI typically utilizes high-performance gradient systems, which unfortunately correlate with increased sound-pressure output.^{2–4} There are numerous ways to address the issue, e.g., earplugs, active noise-cancelling headphones, software-optimized acoustic noise reduction (ANR) protocols, hardware modifications, and/or unlisted site-specific and user-modified methods.^{3,9} Despite these options and technological advancements, there is little

Abbreviations: dB, decibel; HFE, Human Factors/Ergonomics; PETT, *People, Environment, Tools, and Tasks*; a concept for looking at sociotechnical interactions in a work system; ANR, acoustic noise reduction. We use this in conjunction with "software-optimized ANR pulse sequences", i.e., "quiet" pulse sequences.

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knowledge about how MR personnel approach acoustic noise in practice. To better prepare for future applications and noise reduction development, it is crucial to seek out and listen to the experiences and thoughts of MR radiographers – who are primarily responsible for operating scanners and ensuring patient safety – and identify potential challenges, needs, and pitfalls.

When studying safety aspects in healthcare, a Human Factors/Ergonomics (HFE) framework is suitable.¹⁰ HFE is intended to reduce error, increase productivity, and enhance safety and comfort during interactions between humans and the systems they work with.¹¹ A ‘system’ can be a physical device (e.g., an MR scanner), but may also be larger environmental contexts, such as a work site or organization.¹² At its minimum, every work system comprises People, an Environment, Tools, and Tasks – PETT – and the interactions between these. As a concept, PETT can be used to identify barriers or facilitators within each component and pinpoint factors that need to be addressed.¹³

By exploring MR radiographers’ experiences of acoustic noise within a clinical context, we can gain valuable insights from a user perspective and identify areas that require improvement. Therefore, the aim of this study was to explore how MR radiographers manage acoustic noise in clinical MR settings.

Methods

Context

For this study, we conducted fifteen semi-structured individual interviews using an inductive qualitative design.¹⁴ Eligible study participants were radiographers in Sweden working clinically at an MR department with at least one year of MR experience. Adopting an interpretive description approach,¹⁵ we aimed to develop clinical understanding and generate knowledge that would inform clinical practice, recognizing that participants and researchers together (co-)construct understandings.^{15–17} Each interview was performed and video recorded via Zoom (Zoom Video Communications, Inc., San Jose, CA, USA), to enable nationwide participation. Participation was voluntary, with informed consent obtained, and data were pseudonymized to ensure confidentiality. The study was approved by the Swedish Ethical Review Authority (DNR 2022-05555-01).

Data collection

The first author, who is also an MR radiographer, performed all interviews. The interviewer informed the participants of his professional background before starting the interviews, which allowed participants to use technical terms and jargon if they preferred. They were also informed that probing questions might occur to follow up uncertainties or confirm understandings. An interview guide (see Appendix) was used that included open-ended questions about experiences of acoustic noise in MRI. We conducted an individual pilot interview to test the interview guide; based on this, the guide’s structure was minimally adjusted, but the original questions were retained, and the pilot interview was included in the study. Using convenient sampling, three participants were recruited via advertisement on social media through the national radiographer professional association and trade union, and the remaining participants were recruited by reaching out to MR units and contacts in our professional networks, via email and/or telephone. We purposively included radiographers from different hospitals, with varying experiences and roles, to account for local and cultural aspects and gain sufficient information power.¹⁸ Interviews were conducted between October 2022 and April 2023.

In total, fifteen MR radiographers (nine women and six men, aged 30–60 with a median age of 42) from fifteen public hospitals were included. The hospitals ranged from larger university hospitals to smaller county hospitals, spanning from northern to southern Sweden. The participants worked either with only 1.5-Tesla MR systems, or with a mixture of 1.5- and 3-Tesla systems. Participants had worked as radiographers for between 4.5 and 37 years (median: 16 years), and their MR experience ranged between 2.5 and 29 years (median: 10 years). The interviews lasted between 23 and 69 min (median: 36 min).

Data analysis

We used Braun and Clarke’s thematic analysis¹⁹ to analyze data inductively. Inspired by interpretive description,¹⁵ our analysis focused on the practical implications of participants’ noise management from their clinical experiences in different work and healthcare environments. We also approached the data by identifying various system factors that participants interacted with, following the PETT concept.¹³ The analysis steps are summarized in Table 1.

After six months of data analysis and continuous discussions, all five authors had collectively reviewed the data, establishing themes through consensus (Table 2 presents an example). This collaborative approach, involving researchers with backgrounds in radiography, nursing, and medical physics, aimed to moderate individual biases and enhance trustworthiness.^{20,21}

Results

The analysis yielded three main themes relating to how MR radiographers manage acoustic noise: (I) *Navigating Occupational Noise: Risk Management and Adaptation*; (II) *Protecting the Patient and Serving the Exam*, and (III) *Establishing a Safe Healthcare Environment with Organizational Support*. A thematic map is presented in Fig. 1.

Navigating Occupational Noise: Risk Management and Adaptation

Every radiographer described dealing with noise in their MR work; however, its perceived impact influenced how actively they managed it. Some experienced noise as a problematic feature compromising their work environment, where working in less soundproofed settings generated more health-related concerns. Some participants had experienced headaches, fatigue, and/or difficulties concentrating because of constant scanner noise seeping into their control rooms. This exposure extended into their personal lives, making them less tolerant of loud noises at home, e.g., from their children.

“When I transitioned from the other modalities and started working with MRI, I experienced a sort of mental fatigue, and – not difficulty concentrating per se – but still, it was noticeable that it was noisy, you know. I was constantly aware of the sound. So I felt mentally tired, my head ached a bit on and off – so, headaches.” (Participant 4)

Some radiographers were concerned about whether their careers in MRI had contributed to hearing degradation. One participant even recounted an incident in which a colleague standing in the scanner room without hearing protection experienced acute tinnitus.

The radiographers described specific strategies for their own hearing safety. Participants seldom remained in the MR room during scans, e.g., for patient support, but generally wore headphones when they did. Personnel presence in the active scanning area had gradually decreased over the last decade. Moreover, some

Table 1
The phases of thematic analysis of the data, based on Braun & Clarke¹⁹.

Phase	Description of the process
1. Familiarising yourself with the data:	The first author (AG) transcribed all interviews verbatim using MAXQDA (v. 22.7.0; VERBI Software, Berlin). Then, three authors (AG; LL; JW) individually read and re-read all transcripts. This was followed by a joint discussion session where we collaboratively shared our initial impressions of the data.
2. Generating initial codes:	To organize the data, two authors (AG; LL) independently labeled data extracts from each transcript into codes using MAXQDA and Microsoft Word, respectively. These codes were then discussed and compared; initially noteworthy codes, including commonly repeated ones, were compiled into a shared document for a comprehensive overview.
3. Searching for themes:	The same three authors from Phase 1 discussed potential themes together, collating data based on three tables of contents: (I) noise-related symptoms, (II) strategies for noise reduction, and (III) organizational factors that either improve or worsen the noise environment. We placed coded data extracts under these initial themes in the shared document.
4. Reviewing themes:	All five authors discussed the possible themes developed during Phase 3. To refine our focus and provide a more targeted analysis, we concentrated on the management aspects of acoustic noise. This approach generated themes that contextualized noise management in relation to: (I) the radiographers' health and work environment, (II) the examination and healthcare environment, and (III) interactions within the organizational system. We drew up a map of potential theme names to ascertain how they stood on their own.
5. Defining and naming themes:	We refined the theme names and provided each with a written definition arc to ensure distinct separation between them, while also identifying possible interdependencies and the need for sub-themes.
6. Producing the report:	Data extracts were carefully chosen to exemplify the themes; our findings were compared to related literature to further discuss implications; the manuscript was finalized.

participants working in poorly soundproofed control rooms avoided scheduling particularly loud exams consecutively. At some sites, personnel wore earplugs/-muffs in the control room to mitigate scanner noise leakage. A few participants made sure to leave the MR section during breaks, or requested allocation to another imaging modality the next day.

"Well, it feels very satisfying when you leave because you no longer hear the scanner constantly running in the background. [...] Otherwise, you become quite mentally fatigued ... that's my standpoint. When you feel tired, you have to communicate with your colleagues or supervisors, tell them 'I need to take a break; I want to work on a different modality tomorrow' - to avoid a situation where you have to work with MRI every single day." (Participant 12)

In contrast, some radiographers managed by considering noise as an integral aspect of their job to which they had become accustomed. However, cultural norms and/or adaptation may play a role here. For example, some mentioned that experienced staff could – or were expected to – handle scanner noise, whereas newcomers might be more sensitive to it.

"Well, I think, partly, it's very different how people perceive noise. Yes, I can imagine that we ... those of us who have been working in MRI for a long time and are accustomed to it, well, it makes noise. It should make noise ... it's a comfort in knowing when the scanner generates images and when it doesn't generate images ... And we're used to it always making noise, you know." (Participant 9)

Participants stressed the importance of soundproofing between the scanner and control room for enduring work. In the control room, newer scanners and modern site renovations were perceived as quieter than older ones. Radiographers with experience of mobile MR trailers found these environments considerably louder than their current clinics. They described feeling drained after long shifts due to constant noise exposure, despite wearing headphones. Conversely, participants working in well-soundproofed control rooms sometimes struggled to discern when a pulse sequence had ended due to the absence of audible MR noise, requiring them to stay vigilant and avoid multitasking during scanning. This presented an unexpected challenge: a quiet work environment is preferred, yet the scanner noise is a reassuring indicator of the scanner operating.

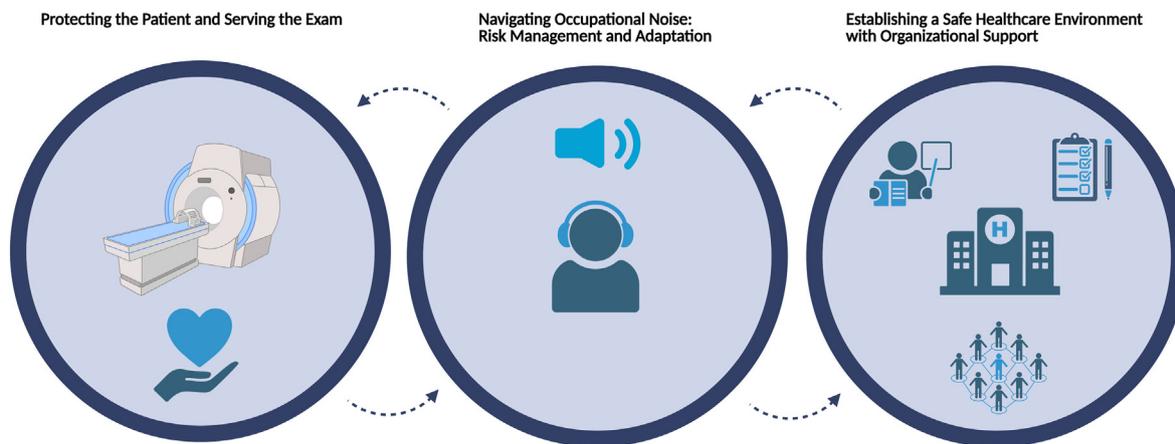
Protecting the Patient and Serving the Exam

Participants described that noise could potentially hinder patients' well-being and ability to complete the examination. Several radiographers identified noise as a primary source of discomfort and a common cause of patient complaints. A few had also encountered patients who developed acute tinnitus following their MRI.

"That's like the most common question we get. I mean, it's really damn loud. They [patients] might be able to handle the [confined] space, but everyone complains about the noise, you know." (Participant 7)

Table 2
Example of the coding and theme-generating processes of thematic analysis.

Data extract	Code(s)	Theme
<i>"We need to work on establishing a method, optimizing the image acquisition. It takes time, and we can't do it on all scanners. We have different field strengths, different manufacturers, and we don't have the time [laughs]. So, it's, ah, it's something that, yes, one would have wished ... to get to work a bit more on that."</i> (Participant 5)	Production is a higher priority than quality assurance Time constraints Aspiring to more	Establishing a Safe Healthcare Environment with Organizational Support



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Figure 1. Finalized thematic map of the analysis.

To protect the patient and increase the likelihood of a successful exam, the radiographers employed strategies to minimize noise exposure. The primary approach was to use earplugs and headphones. Often patients received both, but some hospitals only offered headphones for feet-first exams or at scanners below 3-T. This distinction seemed to stem from routines, underpinned by the belief that acoustic noise is more intense at the scanner isocenter than the gantry edges. A few participants viewed the MR manufacturer’s headphones as “communication aids” – not suitable as proper hearing protection. These radiographers always ensured that patients wore earplugs. Several participants had access to various types and sizes of earplugs for ear canals of different shapes. If difficult to fit properly, some occasionally cut the earplugs with scissors to ensure the correct fit.

Most radiographers also used ANR sequences, but their application varied. Some routinely included ANR in their protocols, while a few had access to but had never used them. Others only utilized them for infants and toddlers (e.g., feed-and-wrap procedures), pregnant patients, or children under mild sedation. A few participants replaced conventional imaging with ANR sequences when needed, particularly if the patient was noise-sensitive or anxious.

Participants experienced certain patient groups as more noise-sensitive than others. Commonly mentioned were children, psychiatric or traumatized patients, sedated patients, patients with tinnitus or impaired hearing, and patients with headaches or migraines. At times, the radiographers perceived the scanner noise as a “tipping point”, where the noise, in combination with these factors, led patients to abort the examination.

“They can be completely calm when you set them up, and then when you start scanning, they press the alarm ... and by that, they mean that it feels like something’s wrong because of the loud noise. Like something is malfunctioning, so they get anxious.” (Participant 8)

The radiographers also encountered patients who had fled war and experienced the MR noise as shellfire, triggering traumatic memories that resulted in aborted exams. The participants’ awareness of these noise-sensitive traits indicated a preparedness to manage potentially exam-disrupting challenges. Recognizing these patients allowed radiographers to adapt, employing additional strategies to assist the patient during the exam.

“We do have a certain patient category that has been through war ... and we can’t completely remove the noise. Many of them

actually experience it as artillery fire. [...] We actually have some patients who don’t want to be in the MR scanner for that reason” (Participant 4)

Additional strategies for noise reduction included: using silicone mold or dental putty in the external ear, securing headphones with pillows or foam, using active noise cancellation, using soft-shelled ear muffs (e.g., MiniMuffs®) for children, playing music or films to mask the MR noise, selecting quieter scanners for noise-sensitive patients, employing the quietest pulse sequences first, and accelerating sequences to minimize exposure time.

Participants often combined strategies for pediatric exams, e.g., triple layers of hearing protection plus ANR sequences. These measures were taken to not only protect hearing, but also minimize the risk of waking a sleeping or sedated child. The participants stressed the radiographer’s responsibility to apply proper hearing protection here, as children may not be able to communicate if the noise is too loud.

“Well, partly, children can’t really voice their concerns, I think, if they feel bad because of the noise, as adults can. An adult can just say that it’s way too loud and ‘you need to do something about this because I can’t stand this noise’ ... but children can’t do it in the same way” (Participant 2)

Another key strategy was patient education. By informing patients about the noise and importance of hearing protection, participants felt that patients were better prepared, more receptive to hearing protection, and more likely to complete the examination. Notably, the radiographers found it nearly impossible to communicate with patients during scanning due to the noise. Instead, information was given in advance or during scan breaks.

Ultimately, participants felt that the majority of patients accept loud noise as a necessary aspect of undergoing the examination. Some patients even find solace in the scanner noise, and on occasion, sleep through the procedure despite the volume.

Establishing a Safe Healthcare Environment with Organizational Support

Participants emphasized the need for a safety culture and increased proactive measures, including investments in quality assurance, development, education, policy, and scheduling, to improve safety standards. Consequently, work organization plays a

pivotal role in ensuring the necessary conditions for managing acoustic noise.

Some radiographers criticized their workplaces for a lack of commitment in ensuring a bearable sound environment. Despite noise measurements ruling out hearing-damaging levels, their workplaces seemed to disregard the cognitive load imposed. Some felt ignored by management that failed to address personnel's annoyance and fatigue due to daily noise exposure. Wearing hearing protection was felt to be insufficient since it restricts communication, and is physically uncomfortable. Conversely, a few participants described both themselves and their radiographer colleagues being complacent about reporting work environmental issues, thereby partly attributing a lack of organizational support to themselves.

"If something were to come out about it [noise] causing issues in the work environment, it's synonymous with 'okay, now we're going to increase the waiting lists', if we're talking about time. So, I think you probably don't want to see or hear anything ... And I believe people who work there are probably too kind to mention anything. [...] But ... I think probably everyone has thought about that at some point, but very few have actually heard anything about it [the loud work environment], including the management" (Participant 7)

Many felt that productivity and working through waiting lists generally took precedence over development and quality assurance. While all radiographers were positive about increasing efforts to reduce acoustic noise, they seldom had the time nor given the opportunity from management to do so. For example, some felt unsupported in their endeavors to optimize ANR sequences or were not being given training opportunities to acquire the necessary skills. Implementing ANR was seen as time-consuming and impeded exam production, especially when a site had scanners from multiple manufacturers. A few workplaces had solved this by scheduling sequence optimization for after office hours. Some lacked support from their local working group, perceiving their radiologist colleagues to be indifferent to improving hearing safety and patient comfort. One participant explained that if they used ANR software on adult patients, their radiologists would become upset since, in their view, the hospital should prioritize image quality first, and only pediatric patients were exempt for ANR imaging.

"So, I don't think they really dare to go in the direction of, you know, 'we might risk slightly compromising our quality' for the sake of reducing noise. Because that's not the priority. Rather, maybe ... accepting slightly reduced quality to make the sequences much faster so that we can examine more patients. It's more like the investments are heading in that direction." (Participant 6)

A few participants described positive experiences with development initiatives in their workplaces, where collaboration between radiographers, radiologists, physicists, and engineers led to clinical implementations, such as ANR sequences. However, many expressed that such changes often needed to be initiated by a radiographer. The challenge was that many radiographers lacked the knowledge or authority to pursue these changes without assistance from other professions. Radiologists were described as facilitators or as barriers in these scenarios. At some workplaces the radiologists gladly assisted evaluating a new method, e.g., with image quality consultations. At others, they were seen as disengaged, or lacked the knowledge to consult on MR safety strategies. Notably, participants with access to physicists were consistently pleased with their readiness to assist.

"We have noise-reducing sequences in the scanner that we don't use at all. They exist. Part of it is that each sequence probably takes a few seconds longer, but also, we don't really know how the image quality is because it hasn't been tested properly. [...] So no one wants to put in the work for sequence optimization. Instead, you have to tinker with it yourself. And as a radiographer, you feel you don't really know what the physicians want to see." (Participant 3)

Some participants felt limited by their workplaces' noise-reduction efforts. Although not all clinics had formal safety guidelines for acoustic noise, the participants valued the concept of such policies for guidance. Existing policies, however, were sparse and mainly recommended earplugs and headphones. Participants expressed the need for additional noise-reduction devices and aids. These included sound level meters for real-time monitoring during scanning, improved microphones and intercom systems to enhance patient communication, extra headphone padding, and larger head coils to accommodate thicker headphones. They also desired more ANR software options from MR manufacturers, alongside increased collaboration and overall support. Lastly, they highlighted the importance of education regarding noise reduction, both in undergraduate programs and throughout their clinical work.

Discussion

The participants experienced noise as a problematic feature of MRI, resulting in various challenges to be managed. Noise was considered disruptive, discomfoting, and a possible hindrance to patients undergoing MRI. These experiences align with previous literature, linking MR noise to anxiety,^{5,22} discomfort,²³ reduced exam success rate,^{3,24} increased workload,⁸ disrupted communication,⁷ and hearing impairment.^{9,23} Furthermore, participants who work in loud control rooms expressed concerns about cognitive symptoms and strain. Other studies have also reported adverse health effects of occupational noise, e.g., annoyance, fatigue, difficulty concentrating, and tension headaches, in settings such as obstetrics, intensive care units, and operating rooms.^{25–28} From a HFE and PETT perspective,¹³ our study findings position noise as a barrier to safety, comfort, and productivity, recognizing radiographers and patients as the primary affected *people* in terms of physical and cognitive burden. As such, investing in soundproofing and auditory ergonomic site planning not only facilitates a salutary work environment. It also prioritizes the well-being of personnel over the mere use of hearing protection devices, thereby improving the overall physical setting. Based on the European Directive 2003/10/EC,²⁹ Swedish legislation (AFS 2005:16)³⁰ demands that employers provide a tolerable noise environment, but does not set a lower limit below which noise-reducing efforts are no longer motivated. It does, however, encourage workplaces to reduce noise as much as reasonably possible, taking employees' experienced difficulties into account.

To reduce noise exposure in the scanner room, the IEC 60601-2-33 standard³¹ recommends passive hearing protection devices, i.e., earplugs and headphones. While our study participants had routines for such devices, they sometimes found it problematic to fit the earplugs properly and adopted other strategies (e.g., sound-dampening putty, ANR sequences, or active noise-cancelling headphones). Viewed from the PETT framework, the *task* of providing the patient (*person*) with earplugs (*tool*) requires adaptation when the earplugs do not fit. Instead of cutting them to fit the patient's ears, which compromises the dampening integrity of the earplugs,³² the ideal would be for the organization (*environment*) to provide different sizes or tools, and raise awareness of the risks of tampering with earplugs (by cutting them), leaving the

radiographer with options and informed choices. In this scenario, however, the personnel have found a workaround, but it may not be the safest solution. This example illustrates how human factors work, and is not meant to blame the individual radiographer. Rather, it highlights the importance of *system orientation* and *person centredness* within a healthcare organization.³³ These notions emphasize a holistic system view where invested efforts should support the people who are central to the system and be fitted to their capabilities, limitations, and needs.

Several participants described using three layers of passive hearing protection for noise-sensitive patients. In practice, a second layer only adds 5 dB of attenuation to the first (presumably superior) device.³¹ Where possible, combining hearing protection and noise control methods might more effectively reduce the total sound pressure exposure.⁹ Participants had concerns regarding ANR imaging, including sequence limitations, potential image quality degradation, and increased scan time. Assessing the extent of noise reduction is also challenging without access to a sound level meter or other MR-system-specific noise level indications. These concerns align with the current scope of ANR imaging, where its clinical utility depends on individual weightings, scanners, and software.^{34–39} Despite this, most participants viewed ANR imaging positively as a practical tool. However, utilizing this strategy successfully requires knowledge and familiarity, emphasizing the need for educational support and training.

Our study shows that the ability of radiographers to manage acoustic noise depends on organizations and their ability to accommodate the needs and preferences of their employees. The radiographers described often needing to initiate noise reduction efforts themselves, but lacking, to various degrees, organizational and collegial support. In a professional context, this suggests that MR-generated noise is primarily of concern for MR operators, and perhaps not prioritized or fully understood by others. Overviews of MRI-related incidents list acoustic noise as one of the more commonly reported causes.^{40–42} However, it is difficult to determine its severity based solely on this, since incidents are severely underreported.^{41–44} Our participants' accounts of both patients and colleagues experiencing acute tinnitus after an MRI, without such incidents being reported, attest to this. There seems to be an implicit understanding that incidents related to occupational noise are seldom reported, as if personnel were attributing it to their own negligence in not using proper hearing protection, and “deserving” symptoms such as temporary tinnitus and headaches. Once again, this highlights the need for system orientation³³ and cultivating a safety culture.

Although our data is limited, it conveys the adverse impact of acoustic noise in MRI and the importance of avoiding complacency. We suggest that MR sites inventory their current noise reduction tools and policies, and prioritize personnel training efforts. For routine consistency and patient safety, sites should consider using both earplugs and headphones if possible, regardless of whether exams are feet- or head-first. Moreover, manufacturers could increase their promotion of ANR options, including educational workshops, to encourage clinical adoption. Any image quality concerns should be assessed locally before implementation, however. MR sites need to endorse quality assurance as a mainstay work task and provide opportunities for this to take place.

Limitations

Data collection was conducted by a single interviewer, which could have introduced biases, such as overlooking different perspectives or relevant details during the interviews.¹⁴ However, the interviewer's expertise in MRI facilitated technical discussions and validation of the participants' experiences.^{14,19,21,45} The interviewer

was acquainted professionally with some participants, which could have influenced their responses due to concerns about their relationship.⁴⁵ This acquaintance, however, could also have increased their comfort, leading to more open and honest responses.²¹

Our study design does not provide data on the sound pressure levels in the participants' control rooms during scanning. Nor does our study account for any existing hearing impairments among participants or their tolerance for noise exposure in non-work surroundings, which might affect how they perceive and manage noise within their MRI work. Further research that addresses these factors and improves our understandings of them could improve the working conditions within MRI.

Limiting our sample to Swedish radiographers may have narrowed our insights. For example, interventional personnel and researchers, who more commonly stay in the MR room or give instructions during scanning, may have different experiences. Further research could yield valuable insights here, including from radiologists and leading management, or by exploring organizational attitudes. While our study participants independently described similar experiences, there may have been a participation bias since only interested radiographers contacted us or agreed to participate. However, it seems plausible that these experiences are transferable to other MR settings beyond these fifteen hospitals given the globally increasing standardization of MR work divisions, organizational structures, and safety requirements.^{46–48}

Conclusion

Radiographers show a willingness to adapt and mitigate MR noise to enhance both safety and comfort for patients and personnel, all while striving to deliver a diagnostic exam. Yet, they require tools and support to effectively manage, suggesting a need for work organizations to adopt more proactive, holistic approaches to safety initiatives. The radiographers also commended research advancements and manufacturer investments, and expressed a need for more dialogue and educational platforms dedicated to solutions that reduce acoustic noise.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Copilot, powered by OpenAI's GPT-4 language model, in order to check spelling and improve readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Conflict of interest statement

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.radi.2024.04.002>.

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QUESTIONNAIRE

A8(25)

Managing acoustic noise within MRI: A qualitative interview study among Swedish radiographers

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- **Some questions may have more than one correct answer;** in which case you must mark **all** the correct answers.

Introduction

Question 1: What was the range of sound pressure levels typically produced by MRI scanners?

- A: 50-70 dB
- B: 70-85 dB
- C: 85-130 dB
- D: 100-150 Db

Question 2: What is the main aim of the study?

- A: To report on noise levels during MRI
- B: To understand how MR radiographers manage acoustic noise in clinical settings
- C: To investigate patient satisfaction with MRI
- D: To investigate the effectiveness of various types of earplugs to lessen noise levels

Results

Question 3: What was **NOT** one of the typical reactions of radiographers working in poorly soundproofed control rooms?

- A: Use of earplugs
- B: Avoiding the consecutive scheduling of loud exams
- C: Insisting on regular hearing tests on the employer's cost
- D: Requesting allocations to another imaging modality

Question 4: Some participants had experienced headaches, fatigue, and/or difficulties concentrating because of constant scanner noise seeping into their control rooms. This exposure did **NOT** extend into their personal lives, making them less tolerant of loud noises at home, e.g., from their children.

Is this statement **TRUE** or **FALSE**?

- A: TRUE
- B: FALSE

Question 5: How did some radiographers perceive the MR scanner noise?

- A: As a reassuring indicator of scanner operation in well soundproofed control rooms
- B: As an unnecessary distraction
- C: As a minor inconvenience
- D: As a serious safety hazard

Question 6: Which of the following statements are **TRUE** regarding the use of ANR sequences?

- A: Application of ANR sequences was uniform across radiographers
- B: Some radiographers used them only for toddlers and infants, children under mild sedation and pregnant patients
- C: A few replaced conventional imaging with ANR sequences when needed, particularly if the patient was noise sensitive or anxious

Question 7: Is it **TRUE** that none of the radiographers reported that they encountered patients who had fled war and experienced the MR noise as shellfire – triggering traumatic memories that resulted in aborted exams?

- A: YES
- B: NO

Question 8: Which **TWO** methods were most commonly used by MR radiographers to protect patients from acoustic noise during MRI scans?

- A: Headphones
- B: Earplugs
- C: Soundproofed rooms
- D: ANR sequences

Question 9: Which patient groups were **NOT** identified as more sensitive to MRI noise?

- A: Elderly patients
- B: Psychiatric patients
- C: Patients with tinnitus
- D: Patients with headaches or migraines

Question 10: What was a key strategy for radiographers to complete the examination?

- A: Patient education
- B: Informed consent
- C: Patient comfort

Discussion

Question 11: What was a commonly reported health issue among radiographers working in noisy MRI environments?

- A: Increased risk of cancer
- B: Cognitive symptoms and strain
- C: Hearing loss
- D: Increased heart rate

Question 12: MRI noise was considered as and / or linked to

- A: Disruptive and discomforting
- B: Anxiety
- C: Increased workload
- D: Disruptive communication and hearing impairment
- E: An increase in blood pressure

Question 13: What was **NOT** a significant concern for radiographers when using acoustic noise reduction (ANR) sequences during MRI?

- A: Increased scan time
- B: Image quality degradation
- C: Patient discomfort
- D: Sequence limitations

Question 14: There seems to be an implicit understanding that incidents related to occupational noise are seldom reported, as if personnel were attributing it to their own negligence in not using proper hearing protection, and “deserving” symptoms such as temporary tinnitus and headaches.

Is this statement **TRUE** or **FALSE**?

- A: TRUE
- B: FALSE

Question 15: What did the study suggest was needed to improve MRI noise management in clinical settings?

- A: More advanced MRI scanners
- B: Organizations and their ability to accommodate the needs and preferences of their employees
- C: Reduced MRI scan times
- D: Higher salaries for radiographers

THE END



MEMBER INFO

(Complete sections marked with an asterisk *)

***FOH number**

***HPCSA number**

ID number

Personal detail changes

I hereby declare that the completion of this document is my own effort without any assistance.

SIGNED:

DATE:

This activity is accredited for **THREE (3) CLINICAL** CEU'S. You have to achieve **70%** to pass this activity.

ANSWER SHEET

A8(25)

Managing acoustic noise within MRI: A qualitative interview study among Swedish radiographers

	*Time spent on activity						hour					min				
	A	B	C	D	E		A	B	C	D	E	A	B	C	D	E
1						9										
2						10										
3						11										
4						12										
5						13										
6						14										
7						15										
8																

How relevant was the content of this activity to your scope of practice?			
			
Not at all	Somewhat	Mostly	Extremely

RETURN ANSWER SHEET TO

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