

ENHANCING CONTRAST SAFETY KNOWLEDGE IN RADIOLOGY RESIDENTS VIA A NATIONAL VIRTUAL WORKSHOP



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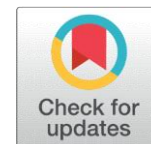
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ABSTRACT

Background: Training in contrast-related issues and managing contrast reactions are essential skills for radiology residents from their early training years. This study aims to evaluate the effectiveness of a national virtual contrast workshop for first-year radiology residents across the Kingdom.

Methods: All first-year radiology residents from across the Kingdom attended a one-day contrast workshop as part of the new "Core Radiology Skills" rotation. The workshop was delivered via a virtual platform and included didactic lectures and simulated case scenarios. Residents were asked to complete optional pre- and post-tests (20 multiple-choice questions) and a feedback form. The learning outcomes, lectures, simulated case scenarios, and tests were based on the content of the 2021 American College of Radiology (ACR) Manual on Contrast Media.

Results: A total of 139 of 177 first- and second-year radiology residents completed the workshop and answered the pre-and post-tests. Most participants were from Riyadh province (41.8%) and Makkah province (31.6%). The mean overall pre-test score was 88.13 out of 200 (SD: 29.58), which significantly increased to 148.56 out of 200 (SD: 38.38) in the post-test, with a P-value of <.001 and a 57.2% overall percent change in scores. Participants' feedback indicated a positive reception of the course.

Conclusion: The national virtual contrast media workshop effectively improved participants' knowledge. Favorable feedback reflects the workshop's success in addressing essential topics and delivering clear learning points. To enhance the educational experience, virtual breakout rooms should be considered. A six-month follow-up refresher course is recommended for long-term knowledge retention.

Keywords: Contrast, Workshop, Safety, Radiology, Residency

1. INTRODUCTION

Contrast media are abundantly used daily in all the divisions of a Radiology Department worldwide. Since contrast material is like any other pharmaceutical agent, it carries risks when administered. There are considerations to using contrast in patients with pre-existing medical conditions such as renal impairment, and there are risks of both allergic and nonallergic-like adverse effects, varying in severity from minor reactions to fatal anaphylaxis. For that, the American College of Radiology (ACR) produced a manual on contrast media. This manual is updated continuously to provide radiologists with up-to-date information on changes in the chemical composition of contrast media and how it would affect patients, especially the impaired, as well as how to manage contrast reactions and pre-medicate for contrast allergy [1].

Since contrast administration takes place in radiology departments, radiologists act as the first line to identify and manage contrast reactions when they arise. Despite that, results from Emory University assessing 13 Radiology Departments showed that most hospitals need more preparedness of individualized contrast reaction kits and that only 29% of radiologists knew the proper IV epinephrine dose to give in a contrast reaction [2].

The lack of preparedness prompted the radiology communities to investigate the best methods to prepare their staff for such events. Since 1997, instructional

courses have been suggested to train radiologists on how to deal with contrast reactions. Echenique et al. noted that such workshops instill confidence in residents and trainees [3]. Moreover, many studies assessed the best methods to deliver this knowledge and how to retain these essential skills. Some studies showed that high-fidelity simulations are an effective method to teach contrast reactions [4,5]. Other studies investigated computer-simulated cases and the effectiveness of lecture-only formats [6-8]. Despite all the efforts, many radiology residency programs do not pay attention to dedicating time to teaching contrast reaction or safety in general [9,10].

Many residents effectively learn about contrast during rotations when problems arise. For example, when a renally impaired patient presents for contrast-enhanced examination, trainees start asking around, searching for answers. They would learn about contrast reactions when they have a real-life encounter. Sometimes a lecture is given by faculty, or a resident comes across contrast-related readings during their study [8].

The Saudi Radiology residency program – like many other international residency programs – require programs to teach contrast administration and adverse contrast reactions to residents as part of its curriculum. Teaching used to be a training-center-directed effort for a long period of time. In 2022, the Saudi Radiology Residency Board curriculum has been revised and updated to include a “Core Radiology Skills” rotation, which is a 4-week course for all first-year residents where it addresses essential information and skills required to know early on training, including contrast safety [11].

With such large target audience of residents who are training across the Kingdom, an in-person delivery of this course was difficult. Hence, a virtual platform was sought to deliver the course. As part of the collaborative efforts between the Radiologic Society of Saudi Arabia (RSSA) and the Saudi Commission of Health Specialties (SCFHS), the RSSA agreed to play a role in the “Core Radiology Skills” rotation and give a full day contrast media workshop in the virtual platform.

This study aims to evaluate the effectiveness of this national virtual contrast media workshop for junior radiology residents across the Kingdom by utilizing objective knowledge-based tests and subjective feedback from participants.

2. MATERIALS AND METHODS

2.1 Study Design and Participants

This research ethics committee exempted this project from obtaining a formal ethical approval. This study is a quasi-experimental study design that used an online test. A pre-and post-test was distributed to participating radiology residents. The residents filled out a pre-test form. After that, the virtual contrast media workshop was conducted with lectures and interactive case-based discussions. After the workshop, the participants filled out a post-test and a feedback form.

Inclusion criteria: All first year radiology residents from across the Kingdom of Saudi Arabia were required to attend the core radiology curriculum course and were included in the study. Some second-year residents elected to attend. The total number of attendees was 177 residents. Exclusion criteria, Workshop participants who did not complete the pre-and post-tests were excluded.

2.2 Data Collection

Pre and Post tests: Each participant received a Google Form QR code to complete the pre-test. The full set of test questions is provided in Appendix 1. Participants were asked to refrain from using references or sharing answers while completing the test. They were given 15 minutes to complete the test. Once the pre-test was completed, participants attended the virtual contrast media workshop organized by SCFHS and delivered by the RSSA.

After the conclusion of the sessions, each participant received a second identical Google Forms QR code to complete the post-test. Participants were asked again to refrain from using references or sharing answers while completing the test. Once the post-test was completed, participants could review the correct answers and clarify them with the instructors. At the 6-month point, the identical post-test was emailed to all the participants to assess their 6-month knowledge retention.

The first section of the Google form collected residents' demographics, including their: names, Saudi Commission for Health Specialties number (SCFHS), email addresses, training year, province, and name of the training institution.

The second section was built of 20 multiple-choice questions based on the taught material from the American College of Radiology (ACR) 2021 contrast manual [1].

The training sessions were mandatory to attend. However, the pre-and post-tests were optional for all residents.

2.3 Feedback Forms

After the session, participants were prompted to complete a feedback form utilizing a Likert scale ranging from "1- completely disagree" to "5- completely agree." The statements evaluated the following aspects:

1. The significance of the topics
2. The clarity of the learning points' delivery
3. The speakers' ability to showcase adequate knowledge of the subject matter
4. The speakers' success in engaging the attendees' attention

Additionally, attendees were provided with an optional free text box for submitting further comments or opinions if they desired to elaborate further.

2.4 Lectures and Sessions

Following pre-testing, participants finished a full-day course of lectures and case scenarios sessions to practice managing contrast-related problems. The course was mainly structured based on the 2021 ACR Contrast Manual [1]. The workshop occurred on March 14th, 2022, from 9:00 AM to 4:00 PM. An outline of the entire course schedule is provided in Appendix 2.

The group of instructors that carried out the course included five board-certified radiologists (specialized in abdominal, cardiothoracic, and pediatric imaging) with the initials YN, AB, AA, BB, and RA, two board-certified nephrologists initialed SD and WA, and a 3rd-year radiology resident initialed MB.

Instructors created simulation cases. Each scenario was created to represent previously established learning outcomes based on the author's expertise and the 2021 ACR Manual on Contrast Media. The instructors acted as simulated patients and walked residents through the scenario based on the participants' questions and answers. Appendix 3 demonstrates some example cases shared during the session, and Appendix 4 is a contrast reaction flowchart created from the contrast manual to be used with the reaction scenarios.

The lectures and simulation sessions aimed to attain specified learning outcomes, emphasizing a thorough comprehension of contrast agent application across several imaging modalities. The objectives encompassed an examination of the various contrast agents utilized in CT, MRI, and ultrasound; an analysis of their indications, contraindications, and related safety issues; an interpretation of the signs and symptoms of contrast reactions, from mild to severe; and the provision of customized treatment recommendations and future preparedness for patients who have encountered contrast reactions. Supplementary objectives included evaluating risk factors and the potential consequences of contrast-induced nephropathy and nephrogenic systemic fibrosis, along with discussing methods of contrast administration in individuals with renal impairment. Additionally, the seminars examined the application of contrast during pregnancy and lactation, emphasizing specific issues for pediatric situations.

2.5 Statistical methods

For statistical analysis, SPSS 22 and Excel were employed for data entry and processing. Descriptive statistics involved pie and bar charts created in Excel to visually represent the data. Categorical variables were summarized using frequencies and percentages, while normally distributed continuous variables were expressed as mean and standard deviation. Inferential statistics included the use of a paired t-test to compare pre-test and post-test results from the Contrast Safety Workshop, with a significance level set at $\alpha < 0.05$. The percent change between pre-test and post-test means was calculated overall and for each province, using the formula; % change = $((\text{the post mean} - \text{the pre mean}) / \text{pre mean}) \times 100$.

3. RESULTS

3.1 Participants' demographics

A total of 177 residents attended the course, with 139 (78.5%) completing the pre-and post-tests. Two residents encountered internet connection problems, and the remainder chose not to participate. Most of the participating residents were in their First year of residency (97%), while the remaining 3% were in their 2nd year.

Most residents were from Riyadh (41.8%) and Makkah (31.6%) provinces. Figure-1 displays the percentage distribution of residents from other provinces. Among the 139 participants, 102 (68%) were males, and 48 (32%) were females.

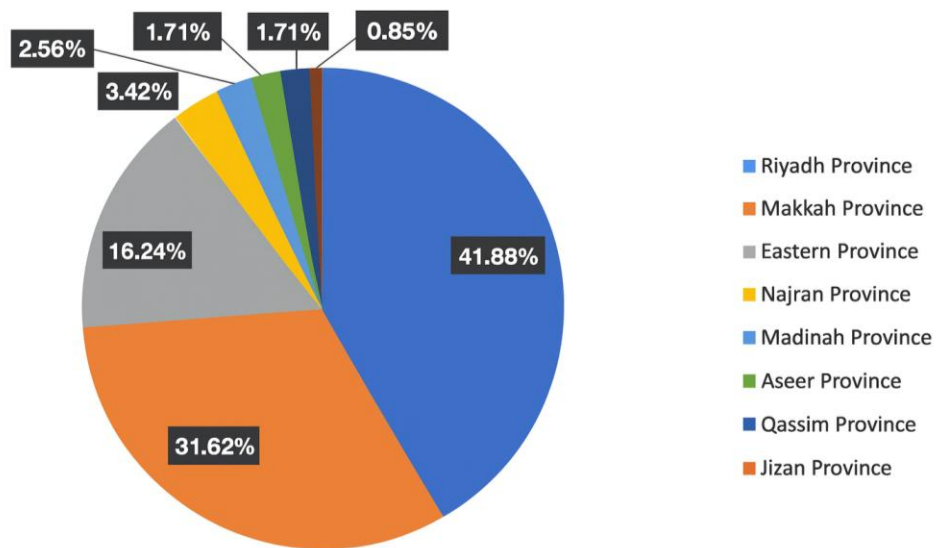


Figure 1. This figure displays the percentage distribution of residents from other provinces.

3.2 Participants test performance

Each correct answer was scored as 10 points (20 questions, total 200 points); results were expressed as raw scores out of 200 and as percentage change to ease interpretation. The mean overall score on the pre-test was 88.13 out of 200 (44.1%) possible points (SD: 29.58). Across all provinces, the average test score increased significantly in the post-test to 148.56 out of 200 (74.3%) (SD: 38.38), with a P-value of <.001 and a 57.2% overall percent change. The 95% CI for the mean difference between pre- and post-test scores was 41.9–59.9 (P < 0.001). Figure-2 illustrates the percent change in the scores of each province, and Table-1 details the mean, standard deviation, and percent change of each province based on the paired Student t-test values. Of all the provinces, only Aseer showed a decrease in the mean scores by 10.2% on the post-test. At the 6-month point, only three residents completed the post-test, with a mean score of 106.7 and individual scores of 60, 80, and 180.

Table 1. Test score comparisons of all participants by province and overall

Province	N	Prescore mean ± SD	Postscore mean ± SD	Prescore - Postscore mean ± SD	t-value	df	P value	Percent Score change
Riyadh	5	86.48 ±	147.96 ±	-61.48 ±	-10.82	53	<0.00	71.1%
	4	27.89	31.65	41.77		1		

Madinah	4	87.5 ± 17.08	122.5 ± 43.49	-35 ± 57.44	-1.21	3	0.155	40%
Makkah	4	91.11 ± 33.04	137.33 ± 37.86	-46.22 ± 45.69	-6.79	44	<0.00	50.7%
	5						1	
Eastern	2	86.52 ± 30.24	133.04 ± 46.24	-46.52 ± 55.15	-4.05	22	<0.00	53.80%
	3						1	
Aseer	5	98 ± 38.34	88 ± 37.01	10 ± 30.82	0.73	4	0.254	-10.2%
Najran	4	90 ± 18.26	145 ± 36.97	55 ± 20.82	-5.25	3	0.007	61.1%
Jizan*	1	80	130					62.5%
Qassim	3	70 ± 26.46	130 ± 50	-60 ± 72.11	-1.44	2	0.143	85.7%
All provinces	1	88.13 ± 29.58	148.56 ± 38.38	-50.93 ± 46.93	-12.67	138	<0.00	57.2%
	3						1	
	9							

N = Number of participants
t-value = Test statistic in a paired student T-test
df = Degree of freedom.
*The correlation and the t cannot be calculated from 1 participant in the region.

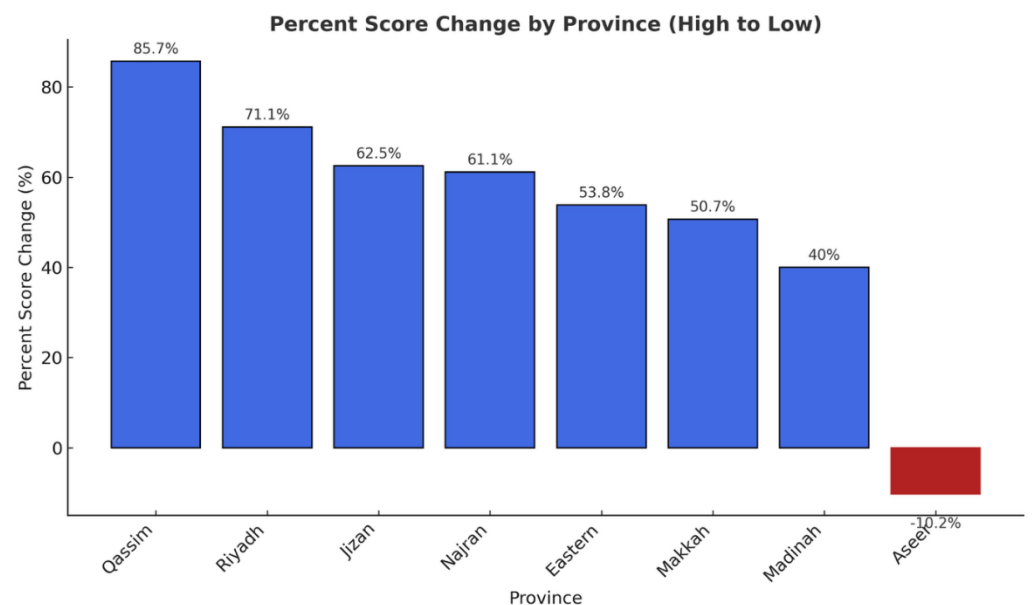


Figure 2. Illustrates the percent change in the scores of each province.

3.3 Participants' Feedback

After completing the course, the participants provided feedback, which was generally positive. The main findings from the feedback forms indicated that the course was well received, with participants appreciating the content and format.

Out of 128 residents (72.3%) who completed feedback forms, most expressed positive opinions about various aspects of the workshop, as detailed in Table-2. Expressly, 78.1% of residents strongly agreed that the topics discussed were important to them, while 74.2% strongly agreed that the learning points were clearly delivered. Furthermore, 72.7% of residents strongly agreed that the speakers demonstrated sufficient knowledge of the topic, and 71.9% strongly agreed that the speakers effectively captured their attention during the presentations. Notably, 68.9% of residents strongly agreed that they would change their practice as a result of attending the workshop.

Table 2. Test score comparisons of all participants by province and overall

Statement	1		2		3		4		5	
	Count	%	Count	%	Count	%	Count	%	Count	%
The topic was important to me	0	0	1	0.8%	4	3.1%	23	18%	100	78.1%
The learning points were clearly delivered	1	0.8%	1	0.8%	6	4.7%	25	19.5%	95	74.2%
The speakers demonstrated sufficient knowledge about the topic	1	0.8%	2	1.6%	5	3.9%	27	21.1%	93	72.7%
The speakers were able to draw my attention to the presentation	1	0.8%	1	0.8%	6	4.7%	28	21.9%	92	71.9%

Note. * 5-points Likert scale: 1= completely disagree to 5= completely agree.

In the free-text comment box, several residents expressed their total satisfaction and considerable benefits gained from attending the workshop. Some participants recommended shortening the lecture durations and replacing them with more case scenarios. Others emphasized the importance of this workshop during the early residency years and suggested offering it to future classes. Due to the time constraints of condensing the workshop into a single day, a few residents mentioned that some faculty members proceeded at a pace that was too fast for them to fully comprehend the presented material. A brief thematic review of the free-text responses revealed recurring positive impressions regarding the workshop's content and structure, with several participants recommending more case-based scenarios and shorter lecture durations to enhance interactivity and engagement.

4. DISCUSSION

We are publishing the results of the first national contrast media workshop that involved all first-year radiology trainees across all Saudi residency training programs. This workshop resulted from the collaboration between the Radiological Society of Saudi Arabia (RSSA) and the scientific board of the Diagnostic Radiology Residency Program under the Saudi Commission for Health Specialties (SCFHS). This workshop was part of the updated residency curriculum, including a 4-week course called "Core Radiology Skills." The contrast media workshop was deemed integral for all first-year residents to learn and practice and was included in the 4-week course [11].

Our study demonstrates that the virtual contrast media workshop significantly improved the post-test scores and received high satisfaction ratings from the participating radiology trainees. This suggests that our workshop effectively enhanced the trainees' knowledge of managing contrast reactions, which is crucial for patient safety in radiology practice.

Our workshop differed from most previously published contrast courses, which mainly focused on managing adverse contrast reactions such as those in the studies by Pfeifer et al. and Ali et al [4,5]. In contrast, this workshop also covered additional essential topics from the American College of Radiology (ACR) Manual on Contrast Media [1]. The manual remains the international reference for safe contrast administration, emphasizing preparedness, recognition of contrast reactions, and management protocols. Integrating this reference into the national curriculum ensures that all radiology residents are trained according to standardized, evidence-based guidelines. To reinforce the workshop's multidisciplinary approach, the teaching team included subspecialty radiologists

and nephrologists, allowing residents to gain a comprehensive understanding of contrast use across different clinical contexts.

Despite the importance of contrast safety, many radiology departments and practitioners still need to improve their preparedness for managing contrast reactions [2]. While only a few institutions offer hands-on training, most programs rely on didactic lectures to teach the management of contrast reactions. A 2012 survey from the Association of Program Directors in Radiology found that only 49% of radiology residency programs provided one lecture per year on contrast reactions, 29.4% provided two lectures, and 16% provided three or more; at that time, only 18% of programs utilized simulation training [10]. More recently, a COARDRI study published in 2016 reported that 89.4% of U.S. residency programs now provide didactic lectures on contrast reactions, while 37.8% incorporate simulation training [9]. The initiative taken by the SCFHS and the RSSA to include a national contrast safety workshop reflects a significant step toward improving early trainee awareness and ensuring that all Saudi radiology graduates are properly trained in contrast safety.

Research indicates that simulation-based training sessions are more effective for teaching proper management of high-acuity, low-frequency occurrences, such as severe contrast reactions, than lectures alone [12,13]. Simulation-based training offers several benefits, including customizing case scenarios for each participant or group, safely making mistakes without endangering actual patients, and engaging in structured debriefing sessions. These debriefings allow participants to assess their performance and reinforce learning, serving as a valuable component of the educational process [14,15].

Verbal simulated case scenarios serve as a viable alternative to high-fidelity simulation labs [14]. While they lack the hands-on component of manikin-based training, they still provide meaningful educational benefits. Our virtual course combined concise lectures with interactive case-based discussions, a structure that residents appreciated and recommended expanding to other courses within the “Core Radiology Skills” program.

Earlier studies on contrast reaction training focused mainly on contrast-related emergencies, without addressing conditions that mimic such reactions. Distinguishing genuine contrast reactions from mimicking conditions is clinically significant because it affects diagnosis and management decisions [16]. Similar to Ali et al [4], our workshop included simulated cases of both true and mimic reactions, along with discussions on contrast administration in patients with comorbidities such as renal impairment, which distinguishes our program from earlier studies.

Our study also differs from prior research regarding the training level and population size of participants. We included the entire cohort of first-year residents across all Saudi training programs. The interprovincial performance data can help regional program directors identify specific training needs among their residents. However, one limitation is that the study focused only on first-year residents, which may limit generalizability to more experienced trainees. Previous studies typically included residents from multiple levels within single institutions [4,17].

One of the intended objectives of this workshop was to assess knowledge retention at six months. Trout et al [17]. found that knowledge retention declined by nine months but remained higher than baseline after six months, suggesting the value of periodic refresher courses. In our study, although a follow-up test was distributed after six months, the very low response rate (n=3) precludes any meaningful conclusion; this finding was therefore reported descriptively without statistical inference. Future iterations may incorporate mandatory short refresher sessions to improve response rates and evaluate long-term retention, as suggested by Picard et al [18].

Even if the workshop did not establish long-term retention, it successfully created early awareness of key contrast safety principles and provided residents with reliable reference materials such as the ACR Manual on Contrast Media [1]. The virtual platform was chosen due to COVID-19 restrictions and logistical limitations, including the large number of residents, limited simulation centers, and cost considerations [12,19].

Although virtual training offers several advantages, including scalability and accessibility, it has limitations. The lack of hands-on experience and real-time instructor feedback may reduce skill acquisition effectiveness, even though short-term knowledge retention and participant satisfaction were high [14]. Additionally, team-based skills and interactive coordination during contrast reactions could not be assessed. Introducing breakout rooms and structured interactive tasks may enhance engagement and simulate real-life teamwork dynamics. Studies comparing hands-on and computer-based simulations have shown comparable knowledge gains but higher satisfaction with physical simulations [6,8].

Despite these limitations, our findings have important implications for radiology residency programs in Saudi Arabia and internationally. The virtual contrast media workshop can be adapted to various training settings, provided that institutional support and faculty expertise are available. Future research should

explore integrating high-fidelity simulations, expanding to multiple training levels, and assessing long-term effects on clinical practice.

Based on our findings, we recommend incorporating breakout rooms for more personalized instruction and conducting biannual refresher sessions to enhance knowledge retention. We also suggest adding hands-on components to strengthen trainee confidence and competence in managing contrast reactions. While virtual case scenarios may not completely replace on-site simulations, they represent a scalable and effective educational model that can meet the needs of large, geographically distributed trainee groups when well-structured and standardized.

5. CONCLUSION

This study demonstrates the positive impact of a virtual contrast media workshop on participating residents' knowledge. The significant improvement in post-test scores and the overwhelmingly favorable feedback indicate the workshop's effectiveness in addressing essential topics and delivering clear learning points. The fact that most residents reported their intention to change their practice due to attending the workshop further underscores its value. A six-month follow-up refresher course should be considered for long-term knowledge retention. Continuously refining the workshop based on feedback and outcomes can serve as an invaluable resource for residents during their early years, ultimately contributing to improved patient care and clinical outcomes.

6. ETHICS APPROVAL

The research project was reviewed and exempted from formal ethical approval by the Research Ethics Committee (REC) of King Abdulaziz University Biomedical Research unit, in accordance with their assessment of the submitted application (HA-02-J-008).

7. AUTHORS' CONTRIBUTIONS

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; drafting, revising, or critically reviewing the article. All authors approved the final version to be published; agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

8. DECLARATION OF COMPETING INTEREST

All authors have read and approved the manuscript, and no conflicts of interest exist.

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10. DECLARATION OF GENERATIVE AI

During the preparation of this work the authors used GPT-4 (OpenAI, San Francisco, USA) to improve the readability of some of the sections, assure homogeneity of the passages and reduce redundancies in writing. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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APPENDIX 1

Pre- and Post-test Questions. The key answers are in “**bold**”.

1- What is the percentage of allergic-like reactions to modern contrast media (low osmolar non-ionic contrast)?

a. Less than 1%

b. 35%

c. 10%

d. 20%

2- A 30-year-old woman came for a contrast-enhanced CT study. She has asthma. What is the likelihood of an allergic-like contrast reaction, and what is your recommendation?

a. Modest risk, restriction of contrast use, and pre-medication are NOT required.

b. Modest risk, restriction of contrast use, and/or pre-medication are required.

c. High-risk pre-medication is required.

d. High-risk, pre-medication is NOT required.

3- Which of the following contrast media crosses/es the placenta and enters the fetus?

a. Both iodinated and gadolinium-based contrast media.

b. Gadolinium-based contrast media.

c. Neither iodinated nor gadolinium-based contrast.

d. Iodinated contrast media.

4- A 24-year-old pregnant lady in her second trimester came to the emergency room with right lower quadrant pain that had been increasing over the past five

days with rigidity on clinical exams. Her white cell count is elevated. Ultrasound was inconclusive, but the ovaries were normal. The emergency physician requested an enhanced CT scan as access to MRI is not available at the institution. He was worried about the effects of the contrast material on the fetus. What is your recommendation regarding the administration of iodinated contrast?

- a. It should be given as it is safe during pregnancy.
- b. It should be given when the benefits out-way the risks.**
- c. Recommend that the patient goes to surgery without further imaging.
- d. It should be withheld, given the potential harm to the fetus.

5- A 32-year-old woman - two weeks postpartum - had undergone an enhanced cervical neck MRI with gadolinium to assess previously resected meningioma grade II. Despite assuring the patient that it is safe to resume breastfeeding, she remains concerned about the effect of gadolinium on her baby. She asks when gadolinium is completely cleared from her breast milk.

- a. After 24 hours.**
- b. After 48 hours.
- c. After 72 hours.
- d. Never.

6- A 56-year-old man was scheduled to undergo an enhanced CT exam. He is diabetic with normal renal functions. He asks about the use of metformin. What is your recommendation?

- a. No need to discontinue metformin before or after the enhanced CT scan.**
- b. The patient should withhold metformin for 48 hours after an enhanced CT scan.
- c. The patient should withhold metformin for 48 hours before and after the enhanced CT scan and reassess the renal function following the test.
- d. The patient should withhold.

Metformin 48 hours before the enhanced CT scan.

7- Which of the following is considered an allergic-like reaction to iodinated IV contrast administration?

a. Bronchospasm.

b. Flushing.

c. Nausea.

d. Hypoglycemia

8- A 35-year-old man with right lower quadrant pain comes to the emergency department. The physician requests a CT abdomen and pelvis with IV contrast. The patient developed some itchiness and a rash on the face and the upper extremities. His vitals are stable, and he reports no breathing difficulty. What is the best next step in management?

a. Administer epinephrine.

b. Give oral Benadryl.

c. Administer IV fluids.

d. Call for CODE.

9- A 78-year-old frail woman had a contrast-enhanced CT chest. She had an 18-gauge cannula in the right antecubital region. She shouted out of pain after the power injector pushed the contrast. On examination, there is swelling in the antecubital area without skin changes, loss of motion, sensation, or pulses. What is the best step of management?

a. Lower the arm below the heart level and apply warm compressors.

b. Elevate the arm and apply cold compressors.

c. Call plastic surgery for concern of compartment syndrome.

d. Administer IV fluids.

10- Which of the following is considered a physiologic response to IV contrast administration?

- a. Diffuse skin erythema.
- b. Vasovagal response.**
- c. Laryngeal edema.
- d. Bronchospasm.

11- What is the most stable component of a gadolinium-based contrast agent (GBCA) combination?

- a. Macrocyclic non-ionic.
- b. Macrocyclic ionic.**
- c. Linear ionic.
- d. Linear non-ionic.

12- An ESRD patient with anuria on hemodialysis three times a week needs urgent cross-sectional imaging to assess a suspicious renal mass; what is the best examination option?

- a. Group II GBCA enhanced MRI scan.
- b. Group I GBCA enhanced MRI scan.
- c. Iodinated contrast-enhanced CT scan.**
- d. Non-contrast MRI scan.

13- Which of the following IV lines is limited to MANUAL contrast injection ONLY?

- a. Central Venous Catheter (CVC).**
- b. Peripheral line gauge (24, 22, 20) for pediatrics more than 10kg.
- c. Peripheral line gauge (22, 20,18) for adults.

d. Power PICC line.

14- Among patients undergoing a contrast-enhanced CT scan with iodinated contrast, which of the following is the primary risk factor for contrast-induced AKI?

a. Age of the patient.

b. Impaired kidney function.

c. The volume of contrast given.

d. Proteinuria

15- Clinical research evaluated different measures to prevent and/or minimize the risk of developing contrast-induced AKI. Which of the following has shown benefit and is recommended for use in specific patient groups?

a. Prophylactic Hemofiltration and Hemodialysis.

b. Intravenous volume expansion with crystalloids.

c. Remote ischemic preconditioning.

d. N-acetylcysteine.

16- A 63-year-old woman with diabetes, hypertension, coronary artery disease, and chronic kidney disease is evaluated for acute abdominal pain and bowel ischemia. She is in extreme pain; her vital signs are heart rate 120 bpm, BP 90/50 mmHg, RR 28 breath /min, and her abdomen is tender all over. Her serum creatinine is 1.7 mg/dL (eGFR of 32 mL/min/1.73 m²). A CT angiography is ordered to confirm the suspicion and take her to an urgent OR. The CT technician is concerned about this patient's abnormal GFR. What is the best plan of management at this point?

a. Make sure nephrology is involved in arranging for hemodialysis after contrast is given.

b. Suggest to the primary team to delay the CT scan until her GFR improves.

c. Arrange for a CT scan to be done urgently as her condition is life-threatening.

d. Decline to do the CT Angiography as this patient is at high risk for Contrast Induced AKI and suggest a different diagnostic modality.

17- Intravenous ultrasound contrast injection can evaluate which of the following?

a. Tubal patency.

b. Complex renal cyst.

c. Gastro-esophageal reflux.

d. Vesicoureteral reflux.

18- Which of the following is the main advantage of using contrast-enhanced ultrasound?

a. It can be used in brain imaging.

b. It is operator independent.

c. It can be used in renal failure patients.

d. It can be used once and lasts for an entire day.

19- What is the most important patient-related risk factor for developing nephrogenic systemic fibrosis?

a. Etiology of renal impairment.

b. Degree of renal impairment.

c. Duration of renal impairment.

d. Age at renal impairment.

20- Which of the following patients does not need an eGFR before a gadolinium-enhanced scan?

- a. A 45-year-old with a single congenital kidney.
- b. A 60-year-old post renal transplant two years ago.
- c. A 75-year-old with heart failure and multiple episodes of acute renal failure due to cardiorenal disease.
- d. A 65-year-old on continuous peritoneal dialysis.**

APPENDIX 2

Table 3. Contrast Media Workshop Course Schedule

Start	End	Lecture/Session
8:45	9:00	Pre-test
9:00	9:30	Iodinated contrast media: types (to include oral), indications, contraindications, special circumstances (medications)
9:30	9:50	Contrast Administration and pregnancy/breastfeeding
9:50	10:00	Case 1: A pregnant woman
		5 min break
10:05	10:20	Contrast media administration, contrast flow dynamics
10:20	10:50	Gadolinium-based contrast media: types, indications, contraindications, complications, safety concerns.
10:50	11:10	Case 2: MRI case
		5 min break
11:15	11:45	Renal impairment and iodinated contrast.

11:45	12:10	Case 3: Contrast the case
12:10	12:30	Gadolinium-based contrast and NSF.
12:30	12:50	Case 4: MRI renal case
		1-hour break
2:00	2:30	Contrast reaction types, risk factors, signs, symptoms, and treatment.
2:30	3:30	Cases 5-8: Reactions!
3:30	3:45	Miscellaneous
3:45	4:00	Post-test and Feedback

APPENDIX 3

Table 4. Examples of an abbreviated version of the contrast scenarios with the general treatment algorithm

Scenario	Treatment Algorithm
Case1: Mild Contrast Reaction Ali Ahmad is a 45-year-old newly diagnosed with colon cancer. Came to the CT suit for a routine initial staging CT Abdomen and pelvis with IV contrast. He developed a skin rash after the IV contrast injection. The technologist calls you to check on the patient.	1. Obtain medical history and do a physical examination. 2. Place the patient on the monitor and obtain vital signs. 3. Assure the patient of having a mild contrast reaction. 4. Administer antihistamine. 5. Offer him to sit in the dept for 30 minutes to an hour to

The patient asks: Is this going to happen again to me?

What is going to happen to me if I need this contrast again? Am I going to die? Then I will refuse the study next time.

ensure no reaction progression.

Yes, it may happen again in the future. We will mark your new allergies in the file.

Assuring the patient to make the necessary preparation in the future will minimize this from happening again. This is giving corticosteroids and antihistamines the day before the examination.

The resident should stress the patient when visiting other hospitals to inform them of this allergy to do the contrast prep.

Case2: Severe Contrast Reaction

Sara is a 35-year-old female with abdominal pain. She comes to the CT suite for a routine CT Abdomen and pelvis with IV contrast.

She develops a cough and shortness of breath after the IV contrast injection. The CT technologist calls you with the patient's complaints to assess.

5 minutes later

Tech: doctor. The patient is getting a

1. Obtain medical history and do a physical examination.
2. Place the patient on the monitor and obtain vital signs.
3. Recognize the scenario as the patient is having a moderate or severe reaction.
4. O2 Mask
5. Keep IV line.
6. Administer bronchodilator.
7. Administer Epinephrine IV or

drowsy BP of 90/60, HR of 120

IM

A minute later, the patient is unresponsive!

8. Call for help.

9. You check for a response, pulse, and breathing and initiate CPR.

The code team arrives and takes over the care of the patient.

10. The resident explained to the husband that the patient had an anaphylactic reaction to the contrast.

The patient stabilizes and is transferred to the ICU for monitoring.

11. This is not related to the strawberry allergy but rather unpredictable.

The husband asks what happened. Is it related to her strawberry allergy? What should we do in the future?

12. It might happen again without contrast allergy preparation.

13. The patient should take contrast allergy preparation for the future if contrast is strongly needed. This is giving corticosteroids and antihistamines the day before the examination.

Case 3: Physiologic Reaction

A 39-year-old woman came to the CT suite for a routine contrast-enhanced CT abdomen for a non-specific liver lesion.

1. Obtain medical history and do a physical examination.

2. Place the patient on the monitor and obtain vital signs.

After the study was concluded, the patient became dizzy and felt the need

3. Recognize the scenario as the patient is having a vasovagal reaction.

4. Keep the patient lying

to throw up when getting out of the CT scanner.

You happened to be in the CT suite, and the tech called you to help. What should you do?

Tech: doctor, the patient is getting better BP 110/70 HR 80

A minute later, the patient felt like herself again. The patient asks: Was this an allergic reaction? What should I do in the future?

Case 4: Contrast Extravasation

Asmaa is a 70-year-old newly diagnosed with breast cancer. She came to the CT suite for a routine initial staging CT Chest, Abdomen, and pelvis with IV contrast.

The patient developed pain at the site of the contrast injection.

The technologist has not scanned the patient yet and called you to evaluate it.

You come after 30 minutes, and the patient feels okay; there is no progression in her symptoms.

Patient: Can I go home now? I am tired of sitting on this

with her legs raised.

5. O2 nasal cannula

6. Administer IV fluid.

7. Prepare atropine and call for code if the patient is worse.

The resident explained to the patient that she had a vasovagal reaction to the contrast.

The patient does not need to take contrast allergy preparation for the future.

1. Obtain history from the patient and the technologist.

2. Physical examination of the site of injection and pain

3. Assure the patient of having extravasated contrast.

4. Elevate the arm.

5. Apply warm or cold compressor.

6. Offer her to sit in the dept for

30 min to an hour to ensure no progression of symptoms to compartment syndrome.

Yes, you may leave.

Instruct the patient on what to do if there is worsening pain, paresthesia, loss of range of

uncomfortable chair! My arthritis is starting to act up.

motion, change in skin color, or worsening of swelling. She should come to the emergency room.

APPENDIX 4

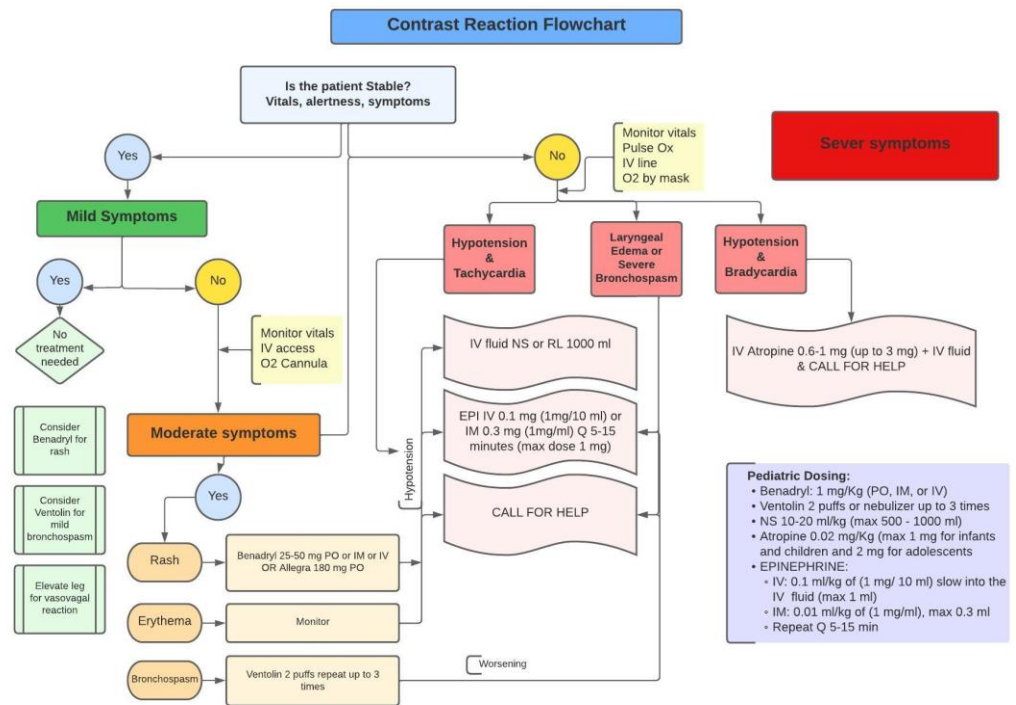


Figure 3. Contrast Reaction Management Flow Chart