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What factors affect a patient's subjective perception of MRI examination

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MRI is becoming increasingly available and more common. However, it is a long examination, within a limited space, and making strong demands on the patient for proper co-operation. Using survey data collected by prospective questionnaire, this work examines the influence of patient preparation and type of MRI device on patients' subjective perception of the examination. The work analysed 800 patient questionnaires from 7 radiology centres, 12 MRI machines from 3 manufacturers. It was shown that 20% of patients were not informed at all or only insufficiently about the MRI examination by the referring physician, and this had a statistically significant effect on subjective perception as to the length of the examination. In claustrophobic patients, there was no significant difference in the perception of MRI examination between machine types (open vs. closed) or between bore size. This work demonstrated the influence of technical parameters of MRI devices on some other evaluated aspects in terms of patients' perception of MRI examinations (such as noise perception or peripheral nerves irritation) and that the preparation prior to the examination itself plays also an important role. Sufficient explanation from the referring physician, good workplace time management, and sufficient communication with the patient influence the subjective perception of the examination and thus indirectly its diagnostic benefit.

Keywords Magnetic resonance imaging, Healthcare Quality Assessment, Time management

Magnetic resonance imaging (MRI) does not use ionizing radiation and in this respect, it is considered as a safe method. On the other hand, the system transmits electromagnetic pulses to the patient, which may lead to tissue heating, stimulation of peripheral nerves and excessive noise during the examination. Although it is not life threatening, it could be perceived as uncomfortable especially for children and more sensitive persons. The average number of MRI examinations per 1,000 inhabitants in 2019 was, for example, 128, 62 and 145, respectively, in the USA, Canada and Germany[1]. In the case of the USA, this represents an increase of 142% compared to the year 2000, when an average of 53 MRI examinations were performed per 1,000 inhabitants[2]. It is important, therefore, to know how the examination is perceived by patients. MRI examination is time-consuming, it is very sensitive to movement of the patient during the examination, the patient can be instructed on what to do and what to expect overall, and the resulting diagnostic benefit is very dependent on the patient's co-operation. In the previous work, some correlations were found between knowledge about principles of MRI examination and education of the patient, however only 40.5% of patients actively seek information about MRI examination[3]. Sin et al. in older work from 2013 points to a lack of patients' general knowledge of imaging methods including MRI[4] and Törnqvist et al. proved that the lack of information increases presence of motion artifacts in MRI images[5]. These findings correlate with our empirical experience that the patient often comes to the examination site not knowing what exactly awaits him or her even in this era of the internet, when all relevant information is quite easily accessible. Presence and especially movement of patient in high static magnetic field can evoke vertigo or headache which was reported in several works especially in ultra-high magnetic MRI systems[6,7]. This in combination with limited space, increased noise, and restricted movement can often induce an increased level of stress in the patient and an overall negative perception of the examination which was proved by two recent

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studies[8,9]. MRI systems on the market come in different designs, magnetic field strength (0.5T–7T), and from different manufacturers at different price levels which may subjectively be perceived differently[10–12]. It can be very difficult to determine which machine is optimal for a specific facility and how these technological parameters will affect the patient's feeling about the examination. Thus, the purpose of this multi-center multivendor study is to evaluate the patients' subjective perception of MRI examination procedure and to identify potential factors that could affect the patients' feeling and possibly influence the diagnostic benefit of the examination.

Namely, we intend to test following hypotheses:

1. Patients are not sufficiently instructed by the referring physician about the MRI examination procedure and this factor is important for the perception of MRI examination.
2. Patients examined repeatedly will perceive the MRI examination differently from the patients examined for the first time.
3. The construction, magnetic field strength or manufacturer of the MRI system may affect patients' claustrophobic feelings, noise perception, tissue heating, peripheral nerve stimulation and overall comfort during the examination.
4. Waiting time before the examination and staff behaviour affect the perception of the MRI examination.

Materials and methods

This prospective study was conducted using a voluntary anonymous paper questionnaire survey which provided all information on the project (informed consent was obtained from the participants), was approved by the Ethics Committee of the University Hospital Brno and all methods were performed in accordance with the relevant guidelines and regulations. The questionnaire survey was done at 7 healthcare facilities (2 larger university hospitals and 5 smaller local hospitals) in 5 cities on 12 MRI machines from 3 manufacturers (Table 1) during the period from 1 November 2021 to 31 January 2022. One machine was unique in design because it was an open system whereas the others were all superconducting closed systems. A hybrid PET/MRI was also included, which looks similar to other MRI machines from the patient's perspective. All entities involved agreed to the placement and processing of the questionnaires.

Using the freely available software SDAPS (Scripts for Data Acquisition with Paper-based Surveys, version 1.9.9, https://sdaps.org/)[13] and taking into account the recommendations under work of Pagano et al.[14] a paper questionnaire was created with two sets of questions to which the patient responded before MRI examination that gauged general questions (age and sex), his/her feelings prior to the examination and other relevant information (e.g. known claustrophobia, previous experience with MRI or prior instruction by the referring physician) (11 questions) and after MRI examination that collected impressions related to the examination itself, (e.g. perception of duration, noise, heating or irritation of peripheral nerves) mostly on semiquantitative 4-point scale (19 questions). A few other questions concerned the staff behaviour and other aspects, that could also modify the perception of MRI examination. All participants filled the questionnaire in Czech language, English translated version of the questionnaire can be found in supplemental material 1.

At the beginning of the study, the personnel administering the paper questionnaires (radiological technician or nurse) were trained properly. The questionnaire was not administered to patients scheduled for general anaesthesia or those unable to fill out the questionnaire for other reasons (generally poor clinical state, consciousness alteration advanced mental disability, etc.). Exclusion criteria were failure to fill in the age category or gender. Inclusion criterion was age over 5 years (with the possible assistance of an accompanying person in the case of minors). Partially completed questionnaires were not excluded from the study if patients declined to provide responses for one or more questions other than age and gender.

After filling up of the paper questionnaires, the patients put them into the box at each MRI department and all questionnaires were collected from all sites after 31st of January 2022. The forms were subsequently scanned and the data were extracted using optical mark recognition implemented in SDAPS software. The data were

MRI type, bore, vendor	Median age interval[b] (25th–75th quartile range)	Male	Female	*N*
1T[a]	41–50 (11–60)	15	31	46
1,5T	41–50 (21–60)	210	286	497
3T	41–50 (31–60)	110	147	257
Open bore[a]	41–50 (11–60)	15	31	46
60 cm	41–50 (31–70)	101	159	260
70 cm	41–50 (21–60)	219	274	494
GE[c]	41–50 (31–60)	73	102	175
Philips[d]	41–50 (31–60)	149	194	343
Siemens[e]	41–50 (21–60)	113	169	282

Table 1. Age and gender distributions according to field strength, bore size, and manufacturer. [a]1T = horizontal open bore system. [b]Age data were collected by intervals (i.e. 0–10, 11–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71–80, 81–90, and 90 + years). 25th − 75th quartile ranges thus reflect the lower and upper ends of the relevant quartile ranges. [c]GE HealthCare Technologies, Inc., Illinois, USA. [d]Philips Healthcare, Inc., Best, Netherlands. [e]Siemens Healthcare, Inc., Erlangen, Germany.

subsequently checked using the dedicated interface in SDAPS software and manual corrections were made by KJ, if there were some errors in the automatic process of recognising the answers.

For the statistical evaluation of the four-point scale, only two categories were created by merging the categories "agree" and "somewhat agree" as well as "disagree" and "somewhat disagree".

All monitored parameters were compared for relationship to strength of the magnetic field, bore size, and manufacturer. Selected parameters were evaluated relative to one another, such as how the noise level was evaluated by patients who answered that they did not have any hearing protection or whether the perception of a given parameter differed among patients who were having an MRI examination for the first time compared to others who had been examined previously by MRI.

For statistical evaluation, the chi-square (χ^2) (if the requisite conditions were met) or Fischer exact test was used. IBM Statistical Package for the Social Sciences (SPSS, IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0, https://www.ibm.com/spss) software was used for statistical calculations. The level of significance was set at $p < 0.05$.

Results

A total of 816 questionnaires were collected, with 16 subsequently excluded based on the abovementioned exclusion criteria. Thus, 800 questionnaires were analysed in the end. Some of the patients did not respond to all the questions, therefore, for each result, the total number of respondents, who answered the specific question, is reported throughout the text besides the relative and absolute frequencies of the answers. Age and gender distributions in relation to MRI device field strength, bore size and manufacturer are shown in Table 1.

Among 798 responses to the question, 30% (239) were undergoing MRI examination for the first time, 55% (436) previously had had 1–5 examinations, and 15% (123) had been MRI examined more than 5 times.

One hundred thirteen respondents (14.1% [113/800]) had not been informed by their referring physicians about what to expect during the examination at all, and 5.9% (47/800) considered the information provided to have been insufficient. By correlating the perception of the examination duration with the quality of information obtained from the referring physician, we found statistically significant relation between those two parameters, as 14.8% (13/88) of the uninformed patients found the MRI examination to be unreasonably long, whereas only 4.9% (26/531) of the informed respondents perceived the examination to be unreasonably long ($p < 0.001$, χ^2). This applied to both patients undergoing MRI for the first time, as well as to the patients, who underwent 1–5 prior examinations in the past. If a patient already had completed more than 5 MRI examinations, the influence of providing sufficient information about the examination was no longer statistically significant in terms of the perception of examination duration.

Eighty-three (10.4%) of the 800 respondents stated that they were claustrophobic before the examination and 16.5% (132/800) were unsure. Forty-five of the 61 (73.8%) known claustrophobic patients felt claustrophobic during the examination, 20% (22/110) of uncertain patients felt claustrophobic, and only 6.7% (33/493) of patients without known claustrophobia felt claustrophobic. This difference between individual groups was statistically significant ($p < 0.0001$, χ^2). Twenty-six (31.3%) of 83 known claustrophobics were examined on an open-type MRI. There was no statistically significant difference in the perception of claustrophobia between MRI machines with bore sizes 60 cm versus 70 cm ($p = 0.635$, χ^2), between manufacturers ($p = 0.413$, χ^2), or even between open and closed systems ($p = 0.42$, χ^2). When we compared benefits of open bore system in comparison with closed bore system separately for the group of known claustrophobic patients, 80% (16/20) felt claustrophobic in open system and 70.7% (29/41) in closed systems and this difference was not statistically significant ($p = 0.44$, χ^2). None of the patients without known claustrophobia examined on open MRI system reported claustrophobic feelings (0/9), but they were reported by 6.8% (33/485) of patients examined on closed MRI systems; this difference was not statistically significant ($p = 1.0$, Fisher exact test). Claustrophobic feelings were most frequently reported by patients during shoulder examinations (20%, 4/20), followed by head or neck examinations (19.4%, 55/283), and spine examinations (16.8%, 22/131). In contrast, no patients reported feeling claustrophobic during examination of upper extremity (0/11), 4.9% (3/61) during knee examination and 6.7% (2/30) during lover extremity examination.

Four hundred seventy-four (72.4%) of 655 respondents wore protective headphones during the examination, 21.6% (141/655) earplugs, and 6% (39/655) no hearing protective device. Noise was perceived as unbearable for 23.5% (157/668) of all respondents regardless of the hearing protection applied. When respondents regarded hearing protection as insufficient, there was no significant difference ($p = 0.967$, χ^2) in the perceived effectiveness of that protection whether using headphones (11.5% [53/461] perceived as ineffective) or earplugs (11.6% [15/129] perceived as ineffective). In contrast, 28.6% (8/28) of respondents without hearing protection considered the noise to be excessive, which percentage is significantly higher than that for those with hearing protection (11.5% [68/590]) ($p < 0.01$, χ^2). Fifty per cent (18) of relevant respondents examined in 1T open-bore MRI machine (36) perceived the noise as unbearable, 22.5% (93/416) in the case of the 1.5 T machines, and 21.1% (46/218) regarding the 3T machines. These differences were not significant between 1.5T and 3T ($p = 0.683$, χ^2), however between 1T and both 1.5T and 3T significancy was proved (both $p < 0.001$, χ^2). Noise was not perceived differently between the different MRI manufacturer ($p = 0.186$, χ^2) or between 60 and 70 cm bore size ($p = 0.683$, χ^2), however there is difference between open and both 60 cm and 70 cm bore size (both $p < 0.001$, χ^2).

During the examination, 13% (87/669) of relevant respondents did not feel comfortable, mainly those examined in the open MRI system (34% [12/35]), which was statistically more frequent than in closed systems (12% [75/631], $p < 0.01$, Fisher exact test). Fewer felt uncomfortable with the 70 cm (10.6% [45/423]) and 60 cm (14.4% [30/208]), the differences between these two categories were not significant ($p = 0.167$, χ^2). There was no proven statistically significant difference in perceived overall comfort of the examination depending on the manufacturer ($p = 0.915$ χ^2), or even the field strength 1.5T or 3T ($p = 0.755$, χ^2).

Twenty-three per cent (152/661) of respective respondents felt heat during the examination, while this sensation was perceived relatively more frequently in the 1.5T field (25.3% [101/399]) than in the 1T (23.5% [8/34]) and 3T (19.6% [43/219]) fields. Nevertheless, this difference was not statistically significant either between fields 1.5T and 3T ($p=0.11$, χ^2), between bore size 60 cm versus 70 cm ($p=0.26$, χ^2), or among manufacturers ($p=0.955$, χ^2).

Peripheral nerves irritation was reported by 17.7% (117/661) of respondents, among them 25% (9/36) of patients examined in 1T MRI system, 18.8% (77/410) of those examined in 1.5T, and 14.3% (31/217) in 3T field strength ($p=0.174$, χ^2). Differences in the incidence of peripheral irritation depending on the bore size ($p=0.0076$, χ^2) were demonstrated, as the relative frequency of irritation was 25% (9/36) in open, 20.3% (85/419) in 70 cm, and 11% (23/209) in 60 cm MRI machines. A statistically significant difference ($p=0.025$, χ^2) was also demonstrated between manufacturers, with the frequency of irritation being higher for Siemens MRI machines (22.4% [49/219]) than for Philips (15.5% [46/297]) and GE (15% [22/147]) machines.

Thirty-two per cent (218/681) of respondents were not satisfied with the time spent in the waiting room before the examination. Patients who were not satisfied with the waiting time more often considered hearing protection insufficient (16.5% [34/206]) compared to patients who considered the waiting time reasonable (9.6% [42/438]) ($p=0.012$, χ^2).

Just three of 755 (0.4%) respondents considered the behaviour of the staff to be unfriendly.

Discussion

The primary goal of this work at the outset was to determine the factors that influence patients' feelings during MRI examination. Because the MRI examination is itself preceded by several steps, however, and the patient does not only perceive the MRI examination in isolation but may be subconsciously influenced by all the previous steps (information provided by the referring physicians, friendliness of the staff, time spent in the waiting room before the examination, etc.), we decided to draft the questionnaire more extensively and focus also on the preparation before the MRI examination itself.

Clinical closed MRI systems with bore sizes of 60 to 80 cm and magnetic field strengths of 0.5T to 7T can be found on the market. Each variant has its advantages and disadvantages, which is discussed in recent reviews[11,12,15]. As the field strength increases, we generally get a better signal-to-noise ratio (SNR) and better spatial resolution, but also higher specific absorption rate (SAR) values since it increases with square of static magnetic field, more artifacts in the image, and significantly higher acquisition cost. According to the work of Hattori, moreover[16], a 3T machine produces peak sound pressure level 126 dB while the sound of a 1.5T machine at a similar setting reaches just 106 dB. However, in this study we did not prove any differences in perception of noise between MRI systems. This is explained firstly by the age of the Hattori work, when manufacturers could improve production processes in time and reduce the noise levels of MRI machines, and secondly by the effective reduction of noise through the use of protective equipment, which compensates the differences in loudness and patients do not subjectively perceive any difference.

As the bore size increases, we are able to examine larger patients and the patient has greater comfort, which is important in claustrophobic patients[17]. However it is more difficult to maintain a high degree of field homogeneity in a larger volume, which increases artifacts within the image and, in larger patients, poorer SNR from deeper anatomical areas that can be a problem especially during an abdominal examination. Also more powerful gradient system is required since the slew rate decreases with fifth power of the bore radius and it directly influence probability of peripheral nerve stimulation[18,19]. This would be in agreement with our findings, when patients reported peripheral nerve stimulation statistically less frequently in 60 cm bore size systems compared to wider-bore systems. However, we have additionally checked the power (amplitude/slew rate) of each gradient systems, but we did not find any differences in relation to bore size (except open system). Patients examined on Siemens Healthcare MRI systems reported more often stimulation of peripheral nerves compared to the other two manufacturers ($p=0.025$), but this result can be a bit misleading, because not only the gradient system power, but also the setting of individual pulse sequences is relevant, and the methods of determining the stimulation limit between different manufacturers and software versions can play a significant role.

Almost 15% of the uninformed patients considered the length of the MRI examination to be long, while just 5% of those who were informed considered it to be long. That may negatively affect the image quality and diagnostic yield of an examination due to movement artifacts, as these patients may experience stress during the examination associated with an unexpected length of the examination, which was studied by Törnqvist et al.[5] This finding is also in agreement with the work of Munn et al.,[20] who observed a significant difference in the perception of anxiety between informed and uninformed patients. Similarly, in work by Hudson et al.[21], communication and patient education were shown to be the most effective practices for alleviating patient anxiety about MRI imaging.

The respondents correctly anticipated their perception of confined spaces, as claustrophobics really did feel claustrophobic during the MRI examination in the majority of cases (74%), while only 7% of patients not normally claustrophobic felt claustrophobic during MRI, as did 20% of those who had not been sure in advance. Almost half of claustrophobics (46%) were examined in an open system, but, even so, half of them still felt claustrophobic. There was no statistically significant difference in the perception of claustrophobia in closed systems (60 cm vs. 70 cm, $p=0.635$). There was also no difference in perception of the claustrophobic feelings between the patients (regardless on anamnesis of claustrophobia) examined in an open versus closed systems ($p=0.42$), which may be partially explained by a relatively higher proportion of claustrophobic patients examined on open system. However, the differences were not significant between open and closed MRI devices even in a subgroup of patients with known claustrophobia. The work of Hudson et al. has shown that the probability of terminating an examination due to claustrophobia is 3.7 times greater for horizontal open systems than for closed systems and, conversely, for vertically open systems 0.57 times less than for closed systems[22].

The work of Bangard et al.[23], on the contrary, shows that in an open system the examination is better tolerated and the number of completed examinations is higher than in a closed system. That work considered only 36 claustrophobic patients, however, whereas Hudson analysed more than 600,000 examinations. Regardless, based on the results of this work, it can be said that if a patient has a predisposition to claustrophobia, it will manifest itself regardless of the type of MRI machine used.

Nearly a quarter of the respondents were concerned about the high level of noise, but almost 90% of all respondents considered hearing protection to be sufficient. No difference was demonstrated in hearing protection between headphones and earplugs, so the type of protection did not play a role in the overall perception of examination comfort. Also, no effect of field strength, bore size, or manufacturer on the level of noise perception was proven. Not surprisingly, patients without applied hearing protection complained of high noise levels during the examination more frequently compared to those with hearing protection.

Overall discomfort during the examination was felt by 13% of patients, mainly in the open system, which is probably related to the fact that a larger number of claustrophobic and paediatric patients were examined there which are generally more sensitive subjects.

According to our results, there is a connection between the waiting time and the perception of examination noise. This connection can be caused by increased nervousness, the feeling of wasted time in the waiting room, and general impatience during the examination, which can be manifested by an increase in sensitivity to unpleasant environmental stimuli, such as noise.

This work has its weaknesses. One of them is the uneven representation of the number of respondents depending on the field strength, bore size, and manufacturer. Nevertheless, this fact relatively realistically replicates the representation of individual machines and manufacturers on the market in the given area. The use of a PET/MRI machine can slightly distort the results. Even though the design is a 3T MRI machine with a 60 cm bore size, the examinations on that machine consist mainly in trunk or whole-body oncological diagnoses, which deviate slightly from standard MRI examinations normally performed at other facilities. The machines differ by age since installation and technical aspects of the equipment, and that can distort the results. Again, though, this situation corresponds to the current state of equipment at MRI facilities in the given area and best characterizes the actual conditions.

Conclusion

This study showed that technical parameters of different MRI system may to a limited extent influence patients' perception of the examination. Nevertheless, concomitant factors such as waiting time or information given by the referring physician prior to the examination may also influence patients' feeling during the MRI examination. Notably, open MRI system did not reduce claustrophobic perceptions in patients with known claustrophobia compared to closed MRI systems. Several practical conclusions emerge from the results; especially proper informing by the referring physician, effective time management at the MRI facility, application of hearing protection, and communication with the patient are the main points on how to improve the subjective perception of the MRI patient and thereby, indirectly, to influence the quality of the examination.

Data availability

Data are available upon request of the corresponding author in case of legitimate interest.

Received: 29 May 2024; Accepted: 24 September 2024
Published online: 30 September 2024

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Acknowledgements

Supported by the Ministry of Health, Czech Republic - conceptual development of research organization (FNBr, 65269705).

Author contributions

Marek Dostál – Conception, design, analysis, interpretation, draft articleKateřina Jurasová – Acquisition, analysis, draft articleMiloš Keřkovský – Interpretation, revision of manuscriptJiří Vaníček – Hospital Data Acquisition Manager, revision of manuscriptLadislav Kalas – Hospital Data Acquisition Manager, revision of manuscriptLuboš Látal – Hospital Data Acquisition Manager, revision of manuscriptSvatava Janků – Hospital Data Acquisition Manager, revision of manuscriptVladimír Trojek – Hospital Data Acquisition Manager, revision of manuscriptAndrea Šprláková-Puková – Hospital Data Acquisition Manager, revision of manuscriptAll authors approved to submit this manuscript and agree both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Declarations

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-74231-9.

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