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Investigating computed tomography radiographers' expertise in responding to severe contrast media reactions: a cross-sectional study

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Abstract

Background The use of intravenous contrast media (IVCM) in computed tomography (CT) scans enhances image quality by improving detail and accuracy, which is crucial for diagnosing complex medical conditions. While IVCM does provide notable benefits, it also carries the risk of rare but potentially life-threatening adverse reactions. The aim of this study was to evaluate the expertise and preparedness of CT radiographers in managing severe adverse reactions to IVCM. Furthermore, the research seeks to examine how variables such as professional experience, training, and practice location affect the competence of CT radiographers in managing such occurrences.

Methods This cross-sectional survey assessed the knowledge and preparedness of Saudi CT radiographers in managing severe IVCM reactions. Following ethical approval from the Institutional Review Board (IRB) at King Abdullah Medical City (KAMC), an electronic survey was piloted with 15 radiographers for validation before distribution. Participants, recruited via snowball sampling through social media and professional networks, were accredited CT radiographers actively practicing in Saudi Arabia. The study examined knowledge variations based on experience, training, and practice setting. Although the target was 300 participants, 241 responses were obtained, providing meaningful insights into radiographers' competencies in contrast reaction management.

Results We assessed CT radiographers' knowledge and preparedness in managing severe IVCM reactions using different scales, achieving a high response rate of 97.2%. The overall knowledge measure demonstrated strong reliability, with a Cronbach's alpha coefficient of 0.854. The average knowledge score was 25.02 out of 40. Participants exhibited sufficient knowledge in various areas, with the highest proportion (93.4%) demonstrating awareness of precautionary measures for IVCM use. However, only 22.0% of participants attained consistent knowledge across all five assessed knowledge categories.

Conclusions This study demonstrates the importance of continuous professional development and structured training, specifically following international criteria, in improving the understanding of CT radiographers in Saudi

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Arabia about the management of adverse reactions to contrast media. Senior experts, as well as those with international training, demonstrate exceptional expertise.

Keywords Contrast media, Computed tomography, Adverse reactions, Radiographers

Introduction

Computed tomography (CT) scans, when enhanced with intravenous contrast media (IVCM), have significantly improved medical diagnostics by providing highly accurate and detailed imaging, thereby revolutionizing patient care. These technological advancements allow for precise imaging that assists in correct diagnosis and effective therapies, particularly in situations of intricate cardiovascular illnesses and cancers where early detection is essential for successful intervention [1–3]. Despite their common use and benefits, IVCMs carry inherent risks of adverse reactions. These reactions can be categorized into mild (e.g., nausea, vomiting, urticaria, localized pain), moderate (e.g., bronchospasm, hypertension, diffuse erythema), and severe reactions (e.g., pulmonary edema, cardiac arrhythmia, anaphylactic shock, circulatory collapse, and unconsciousness) [4, 5]. The underlying mechanisms of these reactions vary; while mild and moderate reactions are often histamine-mediated hypersensitivity responses, severe reactions can involve direct cardiac depression, endothelial damage, or severe allergic-like responses that necessitate immediate medical intervention [6–9]. The reported incidence of severe adverse reactions remains low, occurring in approximately 0.1–0.2% of low-osmolar contrast agent cases. However, their existence highlights the urgent requirement to respond promptly and skillfully in such circumstances to safeguard patient well-being [6–11].

The function of CT radiographers is crucial; they are frequently the first to identify indications of severe contrast media responses (SCMR), requiring prompt and proficient interventions to minimize hazards to patient well-being. Although radiologists are primarily responsible for managing these reactions, international guidelines from the American College of Radiology (ACR), Royal College of Radiologists (RCR), European Society of Urogenital Radiology (ESUR), and Royal Australian and New Zealand College of Radiologists (RANZCR) also outline important responsibilities for CT radiographers [12–15]. These guidelines share common recommendations, such as screening patients for risk factors (e.g., previous contrast reactions, asthma, renal impairment), ensuring emergency preparedness, and actively monitoring patients post-contrast administration. However, differences exist in their recommendations on premedication protocols, the level of radiographer autonomy in contrast reaction management, and the delegation of emergency response roles. For example, the ACR and ESUR emphasize immediate availability of resuscitation equipment and active monitoring by radiographers [12, 13], whereas RANZCR includes more detailed competency expectations for radiographers in administering emergency medications under supervision [15]. In Saudi Arabia, the Ministry of Health (MOH) aligns its protocols with these international standards, reinforcing radiographers' responsibilities in ensuring patient safety during contrast-enhanced CT procedures [16].

A broader review of the literature highlights variations in CT radiographers' competencies across different regions, emphasizing the need for improved training and standardization. Current research identifies a gap in the existing literature regarding the specific skills and expertise required for CT radiographers in Lithuania. The Lithuanian analysis revealed significant disparities in radiographers' competencies, primarily determined by their level of expertise. Research indicates that radiographers with greater experience exhibit elevated levels of proficiency and self-assurance, implying that their performance improves with the accumulation of practical experience over time [17]. Similarly, studies from Southeast Asia and the Middle East highlight significant inconsistencies in the implementation of global contrast media safety standards, particularly in emergency preparedness [18]. A key limitation in current training models is the lack of standardized education tailored specifically to radiographers, as many existing programs primarily target radiologists and other medical staff. The absence of dedicated, structured training programs results in varying levels of preparedness, with some departments lacking formal SCMR response protocols altogether [18]. This study seeks to address these gaps by evaluating CT radiographers' competencies in Saudi Arabia, examining the effectiveness of current training models, and assessing compliance with standardized emergency protocols.

This study aims to assess the knowledge and preparedness of CT radiographers in managing severe IVCM reactions, with a particular focus on emergency response capabilities. The objectives are twofold: (1) to evaluate radiographers' ability to recognize and manage SCMR efficiently and (2) to assess the effectiveness of existing training programs and departmental policies in equipping radiographers with the necessary skills for contrast emergency management. By identifying key knowledge gaps and training deficiencies, the study hopes to contribute to the development of standardized educational programs that enhance radiographers' preparedness, align with international best practices, and ultimately improve patient safety in radiological practice.

Methods

Research methodology

This cross-sectional study was conducted to assess the knowledge and preparedness of CT radiographers in Saudi Arabia in managing severe IVCM reactions. Before data collection began, ethical approval was obtained from the Institutional Review Board (IRB) at King Abdullah Medical City (KAMC) in Makkah, Saudi Arabia, under permission number 23-1068.

The study followed a structured approach: first, the questionnaire was developed and piloted, then the electronic survey was distributed, and responses were collected and analyzed. The questionnaire design phase involved an initial draft, which was reviewed and refined based on feedback from 15 experienced CT radiographers to enhance clarity and relevance. Adjustments were made primarily to improve linguistic clarity and ensure that the questions accurately reflected real-life clinical scenarios. The same group then completed the revised survey to confirm its final structure before distribution.

Sampling and sample size

Between June 2023 and July 2023, CT radiographers across Saudi Arabia were invited to participate in the study via an electronic survey. We aimed to recruit a sample size of 300 CT radiographers; however, we successfully obtained responses from 241 participants. The survey was distributed through specialist groups on social media platforms, including X (formerly Twitter) and Telegram, using a snowball sampling strategy. This approach was chosen due to the difficulty in accessing an up-to-date and comprehensive list of CT radiographers in Saudi Arabia. Snowball sampling allowed us to leverage professional networks, ensuring participation from various healthcare institutions [19].

This technique uses preexisting networks among CT radiographers, allowing the study to access their professional and social connections in order to find potential volunteers. The survey concentrated on CT radiographers who hold accreditation from the Saudi Commission for Health Specialties (SCFHS) and are currently working in Saudi Arabia. By involving specialists confirmed by a reputable accrediting authority, this recruitment technique not only secured a varied and inclusive sample, but also improved the study's validity. In 2018, the SCFHS accredited 3,773 radiologic radiographers. We projected that the SCFHS would grant an additional 1,000 accreditations annually in 2019 and 2020. Estimates put the total number of professionals at 6,773, including 2,000 diploma-holding radiographers [20, 21].

With a projected annual growth rate of 5% [22, 23], we anticipate that the total number of radiologic radiographers in 2023 will be approximately 7,841. We estimate that approximately 17.5% of the total, or around 1,350 CT radiographers, have expertise in CT imaging. The operational requirements of CT scanners nationwide determine this percentage projection. There are 450 hospitals that have at least one CT scanner. Each scanner needs a minimum of three CT radiographers to operate properly [22, 23]. Therefore, there is a total requirement for roughly 1,350 CT radiographers. Hence, the estimation that 17.5% of radiographers have expertise in CT imaging roughly corresponds to the practical requirements determined by the quantity of CT scanners and the operational demand in Saudi hospitals.

The determined sample size for the investigation, with a target of a 95% confidence level and a 5% margin of error, considering the anticipated maximum variability (50% predicted proportion), was around 300 CT radiographers. We established the sample size by considering the entire estimated population of 1,350 CT radiographers in Saudi Arabia in 2023. We used a formula that accounts for finite population correction, given the relatively limited and well-defined target group of specialized individuals within the healthcare industry. Nevertheless, the study only managed to obtain a sample size of 241 CT radiographers, which fell somewhat short of the anticipated requirement. The difficulties in utilizing snowball sampling, which relies on participants' willingness and ability to recruit future respondents from their networks, may have contributed to the deficiency in achieving the desired sample size. Although limited, the sample size of 241 is significant for obtaining qualitative insights and exploring unique behaviors, views, and experiences among CT radiographers in Saudi Arabia.

Questionnaire design and validation

We created the questionnaire using Google Forms and found it in the supplementary material section for further consultation. The survey consisted of two primary pieces. The first portion collected information on demographics, educational history, accreditation, work experience, and personal experiences with IVCM. This section also included a Likert-scale assessment to measure self-perceived expertise. This section correlated the expertise of CT radiographers in IVCM with their respective professional backgrounds. We subdivided the second component into five segments, each dedicated to unique facets: overall understanding of IVCM, variables that increase risk, patient readiness, detection of severe reactions, and methods for reducing adverse reactions. The response formats exhibited variation, encompassing true/false/don't know alternatives for general, preparation, and strategy-related inquiries. We used a modified 3-point Likert-type scale to assess risk variables and the severity of reactions. To ensure validity and reliability, content validity was established through expert review, while internal consistency was assessed using Cronbach's

alpha, yielding a coefficient of 0.854, indicating strong reliability.

Statistical analysis

The study employed the Statistical Package for Social Sciences (SPSS) for Windows, Version 22, to conduct a thorough statistical analysis, which included both descriptive and inferential techniques. We used descriptive statistics like percentages, frequency distributions, means, and standard deviations to characterize the participants' demographics, experiences, and knowledge areas. We used statistical techniques like analysis of variance (ANOVA) and *t*-tests to compare the knowledge levels among different groups. We also used chi-square tests to investigate the relationships between categorical variables. We also employed logistic regression to identify the factors that predict the knowledge levels of SCMR. The results were presented using tables.

Table 1 Demographic and professional characteristics

Parameter	Level	*N*	%
Age group	20–29	116	48.1
	30–39	98	40.7
	40–49	26	10.8
	50–59	1	0.4
Gender	Male	157	65.1
	Female	84	34.9
Nationality	Saudi	215	89.2
	Non-Saudi	26	10.8
Academic level	PhD	3	1.2
	Masters	26	10.8
	Bachelor	206	85.5
	Diploma	6	2.5
Position	Senior specialist	34	14.1
	Specialist	149	61.8
	Technician	58	24.1
Region	Central region	74	30.7
	Western region	83	34.4
	Eastern region	26	10.8
	Northern region	22	9.1
	Southern region	36	14.9
Working experience	≤ 5 years	112	46.5
	5–10 years	74	30.7
	≥ 10 years	55	22.8
Place of last qualification	Saudi Arabia	207	85.9
	Outside Saudi Arabia	34	14.1
Type of hospital	Military	37	15.4
	Central/specialist	62	25.7
	General	89	36.9
	Private	47	19.5
	University hospital	2	0.8
	Royal Commission Medical Center in Yanbu	1	0.4
	Not specified	3	1.2

Results

Summary of findings

This study assessed CT radiographers' knowledge of managing SCMR and found that the overall knowledge scale demonstrated strong reliability (Cronbach's alpha: 0.854) with an average score of 25.02 out of 40. While 93.4% of participants were aware of the necessary safety measures for SCMR, only 22% demonstrated consistent knowledge across all assessed areas. The study achieved a high response rate of 97.2%. However, formal training on SCMR management was limited, as only 33% of participants reported having received specialized training. Additionally, 17% of participants stated that they had witnessed a SCMR firsthand, yet the majority had not received structured education on managing such cases. Awareness of the risks associated with IVCM was substantial; however, only 56% correctly identified epinephrine as the preferred initial treatment. The findings indicate that experience and the region where radiographers received their education influenced their knowledge levels, emphasizing the importance of continuous training and standardized education in SCMR management.

Table 1 presents a concise overview of the demographics and professional information of the participants. The majority of participants, accounting for 48.1%, fall within the age range of 20–29 years. In terms of gender, 65.1% of the participants are male. Additionally, 89.2% of the participants are Saudi nationals. The majority of individuals possess a bachelor's degree, accounting for 85.5% of the group. Moreover, specialists employ 61.8% of them in Saudi Arabia, with 30.7% working in the Central region and 34.4% in the Western region. Approximately 46.5% of participants possess five years or less of work experience, suggesting a relatively youthful and moderately experienced cohort. 85.9% of the total acquired their qualifications in Saudi Arabia. General hospitals were the most prevalent workplace, representing 36.9% of the cases.

According to Tables 2, 44.4% of participants updated their knowledge on giving IVCM at their department's initial orientation. Meanwhile, 36.5% of the participants took part in further training courses, while 19.1% have not updated their skills since completing their programs. While 82.2% of the participants are knowledgeable about their department's protocols for providing IVCM, only 33.2% have undergone specialized training in handling SCMR, and a mere 17% have directly witnessed a severe response case. The participants' confidence levels in handling such reactions showed substantial variation. Specifically, 12.4% expressed a lack of confidence, 18.3% had a slight amount of confidence, 32% possessed a moderate level of confidence, 26.1% were quite confident, and 11.2% were exceedingly confident.

Table 2 Education and experience in IVCM

Parameter	Level	*N*	%
Last time you learnt about IVCM	Department orientation	107	44.4
	Training course	88	36.5
	Never	46	19.1
Department having a policy on handling IVCM	No	43	17.8
	Yes	198	82.2
Received training for handling patients with SCMR	No	161	66.8
	Yes	80	33.2
Witnessed a SCMR case	No	200	82.9
	Yes	41	17.0
Confidence in managing a SCMR case	Not confident at all	30	12.4
	Slightly confident	44	18.3
	Moderately confident	77	32.0
	Very confident	63	26.1
	Extremely confident	27	11.2

Table 3 Reliability analysis of the different study scales

Scale	No. items	Cronbach's alpha	Mean score	SD score	Adequate knowledge rate⁂
Overall knowledge scale	40	0.854	25.02	5.62	82.6%
Overall knowledge scale without general knowledge about IVCM	35	0.845	-	-	-
General knowledge about IVCM	5	0.450	2.85	0.91	64.3%
Risk factors of SCMR	10	0.727	5.73	1.80	56.4%
Precautions against SCMR	5	0.539	4.09	0.96	93.4%
Recognizing SCMR	10	0.751	7.14	2.20	80.1%
SCMR Management	10	0.859	5.21	2.37	50.2%

⁂Adequate knowledge is defined as a score that surpasses the theoretical average, which is calculated by dividing the maximum possible score by 2. For example, when it comes to general knowledge (with a maximum score of 40), a score greater than 20 is considered sufficient. However, for risk factors (with a maximum score of 10), a score higher than 5 is considered suitable

Table 3 presents an assessment of the reliability of the study scales. The Cronbach's alpha coefficient of 0.854 indicates the reliability of the 40-item overall knowledge scale. However, excluding the general IVCM knowledge questions marginally decreases the reliability to an alpha coefficient of 0.845. The general knowledge regarding the IVCM scale's dependability was low, with an alpha coefficient of 0.450. The SCMR management scale exhibited a good level of reliability, with a coefficient alpha value of 0.859. The participants exhibited varying levels of knowledge across different scales, with an overall knowledge rate of 82.6%. SCMR precautions demonstrated the highest level of sufficiency, with a rate of 93.4%. SCMR management knowledge scored 50.2% on the scale, just above half of the maximum score, indicating the lowest level of adequacy.

Furthermore, Table 4 investigates the relationships between several knowledge subscales related to SCMR. Significant relationships were found between risk factors and overall knowledge ($r = 0.714$, $p < 0.001$), as well as between clinical presentation and overall knowledge ($r = 0.734$, $p < 0.001$). In addition, there was a strong correlation between the general knowledge dimension and risk factors ($r = 0.302$, $p < 0.001$), precautions ($r = 0.196$, $p = 0.002$), and management ($r = 0.163$, $p = 0.011$).

According to Table 5, participants who were 40 years old or older had the highest knowledge ratings about controlling SCMR. Participants with a PhD achieved the highest scores compared to other degrees of education. Senior specialists achieved the highest ratings compared to other work positions, while participants who had their education outside of Saudi Arabia obtained even higher marks, with noticeable variations. The SCMR did not show any significant variation in knowledge levels based on gender, area, experience, or hospital type.

Moreover, according to Table 6, those who participated in the training course had somewhat greater levels of expertise in IVCM compared to those who received department orientation or had no training, with a marginal level of statistical significance. Departments with

Table 4 Correlations between the different knowledge subscales about SCMR

Knowledge dimension	General	Risk factors	Precautions	Clinical presentation	Management	Overall
General	-	0.302 (< 0.001*)	0.196 (0.002*)	0.122 (0.058)	0.163 (0.011*)	0.409 (< 0.001*)
Risk factors	-	-	0.387 (< 0.001*)	0.345 (< 0.001*)	0.330 (< 0.001*)	0.714 (< 0.001*)
Precautions	-	-	-	0.368 (< 0.001*)	0.318 (< 0.001*)	0.605 (< 0.001*)
Presentation	-	-	-	-	0.346 (< 0.001*)	0.734 (< 0.001*)
Management	-	-	-	-	-	0.743 (< 0.001*)
Overall	-	-	-	-	-	-

*Values are Pearson's correlation coefficient (*P*-value)

Table 5 Demographic and professional factors associated with knowledge about SCMR

Factor	Level	Overall knowledge score			Consistent knowledge	
		Mean	SD	*P*-value	Rate	*P*-value
Age group	20–29	24.67	4.64	0.001*	16.4	0.020*
	30–39	24.38	6.41		23.5	
	40+	28.85	5.05		40.7	
Gender	Male	24.81	5.92	0.425	23.6	0.420
	Female	25.42	5.01		19.0	
Nationality	Saudi	24.57	5.53	< 0.001*	19.1	0.002*
	Non-Saudi	28.77	4.96		46.2	
Academic level	PhD	30.33	0.58	0.251	33.3	0.650
	Masters	23.73	8.91		30.8	
	Bachelor	25.11	5.11		20.9	
	Diploma	25.00	4.60		16.7	
Position	Senior specialist	27.09	5.92	0.007*	38.2	0.023*
	Specialist	25.20	5.19		21.5	
	Technician	23.34	6.09		13.8	
Region	Central region	25.14	4.75	0.724	20.3	0.260
	Western region	24.71	6.26		25.3	
	Eastern region	25.35	5.77		23.1	
	Northern region	23.95	6.47		4.5	
	Southern region	25.92	5.17		27.8	
Working experience	≤ 5 years	24.13	5.07	0.068	13.4	0.008*
	5–10 years	25.89	4.70		27.0	
	≥ 10 years	25.67	7.37		32.7	
Place of last qualification	Saudi Arabia	24.60	5.55	0.004*	18.8	0.004*
	Outside Saudi Arabia	27.59	5.40		41.2	
Type of hospital	Military	25.16	5.40	0.015*	21.6	0.004*
	Central/ specialist	26.74	5.59		37.1	
	General	23.45	5.68		12.4	
	Private	25.49	5.33		21.3	
	University hospital	26.00	4.24		0.0	
	RCMC in Yanbu	30.00	-		100.0	
	Not specified	-	-		-	

*The result was statistically significant ($p < 0.05$). We used an independent *t*-test or one-way ANOVA for the overall knowledge score, as appropriate, and a chi-square test for the consistent knowledge rate

Table 6 Association of knowledge with prior education and experience in IVCM

Parameter	Level	Overall knowledge score			Consistent knowledge	
		Mean	SD	*P*-value	Rate	*P*-value
Last time you learnt about IVCM	Department orientation	24.74	5.76	0.050	24.3	0.051
	Training course	26.07	5.48		26.1	
	Never	23.67	5.27		8.7	
Department having a policy on handling IVCM	No	23.30	6.13	0.027*	2.3	< 0.001*
	Yes	25.39	5.44		26.3	
Received training for handling patients with SCMR	No	24.96	5.55	0821	19.3	0.146
	Yes	25.14	5.78		27.5	
Witnessed a SCMR case	No	24.68	5.62	0.342	19.8	0.417
	Yes	25.37	5.61		24.2	
Confidence in managing a SCMR case	Not confident at all	22.20	6.64	0.011*	6.7	0.012*
	Slightly confident	24.02	4.95		9.1	
	Moderately confident	25.78	4.84		26.0	
	Very confident	26.14	6.27		31.7	
	Extremely confident	25.00	4.88		25.9	

*Statistically significant result ($p < 0.05$)

Table 7 Predictors for consistent knowledge about SCMR (multivariate logistic regression)

Predictor	Level	OR	95% CI		*P*-value
Age group	20–29	1.24	0.25	6.27	0.792
	30–39	0.71	0.21	2.38	0.580
	40+	Ref	-	-	0.534
Nationality	Saudi	0.28	0.07	1.18	0.084
	Non-Saudi	Ref	-	-	-
Position	Senior specialist	Ref	-	-	0.036*
	Specialist	0.78	0.30	2.04	0.617
	Technician	0.23	0.07	0.79	0.019*
Working experience	≤ 5 years	0.34	0.09	1.32	0.120
	5–10 years	0.95	0.36	2.51	0.919
	≥ 10 years	Ref	-	-	0.177
Place of last qualification	Saudi Arabia	Ref	-	-	-
	Outside Saudi Arabia	0.97	0.29	3.28	0.963
Department Policies	Absent	0.10	0.01	0.81	0.031*
	Present	Ref	-	-	-
Confidence in managing a SCMR case	Not confident at all	0.61	0.09	3.96	0.603
	Slightly confident	2.47	0.50	12.21	0.268
	Moderately confident	2.16	0.42	11.01	0.354
	Very confident	1.95	0.33	11.58	0.465
	Extremely confident	Ref	-	-	0.204

OR: Odds ratio; 95% CI: 95% confidence interval; *statistically significant result ($p < 0.05$)

IVCM handling policies had staff members with notably superior expertise compared to departments without such policies. There is a strong correlation between confidence levels, especially among highly confident respondents, and the highest knowledge scores. This suggests that there is a wide range of knowledge levels across different levels of confidence. Additional characteristics, such as IVCM treatment training, SCMR case observation, and overall confidence, did not have a significant impact on knowledge scores.

Using logistic regression, Table 7 examines the factors that predict consistent SCMR knowledge. Only working positions and department policies strongly predicted consistent knowledge of SCMR. Technicians had a lower probability (odds ratio (OR): 0.23) of possessing consistent knowledge compared to senior experts. Furthermore, staff members in departments that did not have SCMR rules were less likely (OR = 0.10) to have consistent knowledge. Age, nationality, job experience, final qualification place, and confidence in managing SCMR cases were not statistically significant predictors.

Discussion

The study assessed Saudi CT radiographers' competence in managing severe allergic reactions to IVCM, focusing on their ability to identify symptoms, take appropriate actions, and administer necessary interventions [24]. International guidelines emphasize the role of radiographers in early recognition and immediate response to contrast reactions, yet studies in other regions, such as the UK and Australia, have highlighted similar challenges in ensuring adequate preparedness among radiographers [25]. The researchers established a standard for 'consistent knowledge,' defined as surpassing the theoretical average scores across all five assessed domains, with the knowledge scale demonstrating high reliability (Cronbach's alpha = 0.854). While 93.4% of radiographers in this study recognized the basic precautions required for SCMR, only 22.0% ($n = 53$) demonstrated comprehensive and consistent knowledge across all critical domains. This aligns with prior research conducted in Europe, which found that even in well-regulated healthcare systems, gaps in contrast media reaction management persist due to insufficient hands-on training and limited exposure to real-life emergencies [25]. These findings underscore the need for continuous education and standardized training programs to ensure that radiographers are adequately prepared to manage severe IVCM reactions effectively.

Using logistic regression, Table 7 examines the factors that predict consistent SCMR knowledge. We found that only the presence of working positions and adherence to department policies were significant predictors of consistent knowledge of SCMR. Technicians had a lower probability (odds ratio (OR): 0.23) of possessing consistent knowledge compared to senior experts. Furthermore, staff members in departments that did not have SCMR rules were less likely (OR = 0.10) to have consistent knowledge. Age, nationality, job experience, last qualification place, and confidence in addressing SCMR cases did not demonstrate significant predictive power. These findings suggest that experience alone is not sufficient—structured training and adherence to standardized policies play a critical role in building competence.

The study investigated the relationship between previous education and experience with contrast media, as well as a consistent understanding of SCMR. Participants lacking training in contrast media exhibited a much lower level of consistent knowledge (8.7%) in comparison to those who had received some form of training (24.3% and 26.1%). The statistical finding, while not reaching conventional levels of significance ($p = 0.051$), indicates a potential trend, albeit not definitively significant. Departments that have a specialized policy for managing IVCM showed significantly superior outcomes. Among their workforce, there was a 26.3% rate of strong knowledge, compared to just 2.3% in departments without such rules ($p < 0.001$). Confidence levels had a significant impact on knowledge rates. Individuals who were highly confident or extremely confident in managing severe reactions had higher knowledge scores (31.7% and 25.9%, respectively) compared to those who lacked confidence or

were only slightly confident (6.7% and 9.1%, respectively) ($p = 0.012$). Both adherence to departmental norms and personal confidence are essential for understanding and efficiently handling SCMR.

Self-assessment surveys, commonly used to evaluate overconfidence, ask participants to rank their perceived capabilities. Discrepancies observed between these self-assessments and objective measures of knowledge or performance, such as tests and practical evaluations, suggest the presence of overconfidence. We frequently utilize statistical analysis, such as correlation and regression, to delve deeper into these associations and distinguish between authentic competence and overconfidence. Consistent professional growth and unbiased evaluation are crucial for eliminating excessive self-assurance and ensuring that confidence levels align with actual ability. The study reveals a worrisome deficiency in training among radiographers, as 44.4% of participants said that their most recent instruction on IVCM took place solely at their initial department orientation. Despite 82% of departments having policies for IVCM, the reliance on initial training and the fact that only 34% received specialized training for handling contrast responses highlight a notable disparity in SCMR readiness, which is uncommon but potentially life-threatening.

In comparison, radiography programs in the United States (US) evaluate the ability to handle immediate reactions, suggesting a need for significant enhancements in teaching [26]. These programs often assess radiologists, setting a benchmark for the proficiency required to handle crises involving contrast media responses (CMRs) that range in severity from moderate to severe. This technique could also be beneficial for CT radiographers, particularly if the training includes thorough patient management during imaging procedures.

Recent training techniques, such as simulations, which offer greater interactivity compared to traditional lectures, have demonstrated superior efficacy in enhancing both knowledge and confidence in managing IVCM reactions [26, 27]. Training programs should incorporate these strategies to address all possible levels of reaction intensity, thereby providing comprehensive preparedness [27–29]. In Saudi Arabia, radiographers can enhance practice standards and provide consistent, high-quality care, especially in controlling SCMR, by implementing a systematic strategy comparable to that of radiology programs in the US. This indicates a requirement for continuous hands-on training that prioritizes collaborative learning in order to enhance radiological safety and efficiency.

It is advisable to conduct yearly audits of IVCM reaction management knowledge and skills in order to uphold rigorous standards [17]. This should encompass not only radiologists but also radiographers, nurses, and maybe hospital doctors who are involved in the imaging process. It is desirable for a respected healthcare accreditation organization or professional group to create a nationwide benchmark for these hands-on and collaborative evaluations. Implementing these standards would improve patient safety and care effectiveness in all areas.

According to the study, 17.0% of CT radiographers had seen a patient undergo SCMR. Given the rarity of such reactions in typical clinical practice [6], the percentage is relatively high, indicating a higher frequency of these episodes among the polled group. This discovery highlights the experts' significant vulnerability to infrequent but critical events, emphasizing the critical importance of hands-on experience and rigorous training in dealing with these crises. The high frequency of occurrences emphasizes the importance of a professional response to ensure patient safety and maintain trust in medical imaging services. The statement emphasizes the importance of ongoing education, strict adherence to protocols, and possibly reassessing existing methods in order to improve SCMR management. Furthermore, this discovery suggests that healthcare facilities should prioritize providing structured training and resources for SCMR management. Furthermore, it proposes novel approaches to investigate methods for reducing the frequency and intensity of these undesirable responses, with the ultimate goal of improving patient care and fostering trust in healthcare delivery.

The study found a strong correlation between academic levels and knowledge about IVCM usage in CT scans. Specifically, 97.2% of participants concurred that the use of IVCM enhances the visibility of specific structures in CT scans. Additionally, 86.8% of participants were aware that patients with a history of severe allergic reactions to IVCM may have contraindications for further administration. This correlation was statistically significant, with a *P*-value of less than 0.05. Recent modifications in clinical recommendations have enhanced the management of adverse reactions to IVCM. Previous allergic-type reactions to IVCM dramatically elevate the likelihood of future reactions requiring premedication, especially for individuals who have experienced moderate to severe reactions in the past. Implementing suitable preventive measures, such as the administration of corticosteroids and antihistamines, typically reduces the likelihood of a mild reaction progressing to a more severe one [12]. We typically give these medications 12 to 2 h prior to the treatment to significantly reduce the chances of negative reactions. Recent guidelines propose that patients who have previously experienced only mild reactions may not require any premedication or may only need antihistamine premedication. The choice of premedication should be based on the patient's history and the severity of their previous reactions [30]. This method ensures patient

well-being while reducing unnecessary medication use, particularly in environments where immediate medical assistance is available.

There is increasing concern in the literature about whether CT radiographers have sufficient understanding to effectively manage contrast-induced responses [31–34]. A study has shown that a significant number of CT radiographers may have limited understanding when it comes to recognizing and handling severe responses, such as anaphylaxis [31]. More precisely, a study found that approximately 63% of CT radiographers demonstrated accurate recognition of the signs and symptoms of anaphylaxis, whereas less than half were knowledgeable about the appropriate management measures [31]. Moreover, radiographers who have not received current training on the subject are more likely to make errors in managing contrast reactions [32]. This highlights a notable deficiency in ongoing education and underscores the need for up-to-date and regular training programs to improve the safety and effectiveness of contrast media utilization [33–37].

The study investigated CT radiographers' comprehension of the risk variables linked to IVCM responses. It revealed that a substantial majority of radiographers acknowledge impaired renal function, asthma, and past unpleasant reactions as significant risk factors. More precisely, 89.2% of the participants recognized poor renal function as a risk factor, 88% mentioned asthma, and 80.8% acknowledged previous adverse reactions. These percentages significantly exceed those reported in prior research, such as the one conducted by Khan et al. [31]. Having a high level of awareness is crucial due to the potentially serious repercussions of adverse reactions to IVCM. Gaining a deeper understanding of this topic is crucial for enhancing patient safety during radiological procedures that necessitate the use of contrast media. Training and ongoing professional growth are crucial for maintaining a high level of awareness. Customized education efforts for CT radiographers are necessary to address any knowledge gaps and stay current with the evolving understanding of risk factors associated with IVCM.

The participants in this study demonstrated a rather good level of awareness regarding the initial treatment protocols and standard guidelines for SCMR. The primary treatment for anaphylactic responses involves the prompt injection of epinephrine, diluted at a ratio of 1:1000. Adults should inject 0.3 mg intramuscularly in the mid-outer thigh. Either an auto-injector or a premeasured syringe can accomplish this [35]. The accurate dosage, concentration, and administration technique for injectable epinephrine are crucial but sometimes misconstrued elements, as emphasized in the training assessments [27]. A study found that approximately one-third of participants correctly identified the dosage and speed of epinephrine administration for SCMR due to IVCM. However, half of the participants were aware of the correct method of administration. The results align with the findings of a comparable study carried out in Turkey [38]. The rationale for delivering two intramuscular injections of 0.3 mg of epinephrine is based on the requirement to guarantee prompt and adequate absorption into the bloodstream in order to effectively fight severe allergic reactions. Administration of this protocol may necessitate the involvement of medically qualified professionals, such as radiographers, particularly in urgent situations where a prompt response is crucial [39]. If the patient does not show any improvement after the initial dosage, these injections typically last only a few minutes.

In Saudi Arabia, the regulations regarding radiographers' use of drugs such as epinephrine in emergency situations differ. Usually, only medical practitioners have the authority to prescribe and administer emergency remedies. However, in emergency situations where a medical professional might not be immediately available, authorized radiographers can legally administer emergency drugs in accordance with specific guidelines to stabilize the patient until further medical assistance arrives. In order to perform these potentially life-saving actions, facilities must ensure that radiographers receive adequate training and legal protection under their local health legislation. This approach would be in accordance with established emergency protocols, but its feasibility would be contingent upon the existing legal and regulatory framework governing the dispensation of drugs by non-physician workers [17].

The analysis of this study showed that senior experts achieved superior average knowledge scores (26.89 ± 5.95) compared to both specialists and technicians. Notably, the study also revealed that participants who obtained their qualifications from institutions outside of Saudi Arabia achieved higher scores (27.49 ± 5.35) compared to those who received their qualifications within Saudi Arabia. The statistical study revealed strong relationships between the participant's present job position, the geographical region of their most recent certification, and their overall knowledge scores for the management of reactions to contrast media (P-value < 0.05). These findings indicate that both the level of seniority and the diversity of educational backgrounds are critical factors in determining the extent of knowledge regarding SCMR safe management.

Implications and recommendations

These findings have important implications for radiography training programs and clinical policies in Saudi Arabia. First, there is an urgent need to incorporate standardized, hands-on emergency response training

in radiography curricula. Second, institutions should implement mandatory simulation-based workshops for radiographers, ensuring they are adequately prepared to manage severe contrast reactions. Third, national healthcare accreditation bodies should establish competency benchmarks to assess and standardize emergency training across all radiology departments. Lastly, policies permitting trained radiographers to administer emergency medications should be explored, particularly in high-risk settings where immediate intervention is critical.

Limitations

The study presents several limitations that should be considered. A key constraint is the reliance on self-reported data, which may introduce bias as responses reflect perceived rather than actual competencies. While self-assessment is common in similar studies, it can misestimate expertise. To mitigate this, we ensured content validity through expert review and piloting. Future studies could cross-validate findings using practical assessments, institutional records, or simulations.

The use of snowball sampling, while expanding participant reach, may have introduced selection bias by underrepresenting radiographers from smaller hospitals or those less active on digital platforms. As a result, the sample may not fully reflect the diversity of CT radiographers across Saudi Arabia. Future research should consider systematic sampling methods, such as stratified or random sampling, to improve representativeness.

The generalizability of findings beyond Saudi Arabia is another limitation. Variations in training standards, institutional policies, and emergency response protocols across different countries may affect applicability. However, trends observed in this study—such as gaps in structured training and the impact of experience on competency—align with research from Europe, Australia, and North America. Comparative studies across multiple regions would further assess the global relevance of these findings.

Additionally, as a cross-sectional study, this research provides only a snapshot of radiographers' knowledge at a single point in time. It cannot track how competencies evolve with experience or training. Future research should employ longitudinal designs to evaluate knowledge progression and the impact of ongoing education on SCMR preparedness.

Despite these limitations, this study offers valuable insights into CT radiographers' preparedness for managing IVCM reactions, emphasizing the need for structured education and standardized emergency response training. Addressing these limitations in future research would further strengthen the findings' applicability and robustness.

Conclusions

This study provides insights into the competencies of CT radiographers in Saudi Arabia in managing SCMR. Findings indicate that senior experts have higher knowledge scores than junior staff, highlighting the role of experience in expertise development. Radiographers trained abroad showed greater proficiency, possibly due to differences in education, training exposure, or structured emergency programs. A significant correlation was found between employment positions, qualification location, and overall knowledge scores, reinforcing the need for standardized, ongoing professional development. Implementing training programs aligned with international best practices is essential to equip all radiographers with the necessary skills to manage SCMR effectively.

To enhance emergency preparedness and patient safety, mandatory SCMR training should be introduced, incorporating high-fidelity simulations and hands-on emergency drills. Annual competency assessments should reinforce radiographers' ability to handle real-life emergencies. Healthcare institutions must standardize protocols for contrast media reactions, ensuring clear guidelines on emergency preparedness, including radiographers' roles in administering medications when immediate medical support is unavailable. These findings should inform radiography curricula by integrating structured SCMR management courses. Additionally, establishing a national competency framework will certify radiographers' ability to manage SCMR, ensuring compliance with international safety standards. By implementing these recommendations, healthcare institutions can enhance imaging services, strengthen emergency readiness, and promote high-quality, standardized radiology care in Saudi Arabia and globally.

Abbreviations

ACR	American College of Radiology
ANOVA	Analysis of variance
CMRs	Contrast media responses
CT	Computed tomography
ESUR	European Society of Urogenital Radiology
IRB	Institutional Review Board
IVCM	Intravenous contrast media
KAMC	King Abdullah Medical City
MOH	Ministry of Health
OR	Odds ratio
RANZCR	Royal Australian and New Zealand College of Radiologists
RCR	Royal College of Radiologists
SCFHS	Saudi Commission for Health Specialties
SCMR	Severe contrast media responses
SPSS	Statistical Package for Social Sciences
US	United States

Supplementary Information

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Supplementary Material 1

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Author contributions
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Data availability
Data generated in this study are available from the corresponding author upon reasonable request with a completed Materials Transfer Agreement, excluding the materials including personally identifiable information.

Declarations

Ethics approval and consent to participate
This study was approved by the Institutional Review Board (IRB) at King Abdullah Medical City (KAMC) in Makkah, Saudi Arabia, under authorization number 23-1068. Additionally, all subjects willingly supplied written informed consent. The study adheres to the ethical standards outlined in the 2013 Helsinki Declaration. We provided a clear and concise explanation of the study's goals to all participants. The study ensured the privacy and anonymity of each participant, with no disclosure of their information and equal consideration for all individuals. Voluntary participation was required. The participant is entitled to withdraw at any moment without incurring any penalties. The utilization of an encoded questionnaire does not compromise the privacy and confidentiality of the participant, and we intentionally address concerns regarding privacy. The participant is entitled to receive the benefits of the researcher's (authors') knowledge and expertise.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Piorkowski A, Obuchowicz R, Najjar R. Redefining radiology: a review of artificial intelligence integration in medical imaging. Diagnostics. 2023;13:2760.
2. Cao CF, Ma KL, Shan H, Liu TF, Zhao SQ, Wan Y, et al. CT scans and cancer risks: a systematic review and dose-response meta-analysis. BMC Cancer. 2022;22:1–13.
3. Singh V, Sandean DP, CT Patient Safety And Care. 2023 Jan 2. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2024 Jan–. PMID: 33620869.
4. Andreucci M, Solomon R, Tasanarong A. Side effects of radiographic contrast media: pathogenesis, risk factors, and prevention. Biomed Res Int. 2014;2014.
5. Thomsen HS, Morcos SK. Radiographic contrast media. BJU Int. 2000;86:1–10.
6. Vasavada A, Agrawal N, Parekh P, Vinchurkar M. Extensive idiosyncratic allergic reaction to non-ionic, low osmolar small dose contrast in a patient premedicated with antihistamine and steroids. Case Rep. 2014;2014:bcr2014205323.
7. Baerlocher MO, Asch M, Myers A. The use of contrast media. CMAJ. 2010;182:697–697.
8. Delaney A, Carter A, Fisher M. The prevention of anaphylactoid reactions to iodinated radiological contrast media: a systematic review. BMC Med Imaging. 2006;6:1–7.
9. Kim MH, Lee SY, Lee SE, Yang MS, Jung JW, Park CM, et al. Anaphylaxis to iodinated contrast media: clinical characteristics related with development of anaphylactic shock. PLoS ONE. 2014;9(6):e100154.
10. Trygg E, Bjällmark A, Ahlander BM, Kihlberg J. Radiographers' confidence in handling iodine based contrast media hypersensitivity reactions. Radiography (Lond). 2024;30:21–7.
11. Abu Awwad D, Hill S, Chau M, Lewis S, Jimenez YA. Radiography students' knowledge, attitude and practice relating to infection prevention and control in the use of contrast media injectors in computed tomography. J Med Radiat Sci. 2024;Epub ahead of print. https://doi.org/10.1002/jmrs.820
12. ACR Committee on Drugs and Contrast Media. ACR Manual on Contrast Media. Virginia: American College of Radiology; 2023 [cited 2024 Feb 19]. 151 p. Available from: https://www.acr.org/-/media/ACR/Files/Clinical-Resources/Contrast_Media.pdf?1682766704942
13. European Society of Urogenital Radiology. ESUR Guidelines on Contrast Agents. Paris: European Society of Urogenital Radiology; 2022 [cited 2024 Jan 21]. 46 p. Available from: https://www.esur.org/wp-content/uploads/2022/03/ESUR-Guidelines-10_0-Final-Version.pdf
14. Millar-Mills M, Filippini C, Carter R, Elhassan H, Chen J. Recognition and management of IV contrast reactions– a re-audit. Clin Radiol. 2019;74:e30.
15. Faculty Of Clinical Radiology. RANZCR Iodinated Contrast Guidelines. Sydney: The Royal Australian and New Zealand College of Radiologist; 2018 [cited 2024 Mar 18]. 46 p. Available from: https://www.ranzcr.com/college/document-library/iodinated-contrast-guidelines-2016?searchword=odinated guidelines
16. Assistant Agency for Supportive Medical Services - General Directorate of Radiology & Applied Services. Protocols on the Safe Use of Contrast Media in Radiology Departments. Riyadh: Ministry of Health; 2021 [cited 2024 Jan 7]. 55 p. Available from: https://www.moh.gov.sa/en/Ministry/MediaCenter/Publications/Documents/Protocols-of-CM.pdf
17. Vanckavičiene A, Macijauskiene J, Blaževičiene A, Basevičius A, Andersson BT. Assessment of radiographers' competences from the perspectives of radiographers and radiologists: a cross-sectional survey in Lithuania. BMC Med Educ. 2017;17:1–10.
18. Zhong J, Chen L, Xing Y, Lu J, Shi Y, Wang Y, et al. Just give the contrast? Appraisal of guidelines on intravenous iodinated contrast media use in patients with kidney disease. Insights Imaging. 2024;15:1–13.
19. Naderifar M, Goli H, Ghaljaie F. Snowball sampling: a purposeful method of sampling in qualitative research. Strides Dev Med Educ. 2017;14.
20. Alhozaimi AH, Almusabahi A, Almesned AF. The needs of radiology technologists in radiology departments in Saudi Arabian hospitals. J Res Med Dent Sci. 2023;11:122–31.
21. Alomran S, Alhosni A, Alzahrani K, Alamodi A, Alhazmi R. The reality of the Saudi health workforce during the next ten years 2018–2027. Saudi Comm Health Specialties. 2017;1:17–9.
22. Statista. Hamburg: German database company. 2024 -. [cited 2024 Feb 19]. Available from: https://www.statista.com/statistics/608528/number-of-hospitals-in-saudi-arabia-by-region/
23. Saudi Open Data Portal. Riyadh: Saudi Data & AI Authority. 2024 -. [cited 2024 Feb 5]. Available from: https://od.data.gov.sa/en
24. Baerlocher MO, Asch M, Myers A. Allergic-type reactions to radiographic contrast media. CMAJ. 2010;182:1328–1328.
25. Anaphylactic Reactions in Radiology Procedures. Recent advances in asthma research and treatments. London: IntechOpen Limited. 2021 [cited 2024 Jan 16]. 13 p. Available from: https://cdn.intechopen.com/pdfs/74864.pdf

26. Petscavage JM, Paladin AM, Wang CL, Schopp JG, Richardson ML, Bush WH. Current status of residency training of allergic-like adverse events to contrast media. Acad Radiol. 2012;19:252–5.
27. Wang CL, Soloff EV. Contrast reaction readiness for your department or facility. Radiol Clin North Am. 2020;58:841–50.
28. Ali S, Alexander A, Lambrix M, Ramakrishna R, Yang CW. High-fidelity simulation training for the diagnosis and management of adverse contrast media reactions. Am J Roentgenol. 2019;212:2–8.
29. Pippin K, Everist B, Jones J, Best S, Walter C, Hill J, et al. Implementing contrast reaction management training for residents through high-fidelity simulation. Acad Radiol. 2019;26:118–29.
30. Huynh K, Baghdanian AH, Baghdanian AA, Sun DS, Kolli KP, Zagoria RJ. Updated guidelines for intravenous contrast use for CT and MRI. Emerg Radiol. 2020;27:115–26.
31. Khan F, Abbas F, Hilal K, Samad M, Wahid G, Ali I, Khan A, Sahito AM, Kumari U, Wasim E, Iqbal R, Mumtaz H, Saeed MA. Knowledge assessment of radiologists, radiology residents, and radiographers regarding contrast materials and management of adverse drug reactions occurring due to contrast materials: a cross-sectional study. Ann Med Surg (Lond). 2023;85:3347–52.
32. Coupal TM, Buckley AR, Bhalla S, Li JL, Ho SGF, Holmes A, et al. Management of acute contrast reactions-understanding radiologists' preparedness and the efficacy of simulation-based training in Canada. Can Assoc Radiol J. 2018;69:349–55.
33. Beckett KR, Moriarity AK, Langer JM. Safe use of contrast media: what the radiologist needs to know. Radiographics. 2015;35:1738–50.
34. Morcos SK. Review article: acute serious and fatal reactions to contrast media: our current understanding. Br J Radiol. 2005;78:686–93.
35. Lieberman P, Nicklas RA, Randolph C, Oppenheimer J, Bernstein D, Bernstein J, et al. Anaphylaxis—a practice parameter update 2015. Ann Allergy Asthma Immunol. 2015;115:341–84.
36. Nandwana SB, Walls DG, Torres WE. Radiology department preparedness for the management of severe acute iodinated contrast reactions: do we need to change our approach? Am J Roentgenol. 2015;205:90–4.
37. Pietsch H, Jost G. Contrast media for modern computed tomography. In: Alkadhi H, Euler A, Maintz D, Sahani D, editors. Spectral imaging: dual-energy, multi-energy and photon-counting CT. Springer, Cham; 2022.
38. Arslan G, Balci A, Cubuk R, Cetinkaya F. Knowledge and experience of radiologists working in Istanbul on radiographic contrast medium anaphylaxis. AIMS Allergy Immunol. 2017;1:71–7.
39. Sicherer SH, Simons FER, Mahr TA, Abramson SL, Dinakar C, Fleisher TA, et al. Epinephrine for first-aid management of anaphylaxis. Pediatrics. 2017;139:e20164006.

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