Cross-sectional Study

ANNALS OF MEDICINE & SURGERY

OPEN

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

Faheemullah Khan, MBBS, MD[a], Fakhar Abbas, MBBS[c], Kiran Hilal, MBBS, FCPS[a], Mehreen Samad, MBBS, FCPS[e], Ghazala Wahid, MBBS, FCPS[e], Iftikhar Ali, Pharm-D, Mphil[f], Adil Khan, MBBS[g], Abdul Moiz Sahito, MBBS[b], Usha Kumari, MBBS, MD[b], Ezza Wasim, MBBS[d], Raheel Iqbal, MBBS[e], Hassan Mumtaz, MBBS, MRSPH[h]*, Muhammad Arif Saeed, MBBS, FCPS, FRCR[i]

Purpose: The purpose of this study was to assess the knowledge of the radiology personnel regarding contrast media used in radiology and the management of associated adverse drug reactions.

Methods: A questionnaire-based cross-sectional study was conducted from 21 February to 31 March 2019 in five major hospitals of Peshawar, Pakistan. A 30-item questionnaire was adopted from the existing literature containing both open and closed-ended questions and the authors conducted a pilot study among 25 participants to assess the face validity of the tool. A universal sampling technique was adopted. Descriptive statistics were used to summarize the findings of the study.

Results: Less than half of the participants could correctly classify iodinated contrast media used in radiology on the basis of ionicity and osmolaity. Sixty-three percent chose severe contrast material-induced allergic reaction as type I hypersensitivity reaction while almost half of them correctly identified the features of iodinated contrast media associated with lesser side effects. Very few of them (6.7%) had read the ACR 2018 manual on contrast media. Regarding the risk factors for acute adverse reactions and signs/symptoms of anaphylaxis few could answer satisfactorily. Twenty-eight percent of participants correctly identified epinephrine as the initial medication in an anaphylactic reaction. Regarding the preferred route of administration, concentration and dose of epinephrine, the participants' correct response was quite poor (43.8%, 6.7%, and 8.6%, respectively). More than 65% of participants could name a single intravenous corticosteroid and antihistamine.

Conclusion: Radiology personnel's knowledge regarding contrast material and management of severe contrast material-induced allergic reactions is unsatisfactory.

Keywords: anaphylaxis, gadolinium-based contrast, iodinated contrast, radio-contrast hypersensitivity, radio-contrast media, severe acute contrast allergy

[a]*Department of Radiology, Aga Khan University Hospital,* [b]*Department of Internal Medicine, Dow University of Health Sciences, Karachi,* [c]*Department of Internal Medicine, King Edward Medical University,* [d]*Department of Internal Medicine, King Edward Medical University, Lahore,* [e]*Department of Radiology, Hayatabad Medical Complex,* [f]*Pharmacy Unit, Paraplegic Center, Peshawar,* [g]*Department of Radiology, Combined Military Hospital Abbottabad, Abbottabad,* [h]*Maroof International Hospital, Islamabad, Pakistan and* [i]*Department of Radiology, James Paget University Hospital, Great Yarmouth, UK*

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

**Corresponding author. Address: Clinical Research Associate: Maroof International Hospital, Public Health Scholar: Health Services Academy. E-mail address: Hassanmumtaz.dr@gmail.com (H. Mumtaz).*

Annals of Medicine & Surgery (2023) 85:3347–3352

Received 7 November 2022; Accepted 16 March 2023

Published online 24 April 2023

http://dx.doi.org/10.1097/MS9.0000000000000465

Introduction

Diagnostic imaging has evolved and now plays an important role in the medical profession. There is a significant growth in using imaging methods, which leads to an increase in using radio-contrast media. Half of all contrast-enhanced computerized

HIGHLIGHTS

- This cross sectional study has highlighted gaps in the knowledge of Radiology personnel regarding contrast media and it's associated adverse drug reactions.
- A periodic audit of pharmaceuticals should be required for quality assurance.
- Radiology personnel's knowledge and abilities should be evaluated regularly.
- It is recommended that every 6 months training should be repeated to recapture the learned skills.

tomography (CT) and MRI scans conducted each year employ contrast media (CM)[1,2]. Iodinated contrast media (ICM), gadolinium-based contrast media, and barium-based contrast media are the three commonly used classes of contrast media. The first two are far more regularly used than the third one. ICM are further classified base on its osmolality (hyper, hypo, or iso-) and ionicity (ionic or non-ionic). Because of the significant risk of adverse drug reactions (ADRs), high osmolar contrast media (HOCM) and ionic CM are no longer employed. Non-ionic low osmolar iodinated contrast media are associated with lesser side effects[3]. Gadolinium-based contrast agents (GBCA) are classified based on ionicity (ionic and non-ionic) and chelating agents (linear vs. nonlinear). Linear GBCAs are well-tolerated; however, there is not much difference in ADRs based on the ionicity of GBCAs.

Even if the radio-contrast media is deemed safe, there is still the possibility of ADR. ICM is the third most prevalent cause of ADR, following non-steroidal anti-inflammatory medicines and chemotherapeutic drugs. Severe acute contrast reaction (SACR) is defined as any combination of the following symptoms that require some form of immediate treatment: dyspnoea, sudden drop in blood pressure, cardiac arrest, and loss of consciousness[1,4,5]. This study will focus on SACRs. Because the incidence of SACRs is relatively low, it has been revealed that even in locations with a high patient load, only a few radiology personnel are able to manage SACRs occurring due to usage of CM. The use of contrast media is always a concern of patient safety for hospitals and requires in depth analysis of departments and its personnel preparedness for untoward outcomes. This is the first research in Pakistan to assess radiology personnel's knowledge and preparedness to manage SACRS associated with the use of CM.

Materials and methods

Study design

A questionnaire-based cross-sectional study was designed to collect data from radiology personnel. The survey type was chosen due to its ease of use, time savings, and cost-effectiveness. This research aimed to assess radiology personnel's knowledge of CM and the management of related adverse effects in a sample of public and private hospitals in Khyber Pakhtunkhwa province of Pakistan. The survey took 8–10 min for each participant to complete. All responses were kept anonymous. We utilized the resident teaching sessions, departmental meetings, audit meetings and mortality and morbidity meetings for approaching the participants. This was done after the approval of radiology chair at each of the institute. During the survey, participants were given a set of papers having a covering letter that detailed the purpose of the study and a questionnaire. Participants were informed of the voluntary nature of their participation. Privacy of the participants was assured. Participants were given the option to contact the research investigator if they have any queries regarding the study (e-mail was provided).

Study participants

All the radiology consultants, residents, and charge radiographers working at the five major hospitals of the metropolitan city were included in the study. Trainee radiographers were excluded from the study. The questionnaire was distributed among 210 radiology personnel (consultants, residents, and radiographers). The participants who did not complete the survey ($n = 100$) or did not give consent ($n = 5$) were excluded from the final sample. The response rate was around 50%.

Contents of questionnaire

A 30-item questionnaire was adopted from the existing literature containing both open and closed-ended questions[6–8]. The contents of the questionnaire was reviewed and discussed with four specialists in the field, a researcher and pharmacist to ensure the alignment of the items within the scope of the study. Furthermore, the questionnaire underwent testing for quantitative content validity, which intended to establish expert agreement on how relevant each item is in respect to the measurement purpose. Qualitative content validity (i.e. face validity) was established through piloting the questionnaire in a sample of 25 participants. The aim of face validity was to determine how well participants understood the items and what they thought of the topic they were supposed to be measuring. Each question on the survey was discussed with the participants individually. All of the comments were heard and recorded. The panellists assessed every finding. The main objective was to check whether the changes made to the questionnaire were comprehensible. Moreover, vocabulary adequacy was ensured, the text was harmonized, typographical and grammatical errors were removed for clarity confirmation before launching the questionnaire. Each questionnaire has three parts. In order to evaluate the CVR, a panellist's opinions were used (6 members). Their evaluation was firstly based on Likert scale three-point (1 = not necessary; 2 = useful but not essential; 3 = essential). Furthermore, using a four-point ordinal scale, the expert panel was asked to score 30 items according to their relevance to the tool's underlying construct (1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, and 4 = highly relevant). The questionnaire's CVI and CVR were 0.966 and 0.79, respectively.

The first part of the questionnaire contained items of the participants' basic demographic information. The second and third parts comprised items on knowledge of CM and management of associated ADRs, respectively. Standard practice of scoring was not applied on questionnaire.

Ethical considerations

The work received official ethics approval from Khyber Girls Medical College, Pakistan under reference number 606, dated 20/02/19. The participants' anonymity was protected, and informed permission was presumed for all participants, whether taking part in an online survey (e-signature) or a paper-based survey. The Helsinki Declaration (Revised 2013) and the International Ethical Guidelines for Human Research in Health were used to guide this investigation, which adhered to the highest ethical standards (2016). The work has been reported in line with the STROCSS criteria[9].

Statistical analysis

Statistical Package for Social Sciences (SPSS) for Windows, Version 22 was used to analyze the data. Basic statistics were produced, such as percentages and frequency distributions of various attributes. For normally distributed numerical variable

mean and standard deviation was calculated. Results were presented in tables or figures.

Results

The mean (SD) age of the participants was 32.4 (8.4) years. Out of the total 105 participants, 51.5% ($n = 54$) were males. About 16% (17/105) radiology consultants, nearly 61% (64/105) radiology residents, and 23% (24/105) technicians took part in this study (Table 1). Ninety three percent (98/105) participants had not read the ACR Manual 2018 (Fig. 1). Of those who had read the ACR manual, majority were from technicians (5/7). Only one consultant and one resident had read the ACR manual (Fig. 2). Less than half and about one-quarter of participants could classify ICM based on ionicity and osmolality, respectively. Fifty-six percent (59/105) participants correctly identified the features of ICM associated with lesser side effects. Approximately 65% (68/105) could name a single intravenous antihistamine and 75% (79/105) could name a single intravenous corticosteroid used in contrast media reaction (Table 2). Regarding severe acute contrast media reaction management, responses of the participants are recorded and are presented in Figure 3. Sixty-three percent (60/105) participants correctly identified SACR as type I hypersensitivity reaction. Only 1% (1/105) correctly identified the "additional route of drug administration in severe acute contrast reaction in children". Twenty-six percent (27/105) participants knew about whether or not epinephrine is kept in the same room as their CT scanners. Only two CT scan rooms (2/9) were equipped with injection epinephrine.

Discussion

Our survey is the first one in Pakistan to assess the radiology personnel knowledge regarding CM and management of adverse drugs reactions occurring due to contrast media. In five major hospitals (9 CT suites/rooms) of the metropolitan city covered in the study, only two CT suites (23%) had injection epinephrine available in their drug kit or trolley. According to American College of Radiology (ACR) guidelines on contrast media, injection epinephrine should be readily available in the department CT suite for use in case of severe acute contrast reaction[4]. Twenty-six percent participants in our study knew whether or not injection epinephrine is available in the same room where their CT scanners are lying. This information is very important for radiology personnel as the injection epinephrine is life saving drug in case of anaphylactic reactions. In a survey conducted by Lightfoot *et al*.[7] sixty-two percent knew whether or not injection epinephrine is available in the same room as their CT scanner.

Committee on Drugs and Contrast Media of ACR releases CM manual regularly for radiology community[4]. We found that only 7 participants (7/105) in our study had read the ACR manual on contrast media. Majority of these (5/7) who had read the ACR manual on contrast media were technicians. The reason might be that their diploma examination contains questions on contrast materials. Only one radiology consultant and one radiology resident had read the ACR manual on contrast media. This may be one of the major reasons our study participants had poor knowledge about contrast media and management of associated adverse drug reactions. Less than half and about one-quarter of participants could correctly classify iodinated contrast media based on ionicity and osmolality, reflective of poor understanding of radiology personnel regarding contrast media. This information is important as the non-ionic low osmolar contrast material materials are associated with lesser side effects[3,7].

When asked about the risk factors predisposing to SACR only 13.3% participants in our study could correctly identify those risk factors. Previous reaction to contrast media, atopy, asthma, over 60 years or younger than 5 years of age, and having cardiac or renal disease are some of the known risk factors for contrast media associated adverse drug reactions[1,3,7]. Screening and premedication in at-risk population have proven very beneficial in decreasing the risk of SACR[2]. Few (7.6%) could correctly identify signs and symptoms of anaphylaxis following contrast media administration in our study. Similar study from Turkey reported that more than 50% of their participants correctly identified the signs and symptoms of anaphylaxis[10]. It has been

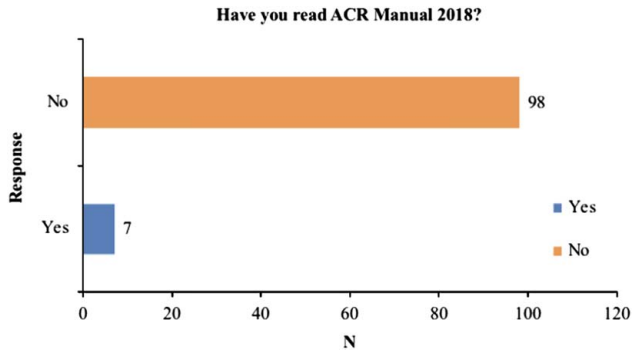

Figure 1. Participants response to the statement "Have you read ACR manual 2018". ACR, American College of Radiology.

Table 1

Have you read ACR manual?.

Designation*	Yes	No
Consultant	1	16
Resident	1	63
Technician	5	19

$n = 105$; $P < 0.05$; CI = 95%.

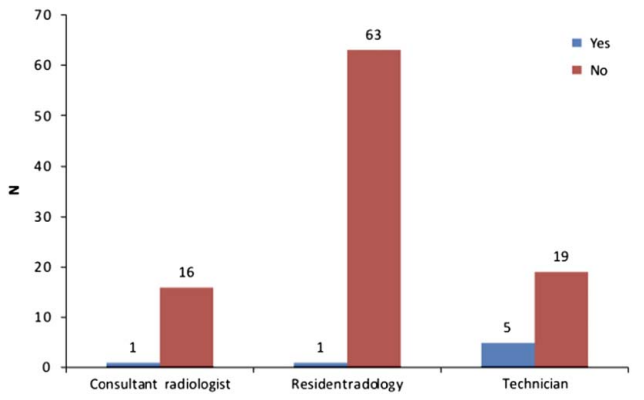

Figure 2. Participants' response to question "have you read ACR manual" based on designation. ACR, American College of Radiology.

Table 2

Knowledge assessment of Radiology personnel on the important questions.

Questions	Designation	Correct	Incorrect
Which intravenous antihistamine is used in acute severe contrast media reaction?	Consultant	14	3
	Resident	45	19
	Technician	9	15
Which intravenous corticosteroid is used in acute severe contrast media reaction?	Consultant	15	2
	Resident	55	9
	Technician	9	15
Classify contrast media based on the iconicity	Consultant	14	3
	Resident	29	35
	Technician	6	18
Features of contrast media which is associated with lower side effects	Consultant	14	3
	Resident	38	26
	Technician	7	17
Name one non-iodinated low osmolality contrast media	Consultant	11	6
	Resident	19	45
	Technician	10	14
Do you know which contrast media is prescribed in your department?	Consultant	9	8
	Resident	17	47
	Technician	15	9
Do you know which equipment is needed to administer an injection of epinephrine during an acute severe contrast media reaction?	Consultant	11	6
	Resident	34	30
	Technician	6	'18
Which intravenous fluid is used for volume expansion during contrast media reaction?	Consultant	10	7
	Resident	27	37
	Technician	4	20
What is the most important medicine to administer in case of anaphylaxis following contrast media reaction?	Consultant	7	10
	Resident	21	43
	Technician	2	22

$n = 105$; $P < 0.05$; CI = 95%.

found that CT scans are increasingly used more frequently in emergency settings. The unpreparedness in such cases may lead to inappropriate screening or insufficient premedication in at-risk individuals[11]. The first-line therapy for anaphylaxis is epinephrine (1 mg/ml aqueous solution [1:1000 dilution]), which should be delivered promptly. In adults, its dose is 0.3 mg intramuscular into the mid-outer thigh with a pre-measured or pre-filled syringe or an auto-injector[12]. In the hands-on training, it has been noticed that the concentration, dosing, and route of administration of injection epinephrine are most commonly mistaken[2]. In one research, half of the participants understood the right route, but only one-third knew the amount and rate of epinephrine administration in SACR due to CM[6]. The study from Turkey reported somewhat similar results for epinephrine dosing and route of administration[10]. In our study less than 50% of the participants correctly identified the optimal epinephrine administration route, with only 8%, 7%, and 3% identifying the correct dose for subcutaneous, intramuscular, and intravenous routes, respectively. A survey conducted in Australia and New Zealand showed that over 40% of participants and over 60% self-reported themselves as poor or fair for dealing with contrast media associated adverse drug reactions and radiological emergencies, respectively[8]. In the survey conducted by Lightfoot and colleagues no radiologist provided the ideal response. Forty one percent of their participants (94 of 231) provided an acceptable administration route, concentration, and dose for epinephrine. Seventeen percent of their participants (39 of 231) provided an overdose for epinephrine when asked about the amount of epinephrine administration in case of anaphylaxis[7]. In a local audit by Bartlett and colleagues in Australia reported that only 43% of their participants could provide correct dosage of epinephrine, and in case of incorrect dosage it was most of the time an over dosage. They also reported poor knowledge of radiologists and radiology residents when asked for corticosteroid, atropine, antihistamine doses and intravenous fluid use[13]. This highlights the alarming situation of radiologists globally putting the patients at risk. Understanding the proper route and amount of epinephrine in an anaphylactic reaction is essential as the wrong dosage may prove detrimental instead of reversing the contrast media associated adverse drug reaction.

The risk of death from a properly treated SACR is modest, perhaps less than 1%. Published data is scarce on the mortality rates of individuals undergoing SACR. Rare acute emergencies to GBCA include refractory non-anaphylactic non-cardiogenic pulmonary oedema. According to evidence, such life-threatening crises are seldom resistive to traditional cardiopulmonary resuscitation and may necessitate Extracorporeal Membrane Oxygenation (ECMO). Rare but life-threatening cases of myocardial ischaemia and necrosis leading to ST-elevation myocardial infarction have also been reported[14,15]. Physicians must be well-prepared to deal with these life-threatening conditions. Anaphylaxis need prompt treatment since the respiratory or cardiac collapse, as well as death, can occur within minutes. It is crucial to treat anaphylaxis as soon as possible since delayed epinephrine delivery is associated with an increase in mortality[12]. In the event of an adverse event during contrast imaging, the American College of Radiology (ACR)-Society for Paediatric Radiology (SPR) recommends that physicians be "immediately available". However, Medicare and Medicaid recommend that contrast injections be performed under the direct supervision of a physician[5].

Study by Nandwana et.al performed a root cause analysis following a newer-event due to the administration of an erroneous dose of epinephrine in multiple radiology departments. They found that in 92.5% of the radiology departments, the pharmacy did not contain the epinephrine injection for emergency administration in case of anaphylaxis due to contrast media. In such cases, it was commonly mistaken to use the epinephrine injection available in the crash cart[6].

Because of lower incidence of life-threatening events in radiology as compared to other departments, radiologists, radiology residents, radiology nurses, and technologists are not accustomed to the management of critical cases. Less than half of the US diagnostic radiology residency programs assess the resident's acute contrast media reaction management ability. The frequency of lectures addressing the contrast media is one, two, and three or more lectures per year (49%, 29.4% and 16%)[16]. The conventional method of training radiology personnel is based on didactic lectures, which are less yielding for efficient training.

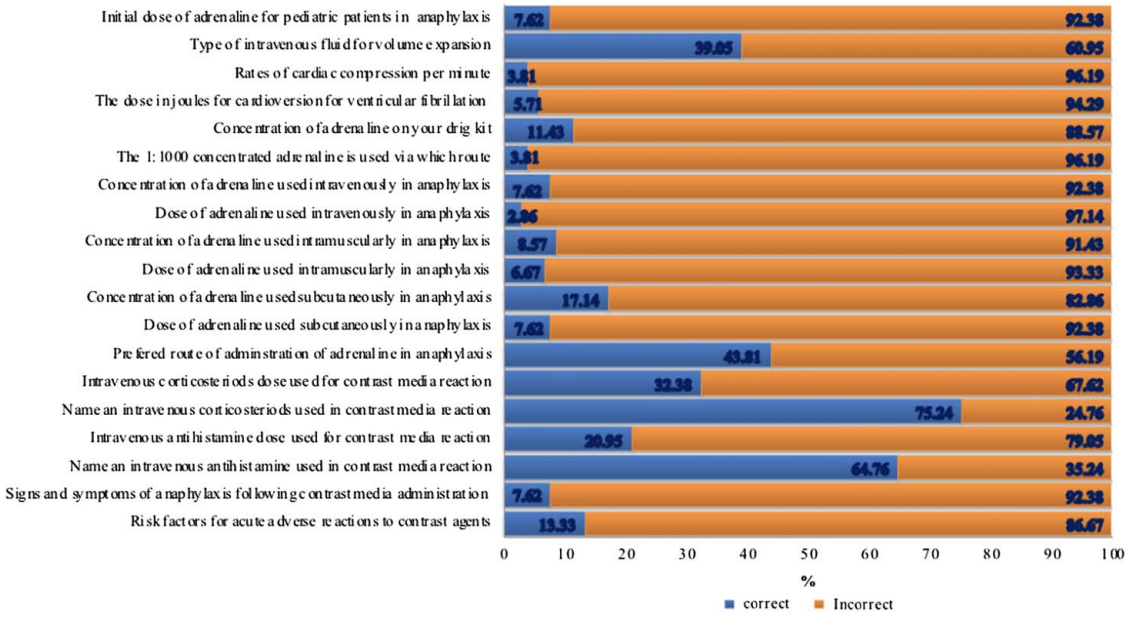

Figure 3. Participants' responses to questions concerning SACR management. Responses have been presented in number where orange colour denotes "Incorrect" and blue colour denote "Correct" using stack bar chart. SACR, severe acute contrast reaction.

Simulation training is being used in 18–37.8% of radiology residency programs only[2,16]. However, hands-on or online high-fidelity simulation and educational modules are getting popular[2]. Simulation training has shown a significant improvement in the knowledge and confidence of the participants. Subsequent training has shown even better performance[17–19]. After a gap of 6 months of training, a decline in performance for dealing with contrast media reactions has been observed. The limiting factors involved in high-fidelity simulation training are the cost and time required from the training faculty and the trainees[2].

Study limitations

There are few limitations to this study. Our study has a limited sample size and only data from one state is obtained. We had a low response rate (50% overall), resulting in a risk of non-responder bias. Radiologists and trainees who chose not to complete the survey may have differed systematically from those who did respond. There is disproportionate number of residents, consultants, and radiographers in the study. So results may not be generalizable. We assessed knowledge and management of SACR so results cannot be generalized to other critical or non-critical conditions in the radiology department. Standard practice of scoring was not applied on questionnaire.

Conclusion

Radiology personnel's knowledge regarding contrast media and management of associated adverse drug reactions is low, whereas, for children, it is critically low. In the radiology department, routine stocking of the dose of manual intramuscular epinephrine injection/auto-injector is critical.

Recommendations

A periodic audit of pharmaceuticals should be required for quality assurance. Radiology personnel's knowledge and abilities should be evaluated regularly. For contrast media reaction management, routine didactic lectures, small interactive group sessions, and hands-on workshops should be held. It is recommended that every 6 months training should be repeated to recapture the learned skills. The ACR manual on contrast media is a great learning resource for radiologists on how to treat reactions to contrast media. Their treatment tables can be posted in the reading rooms. The ACR has a mobile version of the contrast media manual as well.

Ethical approval

The work received official ethics approval from Khyber Girls Medical College, Pakistan under reference number 606, dated 20/02/19.

Consent

Participation was voluntary for all participants and informed permission was presumed for all participants taking part in the study.

Source of funding

None.

Author contribution

Conceptualization: F.K., K.H., M.S. I.A. Data collection: F.K., K.H., M.S., G.W., K.H., R.I., E.W., H.M., M.A.S. Formal

analysis: F.A., I.A., A.K., U.K. Writing—original draft: F.K., F.A., A.M.S., A.K. Writing—review and editing: F.K., U.K., A.M.S., A.K., E.W., R.I., H.M., M.A.S.

Conflicts of interest disclosure

The authors report no actual or potential conflicts of interest.

Data availability statement

Data are available from the corresponding author on request.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Acknowledgements

The authors thank Dr. Henry Knipe (BMedSc, MBBS (Hons), MMed FRANZCR, London, UK) for his intellectual help in questionnaire designing.

References

[1] Beckett KR, Moriarity AK, Langer JM. Safe use of contrast media: what the radiologist needs to know. Radiographics 2015;35:1738–50.
[2] Wang CL, Soloff EV. Contrast reaction readiness for your Department or Facility. Radiol Clin North Am 2020;58:841–50.
[3] Jean-Marc I, Emmanuelle P, Philippe P, *et al*. Allergy-like reactions to iodinated contrast agents. A critical analysis. Fundam Clin Pharmacol 2005;19:263–81.
[4] ACR manual on contrast media: American College of Radiology, Committee on Drugs and Contrast Media; 2022 [cited 2022 10 July]. https://www.acr.org/-/media/ACR/files/clinical-resources/contrast_media.pdf.
[5] Dillman JR, Trout AT, Davenport MS. Allergic-like contrast media reaction management in children. Pediatr Radiol 2018;48:1688–94.
[6] 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? J Am Coll Radiol 2015;205:90–4.
[7] Lightfoot CB, Abraham RJ, Mammen T, *et al*. Survey of radiologists' knowledge regarding the management of severe contrast material-induced allergic reactions. Radiology 2009;251:691–6.
[8] Craig S, Naidoo P. Emergencies in radiology: a survey of radiologists and radiology trainees. J Med Imaging Radiat Oncol 2014;58:164–71.
[9] Agha R, Abdall-Razak A, Crossley E, *et al*. STROCSS 2019 Guideline: strengthening the reporting of cohort studies in surgery. Int J Surg 2019;72:156–65.
[10] Arslan G, Balci A, Cubuk R, *et al*. Knowledge and experience of radiologists working in Istanbul on radiographic contrast medium anaphylaxis. AIMS allergy immunol 2017;1:71–7.
[11] Huynh K, Baghdanian AH, Baghdanian AA, *et al*. Updated guidelines for intravenous contrast use for CT and MRI. Emerg Radiol 2020;27:115–26.
[12] Lieberman P, Nicklas RA, Randolph C, *et al*. Anaphylaxis—a practice parameter update 2015. Ann Allergy Asthma Immunol 2015;115:341–84.
[13] Bartlett MJ, Bynevelt M. Acute contrast reaction management by radiologists: a local audit study. Australas Radiol 2003;47:363–7.
[14] Tanaka H, Urushima M, Hirano S, *et al*. An acute adverse reaction with ST elevation induced by magnetic resonance contrast media: a case of Kounis syndrome. Intern Med 2019;58:243–5.
[15] Guru PK, Bohman JK, Fleming CJ, *et al*. Severe acute cardiopulmonary failure related to gadobutrol magnetic resonance imaging contrast reaction: successful resuscitation with extracorporeal membrane oxygenation. Mayo Clin Proc 2016;91:362–6.
[16] Petscavage JM, Paladin AM, Wang CL, *et al*. Current status of residency training of allergic-like adverse events to contrast media. Acad Radiol 2012;19:252–5.
[17] Ali S, Alexander A, Lambrix M, *et al*. High-fidelity simulation training for the diagnosis and management of adverse contrast media reactions. AJR Am J Roentgenol 2019;212:2–8.
[18] Wheeler M, Powell E, Pallmann P. Use of High-fidelity simulation training for radiology healthcare professionals in the management of acute medical emergencies. Br J Radiol 2021;94:20200520.
[19] Pippin K, Everist B, Jones J, *et al*. Implementing contrast reaction management training for residents through high-fidelity simulation. Acad Radiol 2019;26:118–29.