

Benefit of a Visual Aid in the Management of Moderate-Severity Contrast Media Reactions

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OBJECTIVE. The purpose of this study was to compare management of moderate-severity reactions with and without a visual aid or flowchart in contrast medium reaction simulations.

SUBJECTS AND METHODS. All attending radiologists and trainees were requested to participate in a contrast medium reaction simulation program, including a moderate-severity reaction scenario, and were randomized to groups having or not having a visual aid. The time to administer intramuscular (IM) epinephrine via automated injector and errors in administration were recorded. After the simulation, all participants completed a survey assessing their comfort in treating reactions to contrast media with and without a visual aid.

RESULTS. A total of 138 participants were divided into 21 sessions in the program, with 68 participants in the moderate-severity reaction scenario. Eleven groups were provided a visual aid; 10 groups were not. Errors in management occurred in 18.2% (2 of 11) of groups with visual aids versus 40% (4 of 10) in groups without ($p = 0.35$), with epinephrine self-administration reflecting the most common error. Excluding the groups with errors, the mean time to administration of IM epinephrine was 97 seconds with versus 152 seconds without the visual aid ($p = 0.04$). Of the 138 participants, 97.8% agreed that the poster would aid in medication administration, and 87% agreed that it would help decrease time to administer medications.

CONCLUSION. A visual aid increased the subjective confidence of radiologists in the dose and route of medication administration in the contrast medium reaction simulation and led to faster administration of epinephrine. Self-administration IM epinephrine errors were common and seen in both groups.

Administration of IV contrast agents can lead to a variety of adverse reactions ranging from urticaria to life-threatening anaphylaxis [1]. However, the frequency of such adverse reactions is low, ranging from 0.2% to 0.7% for nonionic iodinated contrast media and 0.06% for gadolinium-based contrast media [2]. Because contrast medium reactions are rare, most radiologists have limited experience managing them, and more than 50% of radiologists do not know the correct dose of epinephrine to administer during a severe reaction [3]. In one 2009 survey, 91% of radiologists correctly identified epinephrine as the initial drug of choice for a contrast medium-related reaction. However, only 41% gave the correct administration route and dose; 11% knew what concentrations were available to them and what concentrations were needed; and 17% would have administered potentially fatal overdoses of epinephrine [4]. This lack of knowledge is a significant concern given that

radiologists are often the sole provider responsible for managing a potentially life-threatening contrast medium reaction.

High-fidelity simulation courses have been shown to be a valuable and cost-effective tool in educating radiologists [5]. Additionally, such simulation courses serve as an opportunity to practice medication administration and basic life support management. These skills are essential in the management of adverse reactions to IV contrast media.

Clinical decision algorithms are commonly used in health care, particularly in emergent clinical situations [6, 7]. These algorithms provide instruction on how to best treat a patient for a given clinical problem. Providing these algorithms in visual aids can expedite clinical decisions when time is critical, such as in the setting of a reaction to contrast media. Errors in management of these situations are common, and errors in epinephrine administration can result in life-threatening events [8–11]. Automated epinephrine intra-

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muscular (IM) devices have been shown to reduce time to epinephrine administration and errors in management. However, errors still occur, including self-administration, which is commonly reported in the general public and health care workers [8, 10].

Our institution conducts an annual course in contrast material reaction management that uses a high-fidelity simulation laboratory as an educational and quality improvement ini-

tiative. Through the course, staff can practice recognition and management of contrast medium reactions and potential mimics of reactions. The purpose of this study was to test the added benefit of having a visual aid in successfully managing a moderate severity contrast medium reaction during a simulation. The visual aid tested was a flowchart (Fig. 1) developed by two of the authors that contained a clinical algorithm for managing

a contrast medium reaction. We hypothesized that access to a visual aid would decrease time to administer IM epinephrine and lower management error rates. We also sought to assess the perceived benefit of the aid with a survey of all simulation course participants.

Subjects and Methods

This study was a HIPAA-compliant prospective quality improvement project approved by our

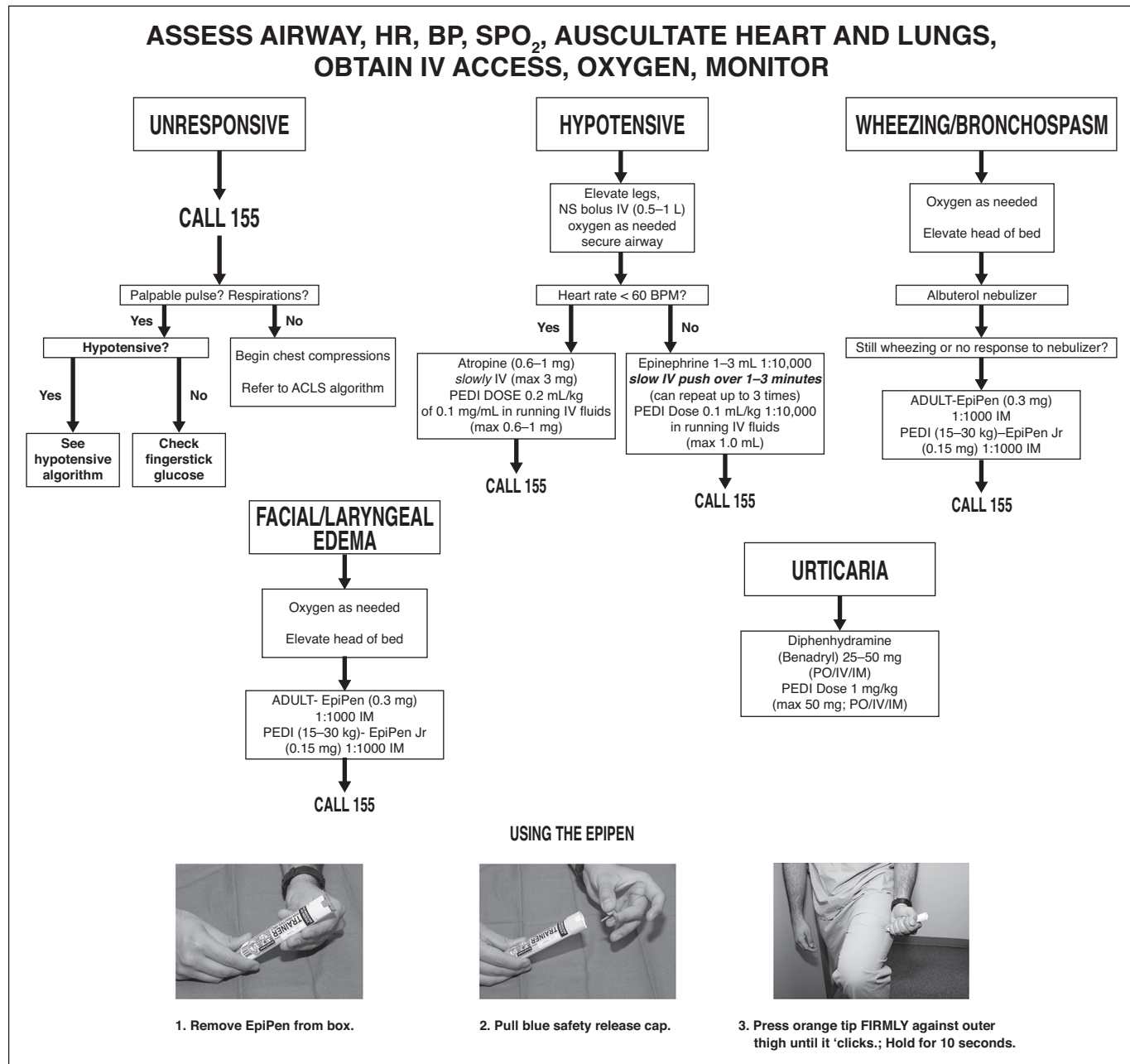


Fig. 1—Visual aid provided to participants of contrast medium reaction simulations, containing clinical algorithm for contrast medium reaction management and instructions for using epinephrine autoinjector (EpiPen, Mylan). Benadryl is produced by Pfizer. HR = heart rate, BP = blood pressure, SPO₂ = functional oxygen saturation, ACLS = advanced cardiac life support, NS = normal saline, BPM = beats per minute, PEDI = pediatric, max = maximum, IM = intramuscular, PO = by mouth.

Visual Aid Use for Contrast Media Reactions

institutional review board with waiver of written informed consent. At our institution, all radiology fellows, radiology residents, radiology mid-level providers, and radiology nurses were required to participate in the annual high-fidelity contrast medium reaction simulation program. Interventional radiologists were exempt from participating in the program, and attendance for attending diagnostic radiologists was optional but part of our department's bonus eligibility requirement.

The program consisted of 21 1-hour sessions (on weekdays at various times between 8:30 am and 4 pm) with a total of eight to 10 participants with varied experience and training, including up to one radiology nurse per group. All department members used an online scheduling website allowing registration for sessions based on their availability. Participants in each session were divided into smaller groups of two to four active responders to a simulation while the other participants observed in the room. This division was done to mimic our clinical practice, in which a small group of individuals usually respond to potential contrast medium reactions, including members of radiology nursing. One of the three scenarios provided to participants was a contrast medium reaction of moderate severity in a pediatric patient for which administration of 0.15 mg of IM epinephrine was the most appropriate management. A visual aid was provided to a group on an alternating basis in chronologic calendar order (11 groups had the aid, 10 did not).

The visual aid provided was a 8.5 × 11 inch (21.6 × 27.9 cm) laminated poster (Fig. 1) placed on top of our department's contrast medium re-

action kit. The kit contains several medications including IV epinephrine (1:10,000 1 mg/10 mL vial), diphenhydramine (Benadryl, Pfizer), IV methylprednisolone sodium succinate (Solu-Medrol, Pfizer), and albuterol nebulizers. Epinephrine autoinjector (EpiPen, Mylan) trainer devices for adult and pediatric use (labels were created for the trainer devices identifying them as adult or pediatric devices with 0.3-mg or 0.15-mg 1:1000 epinephrine doses, respectively) were also present in our contrast medium reaction trainer kit. The visual aid included clinical decision algorithms for response to the following scenarios: unresponsive, hypotensive, wheezing/bronchospasm, facial/laryngeal edema, and urticaria. Both adult and pediatric doses were provided in the algorithms where appropriate. The aid also provided photographs detailing the appropriate use of an epinephrine autoinjector, including how to hold the device.

The moderate-severity contrast medium reaction simulation involved a high-fidelity child mannequin presenting with urticaria and shortness of breath after receiving IV contrast medium. The symptoms did not respond to nebulized albuterol and diphenhydramine. Oxygen saturation subsequently declined with rise in heart rate and respiratory rates, new wheezing, and patient-reported worsening shortness of breath with chest tightness. This scenario was designed to mimic an actual event that occurred in our department. The mannequin had an IV line as well as a thigh pad in place to allow administration of IV or IM medication.

The other two simulation scenarios were not examined in this study. One involved a severe anaphylactic contrast medium reaction requiring the use of IV epinephrine, and the other involved a simulated discussion on the appropriate management and workup of a pregnant patient with suspected pulmonary embolism.

All simulations were followed by a 5- to 10-minute debriefing session during which participants and observers talked about their actions and feelings during the simulation, and the appropriate management was reviewed verbally and with projected presentation slides (PowerPoint, version 2013, Microsoft). Medication delivery was also reviewed during the debriefing. All simulation sessions were taught by one or two members of the radiology department contrast medium simulation team (two attending radiologists, two 3rd year radiology residents, one 2nd year radiology resident). Team members underwent simulation laboratory training at our institution and were mentored by the program leader, who had 4 years' experience in conducting simulations of contrast media reactions.

At the end of all three simulations, all participants were allowed to review the visual aid, in-

cluding participants in sessions for which it was not available for reference and participants who were observers when it was available during the studied simulation event. This step allowed all participants time to review and assess the visual aid. A 12-question survey (Appendix 1) was distributed to all participants with Likert scale ratings gauging the perceived benefit of the visual aid compared with responding without any visual aid.

A member of the contrast medium reaction simulation team observing but not participating in the simulation recorded the medications administered, the time to IM epinephrine injection, and any errors observed during the simulation, including medication dosing errors and improper use of the epinephrine autoinjector trainer device (e.g., self-administration errors occurring when the device is held upside down with the holder's thumb over the needle delivery location). The time to epinephrine administration was started as soon as the contrast medium reaction kit was opened by a participant. Errors were not addressed during the simulation but were reviewed and discussed in the debriefing sessions immediately afterward.

Statistical testing was performed using R software (version 3.3.2, R Foundation for Statistical Computing). The Wilcoxon signed rank test was used for comparing survey responses. Times for epinephrine administration were compared using a *t* test. The proportions of errors were compared with a Fisher exact test. Testing was considered statistically significant with a *p* value of less than 0.05.

Results

A total of 138 participants completed the contrast medium reaction simulation program, of whom 68 participated in the moderate-severity scenario. Of the 138 participants, 79 (57%) were male and 59 (43%) were female, with a mean age of 41 years old (range, 25–74 years old). Eighty-two percent (*n* = 113) had completed the annual simulation-based contrast media reaction training the year before. Table 1 lists level of experience and training of the participants.

Survey results after the training revealed that 55.8% (*n* = 77) of all participants felt very comfortable or comfortable and 44.2% (*n* = 61) felt uncomfortable or very uncomfortable in managing a reaction to contrast media. When asked about their comfort level when a visual aid was available, 93.5% (*n* = 129) of participants felt they would be very comfortable or comfortable managing a contrast medium reaction, whereas 6.5% (*n* = 9) said they would be uncomfortable or very uncomfortable (*p* < 0.001) (Table 2).

TABLE 1: Participant Demographics

Participant Demographic	No. (%) of Patients
Faculty	
> 10 years of experience	35 (25.4)
5–10 years of experience	11 (8.0)
< 5 years of experience	15 (10.9)
Fellows	14 (10.1)
Residents	
Postgraduate year 4	11 (8.0)
Postgraduate year 3	11 (8.0)
Postgraduate year 2	12 (8.7)
Postgraduate year 1	14 (10.1)
Registered nurse	13 (9.4)
Physician's assistant	1 (0.7)
Paramedic	1 (0.7)
Total	138

TABLE 2: Likert Survey Results

Survey Question	Strongly Agree or Very Comfortable	Agree or Comfortable	Neutral	Disagree or Uncomfortable	Strongly Disagree or Very Uncomfortable
Without any visual aids, how comfortable are you managing a contrast medium reaction?	8 (5.8)	69 (50)	NA	59 (42.8)	2 (1.4)
If given access to this poster, how comfortable would you be managing a contrast medium reaction?	52 (37.7)	77 (55.8)	NA	7 (5.1)	2 (1.4)
This poster would help aid in my decision of the correct doses and routes of medication administration in the management of contrast media reactions in adult patients.	89 (64.5)	46 (33.3)	1 (0.7)	0 (0)	2 (1.4)
This poster would help aid in my decision of the correct doses and routes of medication administration in the management of contrast media reactions in pediatric patients.	94 (68.1)	40 (29)	2 (1.4)	0 (0)	2 (1.4)
This poster would help decrease the time I would need to administer the correct medication in the management of a contrast medium reaction.	79 (57.2)	41 (29.7)	15 (10.9)	1 (0.7)	2 (1.4)

Note—Data are number (%) of responses from 138 total participants. NA = not applicable.

Additionally, 97.8% ($n = 134$) of participants strongly agreed or agreed that the flowchart would aid in correct route and dose administration of epinephrine to adult and pediatric patients, and 86.9% ($n = 120$) strongly agreed or agreed that the flowchart would help decrease time to proper administration of medication during a contrast medium reaction.

Mean time to IM epinephrine administration $\pm$ SD did not significantly differ between all groups with versus without the visual aid (111 ± 50 seconds vs 136 ± 60 seconds [$p = 0.31$]). Excluding the groups with errors, the mean time to appropriate administration of IM epinephrine was 97 seconds with versus 152 seconds without the visual aid ($p = 0.04$).

Overall management error rate for all groups was 28.6% (6/21). Two groups (18.2%) with access to the visual aid made an error in IM epinephrine drug administration versus four groups (40%) without access ($p = 0.35$). Epinephrine self-administration accounted for five of six errors (83.3%) and was seen in 23.8% (5/21) of all groups. One (9.1%) occurred in groups with the visual aid versus four (40%) in groups without the visual aid ($p = 0.36$). The remaining error was improper administration of the adult 0.3-mg dose of epinephrine (rather than the appropriate 0.15-mg pediatric dose), which occurred in one group with access to the visual aid.

Discussion

Anaphylactic contrast media reactions are one of the few clinical emergencies encountered and managed by radiologists. Contrast media reactions are infrequent, and, as a result, radiologists' comfort level with managing

these reactions is low [12–17]. Prior studies have shown that high-fidelity simulation programs, such as the one used in this study, are beneficial in training for infrequent events like contrast media reactions [18–22].

Clinical decision making algorithms have been used for years to aid management of multiple conditions across many medical specialties [23]. Although the literature is sparse on the use of visual aids in radiology, they have been used effectively in other subspecialties during emergency situations. For example, one study used cognitive aids in a simulation setting of intraoperative anaphylaxis. Results indicated that groups with a linear cognitive aid (flowchart) performed significantly better than groups with no cognitive aid or a branched (more complex) cognitive aid [24]. Another group studied the use of cognitive aids in the perioperative management of ST-segment elevation myocardial infarction in a simulation setting, with improvement in overall task performance in the groups receiving the visual aid [25]. The concept of visual aids in radiology is not novel, with so-called smartcards developed to help guide radiologists' decisions when responding to contrast media reactions described in the literature and used in radiology departments [26]. Our aid was designed to improve on our department's pocket-sized contrast media reaction card by providing easier directions to follow for reaction management in a flowchart format. In addition, pictures on how to actually use the epinephrine autoinjector were included on our aid to help mitigate risk of mistakes in administration.

With these results in mind, our study sought to augment the results of prior con-

trast medium reaction simulation training programs and assess the utility of visual aids in relation to physician confidence, time to epinephrine administration, and effect on medication dose and administration errors. Of the participants, 87% ($n = 120$) agreed or strongly agreed that the poster would help decrease the time needed to administer the correct medication to manage the contrast medium reaction. Additionally, results of our survey show that the flowchart increased physicians' confidence in their ability to appropriately respond to a moderate-severity contrast medium reaction, with 97.8% of our participants agreeing it would help them to select the correct dose and route of medication administration.

Medication errors are common in medicine and likely even more common within emergency situations like anaphylaxis. Prior work has shown anaphylaxis-related medication error rates in a pediatric emergency department up to 35%, and another study found that only 14.4% ($n = 41$) of doctors surveyed would administer epinephrine correctly [27–30]. Epinephrine is used in both anaphylaxis and cardiac arrest but requires different doses and routes, which may lead to confusion in proper administration [11, 31]. In particular, medication error rates in contrast media reaction simulations as high as 58% have been reported [8, 9]. Epinephrine autoinjectors have been used in an effort to decrease error rates, with studies showing a decrease in time to epinephrine injection and decrease in error rates when compared with manual IM delivery [8, 32]. Furthermore, healthcare providers prefer autoinjectors because of their ease of use, convenience, and speed

of administration, among other reasons [33]. However, using an epinephrine autoinjector does not preclude errors of self-administration, which are still commonly seen. One study documented 15,190 cases of unintentional injection of epinephrine reported to the U.S. Poison Control Center between 1994 and 2007 [10]. In addition, physicians who prescribe epinephrine autoinjectors are often unable to demonstrate to their patients how to properly use the devices [34].

We also encountered high overall error rates in contrast medium reaction management during simulation, with 6/21 (28.6%) of the groups having some medication error. Epinephrine autoinjector self-administration was the most frequent error, accounting for 83.3% (5/6) of the errors and seen in 23.8% (5/21) of the groups in total. We found a higher percentage of this error in the groups without access to the visual aid (4/10, 40%) than in those with access (1/11, 9%), possibly due to images on epinephrine autoinjector usage on the visual aid, but the difference was not statistically significant. This result may indicate a tendency toward fewer errors in groups with the flowchart but was limited by the low number of groups studied.

Groups with the flowcharts showed a tendency toward quicker IM epinephrine administration (mean time, 111 seconds vs 136 seconds). Although the difference did not achieve statistical significance, it may be clinically significant in management of anaphylactic contrast media reactions for which prompt administration of epinephrine is key in proper management [35, 36]. This tendency toward quicker epinephrine administration was accentuated when removing all groups that had an error in management. In this subset, a statistically significant reduction in mean epinephrine administration time was recorded with the visual aid (97 seconds vs 152 seconds, $p = 0.04$). This result highlights the potential of our visual aid to improve management of contrast media reactions by decreasing time needed to administer the proper dose of IM epinephrine.

Our study had several limitations. Our small sample size of observed groups made comparison of small differences in error rates and time to epinephrine administration difficult. Future studies looking at single individuals during a simulated contrast medium reaction event are needed. Because of limitations of availability for both our instructors and the simulation laborato-

ry, we were unable to correlate participant responses on the survey regarding comfort with management errors. In addition, our only measure of effectiveness of the visual aid was time to epinephrine administration and overall error rate identified during observation. Unlike other studies, we did not fully rate responses of the physicians during the simulation, which may have shown a more positive effect of the flowchart visual aid [18, 37, 38]. Additionally, other studies have used more thorough definitions of medication errors, such as treating mild bronchospasm with epinephrine as a first-line treatment, which we did not [9]. We also did not compare the effectiveness of different forms of visual aids; a more simplified visual aid may have yielded different results. Extrapolating the benefit of subjective confidence reported with use of the aid is also difficult if it cannot be shown to improve outcomes and patient safety. We suspect that if we studied a larger sample size of groups, we would have found both an increase in subjective confidence and a statistically significant improvement in error rates, but we cannot make that conclusion from the current data. Lastly, our population group was unusual in that 82% of our participants had already participated in a contrast medium reaction simulation training at our institution and the simulation used in this study was for treatment of a pediatric patient. Therefore, the utility of the visual aid in a population without prior training cannot be inferred from our study.

In conclusion, our study found high rates of self-administration errors with automated epinephrine injectors in groups without and with a visual aid during a simulated contrast medium reaction event, emphasizing the need for continued education in usage of these devices. The visual aid was associated with higher subjective confidence of participants in contrast medium reaction management but resulted in a reduction in observed error rate that was not statistically significant. When comparing groups without management errors, time to epinephrine administration with use of the aid was significantly decreased.

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Visual Aid Use for Contrast Media Reactions

APPENDIX I: Survey With Likert Scale Ratings Gauging Perceived Benefit of Visual Aid

- | | |
|--|---|
| 1. Sex and age
A. Male
B. Female

Age- | C. Disagree
D. Strongly disagree |
| 2. Have you ever completed simulation training on management of contrast reactions?
A. Yes
B. No | 8. The poster would help me reach the appropriate clinical decision.
A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree |
| 3. Level of training
A. R1
B. R2
C. R3
D. R4
E. Fellow
F. Attending- <5 years
G. Attending- 5-10 years
H. Attending- >10 years
I. PA/NP/RA
J. RN | 9. Prior to the simulation, I knew what number to call for additional assistance (and when to call).
A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree |
| 4. Outside of simulation sessions, have you ever administered IM epinephrine before in the setting of a contrast reaction?
A. Yes
B. No | 10. I know the doses and route of administration of medications that may be needed in contrast reaction setting for adults (epinephrine, Benadryl, albuterol, atropine).
A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree |
| 5. If yes , how comfortable were you with giving it?
A. Very comfortable
B. Comfortable
C. Uncomfortable
D. Very uncomfortable | 11. I know the doses and route of administration of medications that may be needed in contrast reaction setting for children (epinephrine, Benadryl, albuterol, atropine).
A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree |
| 6. How comfortable are you managing a contrast reaction overall?
A. Very comfortable
B. Comfortable
C. Uncomfortable
D. Very uncomfortable | 12. I would find a sign or poster with management algorithms for common contrast reaction scenarios helpful to refer to in times of contrast reaction.
A. Strongly agree
B. Agree
C. Disagree
D. Strongly disagree |
| 7. Having a poster would help me reach clinical decisions in a more timely/expeditious manner.
A. Strongly agree
B. Agree | |

Note—Benadryl is manufactured by Pfizer. R1 = first year of radiology residency (postgraduate year 2), R2 = second year of radiology residency (postgraduate year 3), R3 = third year of radiology residency (postgraduate year 4), and R4 = fourth year of radiology residency (postgraduate year 5), PA = physician's assistant, NP = nurse practitioner, RA = radiology assistant, RN = registered nurse, IM = intramuscular.