ORIGINAL SCIENTIFIC PAPER (IZVORNI ZNANSTVENI ČLANAK)

SAR in Magnetic Resonance Imaging: A Study on the Education, Knowledge, and Practice of Radiologic Technologists in the Republic of Croatia

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Abstract

Introduction: Magnetic resonance imaging (MRI), as a modern diagnostic method, presents specific safety challenges due to patients' exposure to strong electromagnetic fields. From this perspective, the Specific Absorption Rate (SAR) is a key safety parameter. Managing SAR in clinical practice is crucial for preventing excessive tissue heating and ensuring patient safety, prevalence of metallic implants, tattoos, and cosmetics containing metallic pigments, as well as the diverse age profile of patients, which necessitates special consideration for thermoregulation in paediatric and geriatric populations. Radiologic technologists play a central role in this process. Still, it remains unclear to what extent they possess formal education and knowledge about SAR, and how these aspects are applied in practice.

Aim: To analyse the current state of education, theoretical knowledge, and clinical practice of radiologic technologists in the Republic of Croatia in the context of SAR management and optimisation during MRI examinations.

Methods: A survey was conducted among radiologic technologists with MRI work experience in the Republic of Croatia. The questionnaire included questions regarding their formal training in MRI safety, understanding of the SAR concept, and implementation of safety protocols in practice.

Results: Neither level of education nor work experience significantly correlated with knowledge scores. No statistically significant difference was found in the number of correct answers between master's degree holders and bachelor's degree holders ($p = 0.382$), nor with total work experience ($p = 0.618$) or MRI-specific experience ($p = 0.409$). In contrast, one-way ANOVA revealed statistically significant regional differences in knowledge levels ($p = 0.049$). A pronounced discrepancy between theoretical knowledge and its practical application was identified. This finding is further supported by the fact that 96.2% of participants expressed a need for additional education.

Conclusion: The findings indicate the necessity of establishing systematic education for radiologic technologists on MRI safety, with a particular focus on SAR management. It is also recommended to implement unified, clearly defined safety protocols and to appoint responsible personnel for MR safety within healthcare institutions.

Keywords: education; magnetic resonance imaging; radiologic technologists; safety protocols; SAR

Introduction

Magnetic resonance imaging (MRI) is one of the most important diagnostic imaging methods in modern medicine due to its ability to generate high-contrast images of soft tissues without ionizing radiation [1]. Despite its great advantages, MRI carries certain safety challenges, particularly due to the exposure of patients to electromagnetic fields, which requires special attention given the increasing number of performed examinations and the growing number of implants in patients [2].

A key safety parameter in MRI is the Specific Absorption Rate (SAR), which defines the amount of radiofre-

quency (RF) energy absorbed in the body per unit mass over time, expressed in W/kg [3]. SAR directly correlates with thermal effects on tissues. Excessive levels of SAR can cause significant local tissue heating, discomfort, or even serious thermal injuries, such as burns, especially if not carefully controlled in clinical practice [4].

Radiologic technologists play a crucial role in adjusting imaging protocols because technical characteristics and parameters, such as TR, sequence duration, flip angle (FA), fat suppression techniques, and coil selection, significantly affect SAR levels [5]. European and international recommendations highlight the importance of a clear division of roles. The MR Medical Director (MRMD) is responsible for MR safety, while the MR Safety Officer (MRSO) implements and supervises safety protocols, educates staff, and analyses incidents [6, 7]. A lack of formal education and the absence of appointed MRSOs directly increase the risk of incidents [7]. In the Republic of Croatia, however, systematic data on radiologic technologists' knowledge and clinical practice regarding SAR are currently unavailable, further justifying the need for this research.

The primary aim of this study was to provide a comprehensive analysis of the current state of education, theoretical knowledge, and clinical practice among radiologic technologists in the Republic of Croatia in relation to SAR management and optimization during MRI examinations. An additional objective was to identify critical gaps in the implementation of safety protocols, with the intention of informing future improvements and supporting the development of targeted continuing education initiatives.

Within this framework, particular emphasis was placed on examining factors that may influence both the understanding and practical application of SAR-related concepts. These included the role of formal education and professional experience, potential regional variability in knowledge levels and clinical approaches, and the extent to which theoretical knowledge is effectively translated into routine clinical practice.

Materials and Methods

Study Design and Participants

A cross-sectional study was conducted using a structured survey questionnaire. The participants were radiologic technologists employed in public and private healthcare institutions in the Republic of Croatia with experience in performing MRI examinations. A total of 52 validly completed questionnaires were collected.

Data Collection Instrument

The structured questionnaire, created specifically for this research, contained 25 questions divided into three sections: demographic and professional data; self-assessment of knowledge and perception of educational needs; and objective assessment of knowledge and clinical practice. The content of the questionnaire was based on current international guidelines (IEC 60601-2-33, ACR Manual on MR Safety, FDA) [8, 9, 10]. The survey questionnaire was distributed electronically via Microsoft Forms.

Statistical Analysis

All responses were exported in .xlsx format and analysed using Microsoft Excel and PSPP. Descriptive analysis and correlation analysis were performed.

Results

Demographic and Professional Characteristics

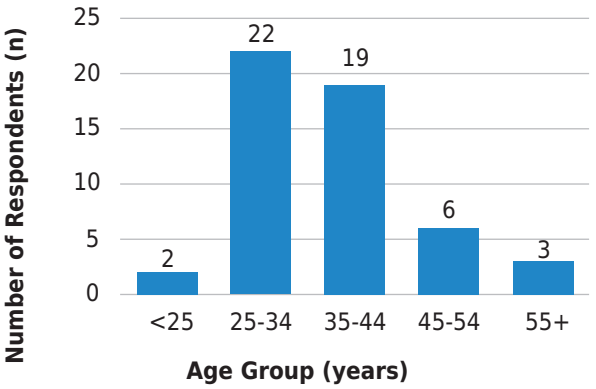

Figure 1. Distribution of respondents by age group

A total of 52 radiologic technologists participated. A slightly larger portion of participants were male (n = 27; 52%) compared to female (n = 25; 48%). The most represented age group was 25–34 years (n = 22; 42.3%), followed by 35–44 years (n = 19; 36.5%). Smaller proportions were observed in the 45–54 (n = 6; 11.5%), 55+ (n = 3; 5.8%), and <25 years (n = 2; 3.8%) age groups (Figure 1).

Regarding their formal education, 40 participants (77%) held bachelor's degrees, while 12 (23%) held master's degrees. The majority of respondents were employed in general hospitals (n = 26; 50%), followed by clinical hospital centres (n = 14; 27%). Smaller proportions worked in the private sector (n = 9; 17%) and clinical hospitals (n = 3; 6%), as shown in Figure 2.

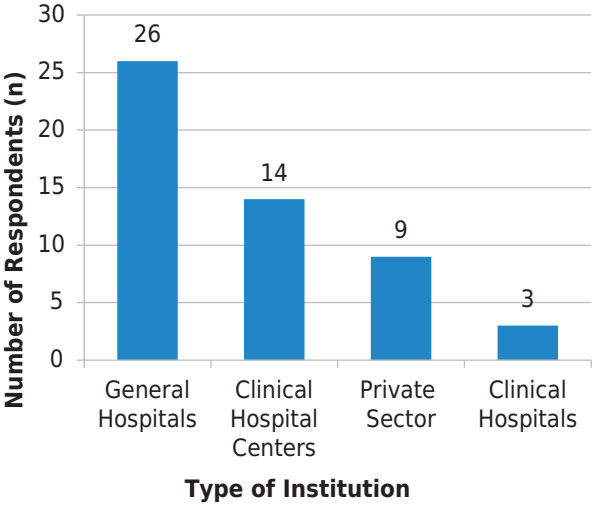

Figure 2. Distribution of respondents by type of healthcare institution

Regarding specific experience in MRI diagnostics, the largest proportion of participants had less than 5 years of experience (n = 22; 42%), followed by those with 5–14 years (n = 20; 38%). A smaller group reported 15–24 years of experience (n = 9; 17%), while only one participant had more than 25 years of MRI experience (n = 1; 2%) (Figure 3).

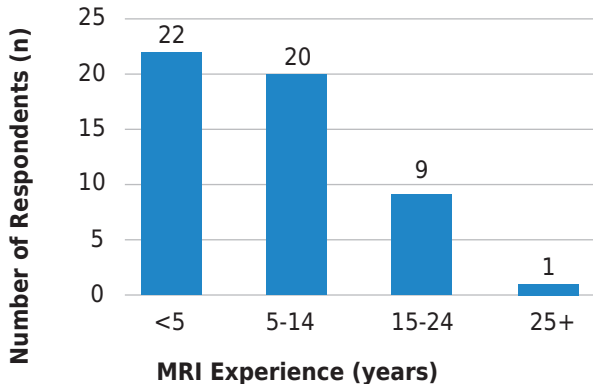

Figure 3. Distribution of respondents according to years of professional experience in MRI diagnostics

From a geographical perspective, the distribution of respondents across Regional Councils indicates that the largest cohort originated from the 4th Regional Council (n = 21; 40%), followed by the 2nd (n = 17; 33%) and the 1st (n = 10; 19%). The smallest representation was observed in the 3rd Regional Council (n = 4; 8%), as shown in Figure 4.

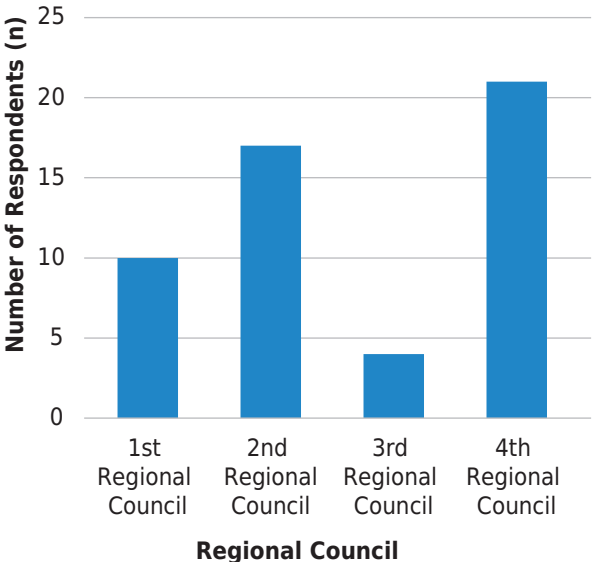

Figure 4. Geographical distribution of respondents by Regional Council

Objective Knowledge on SAR

Participants' objective knowledge of SAR was assessed using 9 questions. The average number of correctly answered questions was 5.08 (56.4%). The concept of SAR was correctly defined by the majority of participants (n = 47; 90%). Furthermore, 88.5% of respondents (n = 46) correctly indicated that SAR is not negligible even during short examinations. The maximum allowed whole-body SAR value in normal operating mode (2 W/kg) was correctly identified by less than half of the participants (n = 25; 48%). A lower level of accuracy was observed in assessing the impact of parallel acquisition techniques on SAR, with only 31% of participants (n = 16) correctly recognizing that these techniques reduce SAR by decreasing acquisition time and the number of RF pulses (Figure 5).

Optimization Practices and Educational Gaps

The most frequently mentioned recommended methods for SAR reduction that technologists recognized were reducing FA (60% of participants) and using sequences with fewer consecutive RF pulses (50%). A substantial majority of respondents (86.5%) perceived a significant discrepancy between the theoretical knowledge of Specific Absorption Rate (SAR) acquired during their academic studies and its practical application in clinical settings (Table 1).

Table 1: Perceived gap between academic education and clinical practice

Perception of Difference	Frequency (n)	Percentage (%)
Significant difference exists	45	86.5%
No significant difference	7	13.5%

Furthermore, the findings underscore a near-universal demand for professional development, with 96.2% of participants expressing a clear need for additional education on SAR management (Table 2). Notably, despite this high level of interest, only 17% of respondents had participated in specific SAR-related training.

Table 2: Participant self-assessment on the need for further education

Need for Additional Education	Frequency (n)	Percentage (%)
Expressed need for education	50	96.2%
No need for further education	2	3.8%

Correlations

Comparing the knowledge test results between master's and bachelor's degree holders in radiologic technology showed no statistically significant difference ($p = 0.382$). Examining the correlation between total work experience and the test result showed a very low, non-significant correlation ($p = 0.618$). However, the knowledge test results showed statistically significant differences among regions

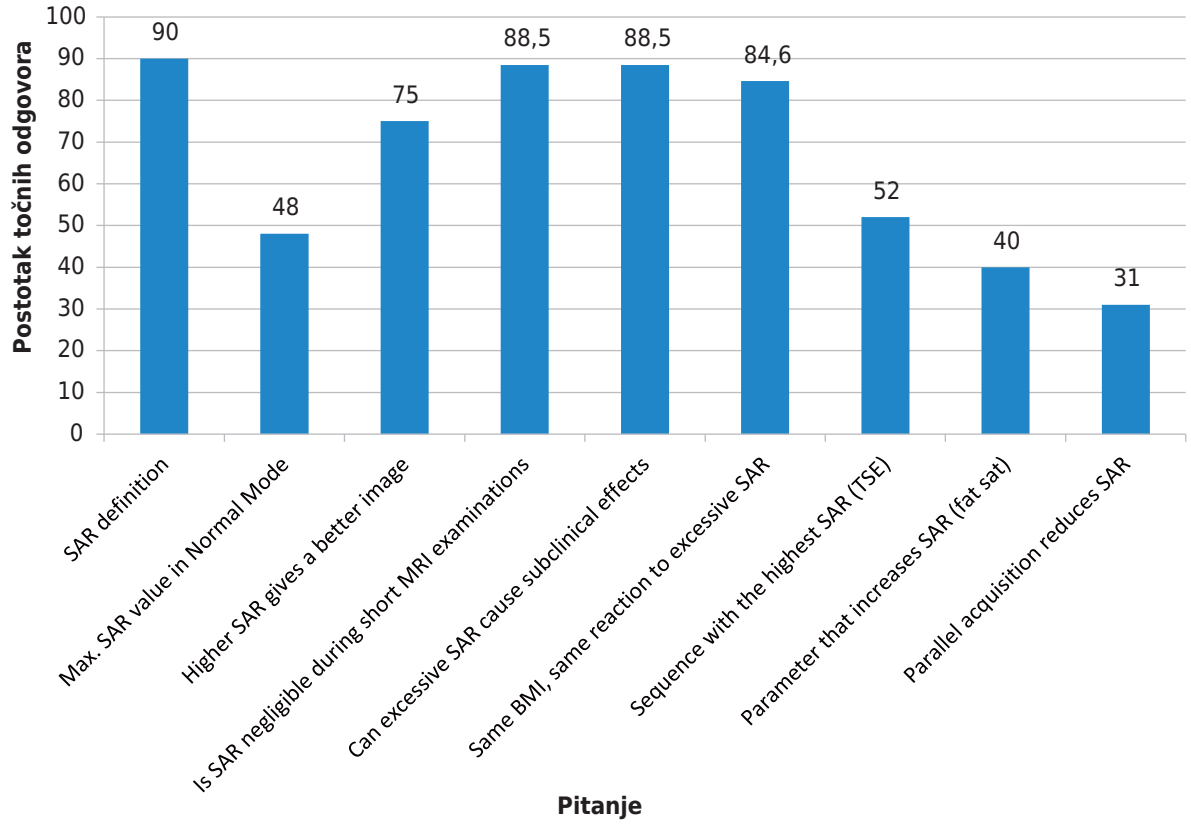

Figure 5. Distribution of correct answers on the objective knowledge test regarding SAR

(p = 0.049), with the highest average score recorded in the 1st Regional Council and the lowest in the 4th Council (Table 3).

Table 3: Comparative Analysis of Knowledge Test Scores by Education and Region

Variable	Group	Mean Score (± SD)	Statistical Significance (p)
Education Level	Master's Degree	6.6±1.4	**0.382**
	Bachelor's Degree	6.2±1.3	
Regional Council	1st Council	7.20±1.76	**0.049**
	4th Council	5.76±1.38	

Experience working on an MRI scanner also did not show a significant correlation with acquired knowledge (p = 0.409) (Table 4).

Table 4: Correlation Between Experience and Knowledge Test Scores

Variable	Correlation Coefficient (r)	Statistical Significance (p)
Specific MRI Experience	Low/Negligible	0.409

Discussion

The results of this research indicate that while radiologic technologists in the Republic of Croatia possess a solid foundational understanding of the Specific Absorption Rate (SAR) concept, significant gaps exist regarding advanced technical parameters and practical optimization strategies. The average score on the objective knowledge test was 56.4%, which represents a moderate level of competency. However, this average masks a sharp decline in performance as questions transitioned from theoretical definitions to clinical application.

The Theory-Practice Gap

While a vast majority of respondents (90%) correctly identified the basic definition of SAR, accuracy plummeted when addressing regulatory limits and technical variables. For instance, only 48% of participants were aware of the maximum allowed SAR value for the whole body in normal operating mode. This discrepancy suggests that while technologists "know of" SAR, they may not be fully equipped to manage SAR within safe regulatory boundaries.

The most critical deficit was observed in practical optimization scenarios. The finding that only 31% of participants understood the impact of parallel acquisition on SAR is particularly concerning, as it directly relates to the technologist's ability to adjust scan parameters to ensure patient safety. This result highlights a substantial disconnect between academic preparation and the complexities of modern clinical practice.

Educational Deficits and Professional Needs

The near-unanimous demand for further education (96.2%), coupled with the perceived discrepancy between academic curricula and clinical reality (86.5%), underscores a systemic gap in professional training. Current educational frameworks appear to provide only a foundational understanding of SAR, and they struggle to keep pace with rapid technological advancements. This is particularly critical as the industry shifts toward higher field strengths, such as 3T and 7T, where precise SAR management becomes a fundamental safety requirement rather than a theoretical consideration. Furthermore, the lack of a statistically significant correlation between work experience and test scores ($p = 0.409$) suggests that "learning on the job" is an insufficient substitute for formal, targeted training. This implies that even seasoned technologists may be operating based on inherited workplace habits rather than evidence-based safety protocols.

Comparison with International Standards

The international radiological community has already recognized these challenges by moving toward standardizing MR safety roles. The American College of Radiology (ACR) emphasizes the necessity of the MR Safety Officer (MRSO) role to bridge the gap between technical knowledge and clinical safety [9]. Similarly, the European Federation of Radiographer Societies (EFRS) is actively developing the European Curriculum for Safety Officers in MRI (ECSO-MRI) to ensure a unified level of competence across Europe [11, 12].

In Croatia, the absence of a formal "MR Safety Officer" certification or a standardized national curriculum for SAR management leaves individual departments to establish their own, often informal, safety benchmarks. Implementing a structured certification process, aligned with EFRS and ACR guidelines, would not only elevate the professional status of radiologic technologists but, more importantly, enhance patient safety by ensuring that SAR optimization is a deliberate, data-driven process rather than a trial-and-error approach.

Study Limitations and Implications

When interpreting these findings, several research limitations should be considered. The sample size of 52 radiologic technologists, although not negligible, may be too small for robust generalizations. Geographical representation was not fully balanced, partly due to the data collection method. Additionally, the objective knowledge test was conducted online without supervision, so it cannot be ruled out that some respondents consulted literature.

Despite these limitations, the findings provide a valuable initial overview of the situation. Based on the results, recommendations include introducing systematic additional education, formalizing the role of the MRSO, developing national guidelines and protocols, improving educational programs, and establishing a system of continuous monitoring in practice.

Conclusion

The research demonstrated that radiologic technologists' understanding of SAR in the Republic of Croatia is primarily grounded in a solid grasp of basic concepts, whereas practical and technical aspects remain insufficiently applied. Neither a higher academic degree nor a longer work tenure statistically influenced knowledge test results, and self-assessment proved to be an unreliable measure of actual competence. Significant differences in the points achieved between the 1st and 4th Regional Councils confirm that the local context can substantially affect the level of expertise.

The strongest message comes from the profession itself: almost all participants expressed the need for additional, practically oriented education, which clearly speaks of awareness, but also of a gap that needs to be filled. Furthermore, it is necessary to enable targeted, evidence-based interventions in terms of MRSO certification, which would create a unified national framework for MR safety.

All data in this paper are part of the results of the master's thesis "SAR in Magnetic Resonance Imaging: A Study on the Education, Knowledge, and Practice of Radiologic Technologists in the Republic of Croatia", written at the Faculty of Health Sciences, University of Split. ■

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SAR u magnetskoj rezonanci: Istraživanje o edukaciji, znanju i praksi radioloških tehnologa u Republici Hrvatskoj

Sažetak

Uvod: Magnetska rezonancija (MR), kao suvremena dijagnostička metoda, predstavlja specifične sigurnosne izazove zbog izlaganja pacijenata snažnim elektromagnetskim poljima. Iz te perspektive, specifična apsorbirana snaga (*engl. Specific Absorption Rate – SAR*) ključni je sigurnosni parametar. Upravljanje SAR-om u kliničkoj praksi presudno je za sprječavanje prekomjernog zagrijavanja tkiva i osiguravanje sigurnosti pacijenata, posebice s obzirom na sve veći broj pregleda, učestalost metalnih implantata, tetovaža i kozmetike koja sadrži metalne pigmente, kao i na različitu dobnu strukturu pacijenata, što zahtijeva poseban obzir prema termoregulaciji kod pedijatrijske i gerijatrijske populacije. Radiološki tehnolozi imaju središnju ulogu u tom procesu, no ostaje nejasno u kojoj mjeri posjeduju formalnu edukaciju i znanje o SAR-u te kako se ti aspekti primjenjuju u praksi.

Cilj: Analizirati trenutačno stanje edukacije, teorijskog znanja i kliničke prakse radioloških tehnologa u Republici Hrvatskoj u kontekstu upravljanja i optimizacije SAR-a tijekom MR pregleda.

Metode: Provedeno je istraživanje među radiološkim tehnolozima s radnim iskustvom na MR-u u Republici Hrvatskoj. Upitnik je obuhvaćao pitanja o njihovoj formalnoj izobrazbi o sigurnosti na MR-u, razumijevanju koncepta SAR-a i provedbi sigurnosnih protokola u praksi.

Rezultati: Rezultati su pokazali da ni razina obrazovanja niti radno iskustvo nisu značajno korelirali s rezultatima na testu znanja. Nije pronađena statistički značajna razlika u broju točnih odgovora između magistara i prvostupnika ($p = 0,382$), kao ni s ukupnim radnim stažom ($p = 0,618$) ili specifičnim iskustvom na MR-u ($p = 0,409$). Jednosmjerna ANOVA otkrila je statistički značajne regionalne razlike u znanju ($p = 0,049$). Rezultati ukazuju na izražen raskorak između teorijskog znanja i njegove praktične primjene, što je dodatno potkrijepljeno činjenicom da je 96,2% ispitanika izrazilo potrebu za dodatnom edukacijom.

Zaključak: Dobiveni nalazi upućuju na nužnost uspostave sustavne edukacije radioloških tehnologa o sigurnosti na MR-u, s posebnim naglaskom na upravljanje SAR-om. Također se preporučuje uvođenje jedinstvenih, jasno definiranih sigurnosnih protokola te imenovanje osoba zaduženih za MR sigurnost unutar zdravstvenih ustanova.

Ključne riječi: edukacija; magnetska rezonanca; radiološki tehnolozi; SAR; sigurnosni protokoli