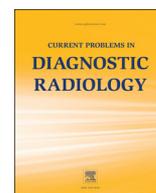




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Variability in the Use of Simulation for Procedural Training in Radiology Residency: Opportunities for Improvement



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Objective: Increased attention to quality and safety has led to a re-evaluation of the classic apprenticeship model for procedural training. Many have proposed simulation as a supplementary teaching tool. The purpose of this study was to assess radiology resident exposure to procedural training and procedural simulation.

Materials and Methods: An IRB-exempt online survey was distributed to current radiology residents in the United States by e-mail. Survey results were summarized using frequency and percentages. Chi-square tests were used for statistical analysis where appropriate.

Results: A total of 353 current residents completed the survey. 37% ($n = 129/353$) of respondents had never used procedure simulation. Of the residents who had used simulation, most did not do so until after having already performed procedures on patients (59%, $n = 132/223$). The presence of a dedicated simulation center was reported by over half of residents (56%, $n = 196/353$) and was associated with prior simulation experience ($P = 0.007$). Residents who had not had procedural simulation were somewhat likely or highly likely (3 and 4 on a 4-point Likert-scale) to participate if it were available (81%, $n = 104/129$). Simulation training was associated with higher comfort levels in performing procedures ($P < 0.001$).

Conclusions: Although procedural simulation training is associated with higher comfort levels when performing procedures, there is variable use in radiology resident training and its use is not currently optimized. Given the increased emphasis on patient safety, these results suggest the need to increase procedural simulation use during residency, including an earlier introduction to simulation before patient exposure.

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Introduction

Recent changes in the hospital setting, including productivity pressures on both attending physicians and trainees and increased attention to quality and safety, have led to a re-evaluation of the classic “see one, do one, teach one” apprenticeship model for procedural training.^{1–4} Although medical trainees will inevitably be required to perform procedures on patients as part of their training, they should ideally only be permitted to do so after optimizing their prior knowledge and skill set.⁴ Simulation has been proposed as an additional teaching tool in procedural training.^{1–7}

Adult learning principles explain why simulation training is beneficial. The *cognitive load theory* posits that working memory is limited and may be easily overwhelmed in learning new tasks.^{17,18} In simulation, an instructor breaks down complicated procedures into simple subtasks, reducing the burden on working memory.¹⁷ Furthermore, the concept of *deliberate practice*, which strives to

improve performance by goal-oriented training, is naturally integrated into simulation training by allowing residents to monitor their performance and receive immediate feedback.^{8,17,19–22} Deliberate practice has been shown to be successful in improving procedural skills such as lumbar puncture,²¹ thoracentesis,²⁰ and placement of temporary hemodialysis catheters.¹⁹

The number of peer-reviewed publications on high-fidelity simulation in medical education has risen exponentially since the 1990s⁸; a PubMed search of the phrase “high-fidelity simulation” yields 586 articles published since 2007, with only 14 published in 2007, growing to 136 published in 2016. Several studies within radiology have shown the benefits of procedural simulation, citing both subjective benefits, such as increased confidence in skills,⁹ as well as objective measures, including decreased fluoroscopic time (and thus radiation dose),¹⁰ improved biopsy accuracy,^{11,12} and decreased complication rates.¹²

Despite this existing evidence that simulation training improves patient safety and effectiveness of care, it is currently unclear how many residency programs use simulation training. The purpose of this study was to assess radiology resident exposure to procedural training including use of procedural simulation via a national survey.

Source of support: Dana Farber Imaging—Jack Meyer Resident Education Fund.

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<https://doi.org/10.1067/j.cpradiol.2018.02.008>

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Materials and Methods

The study was reviewed and exempted by our institutional review board. Informed consent was implied by voluntary, anonymous completion of the survey.

Survey

An online survey was created using REDCap (Research Electronic Data Capture), hosted by Partners HealthCare Research Computing Enterprise Research Infrastructure and Services (ERIS) group,¹³ which included both demographic and program-specific questions. These questions were written with categorical response choices, to protect the identities of individual residents. The remaining questions focused on aspects of procedural training, including residency year(s) offering procedure training, subspecialties providing hands-on exposure and the level of trainee participation in procedures. A subset of questions was dedicated to the use of procedure simulation. Using branching logic, additional items were provided based upon the respondent's exposure to procedural simulation. Questions were reviewed and edited by a focus group of attending, fellow and resident radiologists (Appendix).

Subjects and Recruitment

On February 7, 2017, an e-mail containing a link to the survey was sent to members of the American Alliance of Academic Chief Residents in Radiology (A3CR2) and Association of Program Directors in Radiology (APRD), affinity groups of the Association of University of Radiologists, composed of program directors and chief residents of approximately 189 programs. Program directors and chief residents were asked to forward the e-mail to their current residents at their discretion. E-mails contained an explanation of the study's purpose, as well as the voluntary and anonymous nature of the survey. A reminder e-mail was sent on February 21, 2017, 2 weeks following the initial e-mail. The survey was closed after 4 weeks.

Analysis

The survey data were collected and stored using Research Electronic Data Capture (REDCap), hosted by Partners HealthCare Research Computing Enterprise Research Infrastructure and Services (ERIS) group.¹³ Associations between categorical and ordinal responses were analyzed by the chi-square test using the Statistical Package of Social Sciences version 22.0 (SPSS Inc, Chicago, IL). A 2-sided *P* value of less than or equal to 0.05 was considered statistically significant.

Results

Respondent Characteristics

353 current radiology residents completed the online survey. Residents were nearly equally distributed between postgraduate years, ranging from 22%–28%. There was a predominance of responses from residents at programs with a residency class size of eight residents per year or larger ($n = 248/352$, 70%). Resident and program demographic information is summarized in Table 1. Most residents plan on performing procedures during their career ($n = 252/348$, 72%), with some undecided ($n = 76/348$, 22%) and a small remainder planning on practicing diagnostic radiology only ($n = 20/348$, 6%).

TABLE 1
Respondent characteristics ($n = 353$)

Characteristic	Answer options	No. (%) of responses
Postgraduate year (PGY)	PGY-2	88 (25)
	PGY-3	90 (26)
	PGY-4	77 (22)
	PGY-5	97 (28)
	< 25	0 (0)
Age	25–29	125 (36)
	30–34	188 (54)
	35–40	33 (9)
	> 40	4 (1)
	Sex	Male
	Female	104 (30)
Residency size (# of residents per year)	1–4	35 (10)
	5–7	69 (20)
	8–10	117 (33)
	> 10	131 (37)
	Residency location within the United States	Northeast
Southeast		50 (14)
Midwest		139 (40)
Northwest		47 (13)
Southwest		28 (8)

Procedure Exposure on Live Patients

Most residents reported hands-on exposure to radiologic procedures on live patients starting postgraduate year-2 (PGY-2) ($n = 295/352$, 84%), with 16% ($n = 55/353$) waiting until PGY-3 year and 1% ($n = 2/352$) waiting until PGY-4.

Vascular interventional radiology (VIR) was the most frequently reported subspecialty in which residents get hands-on exposure to procedures ($n = 336/352$, 95%), followed by breast ($n = 298/352$, 85%), musculoskeletal ($n = 295/352$, 84%), abdominal ($n = 261/352$, 74%) and neuroradiology ($n = 259/352$, 74%).

When asked about average level of participation in radiologic procedures, 55% ($n = 192/351$) of residents report performing most steps of a procedure with attending assistance, with 24% ($n = 85/351$) performing the procedure entirely with attending supervision, 19% ($n = 68/351$) primarily assisting the attending and 2% ($n = 6/351$) observing only. All but one of the six residents that reported “observation only” were PGY-2 residents. There was a trend towards increasing independence over the 4 years (Fig 1). In stratifying level of participation by size of residency class, the percentage of those performing procedures entirely with attending supervision was nearly equal for all residency sizes (ranging from $n = 20$ –22/85, 23%–26%).

Simulation Exposure

37% of residents have not participated in any procedure simulation ($n = 129/353$). Of the residents who have used

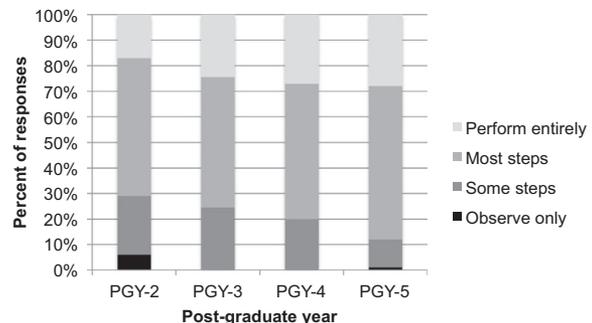


FIG 1. Average level of participation in procedures by postgraduate year. Residents report increasing independence when performing procedures over the 4 years of residency.

TABLE 2
Summary of respondents' simulation experience

Simulation experience	Answer options	No. (%) of responses
Prior procedure simulation	Yes	224 (63)
	No	129 (37)
Number of simulation sessions	1	79 (35)
	2-5	135 (60)
	6-9	9 (4)
	> 10	1 (1)
Earliest year of simulation	PGY-2	175 (79)
	PGY-3	34 (15)
	PGY-4	9 (4)
	PGY-5	3 (2)
Simulation before performing procedures on patients	Yes	91 (41)
	No	132 (59)
Imaging modality used (select all that apply)	Ultrasound	220 (99)
	Fluoroscopy	28 (13)
	Computed tomography	11 (5)
	MRI	2 (1)
Sections using simulation (select all that apply)	Breast	97 (44)
	Abdominal	95 (43)
	Vascular	57 (26)
	Musculoskeletal	23 (10)
	Neuro	13 (6)
	Chest	7 (3)
	Pediatrics	3 (1)
	Emergency	2 (1)
How helpful is simulation?	Not at all helpful	13 (6)
	Somewhat helpful	149 (67)
	Very helpful	58 (26)
	Essential	4 (2)

simulation ($n = 224/353$, 63%), most first participated during PGY-2 ($n = 175/221$, 79%), but not until after having already performed procedures on patients ($n = 132/223$, 59%). Therefore, a total of 74% of respondents ($n = 261/353$) did not have simulation prior to patient exposure. Table 2 summarizes residents' past simulation experience.

The reported average level of procedure participation was similar for residents regardless of prior simulation use, except for the highest level of participation (perform procedure entirely with attending supervision), which had a higher percentage of residents with prior simulation training than without (28% vs 17%) ($P = 0.002$).

Regarding perceived helpfulness of procedure simulation, most residents reported it to be only somewhat helpful ($n = 149/224$, 67%), with smaller numbers reporting simulation as not at all helpful ($n = 13/224$, 6%), very helpful (58/224, 26%), or essential ($n = 4/224$, 2%). All of the residents that selected "essential" were PGY-2, while none of the residents that selected "not at all helpful" were PGY-2. Most residents that found simulation to be very helpful had 2-5 simulation sessions (67%, $n = 39/58$) and the one resident who reported 10 or more sessions found them to be "essential."

Of the 129 residents who have not participated in procedural simulation, 80% were either very likely ($n = 65/129$, 50%) or somewhat likely ($n = 39/129$, 30%) to participate if it were available to them.

Most residents were not influenced by the availability of procedural simulation when selecting a residency program ($n = 209/353$, 59%) or were not aware of procedural simulation when making ranking decisions ($n = 135/353$, 38%).

Procedure Comfort Level

Prior simulation experience was significantly associated with higher comfort levels in performing procedures, while lack of

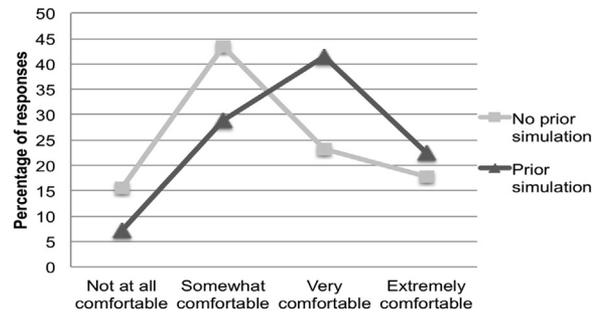


FIG 2. Procedure comfort level and prior simulation exposure. Prior simulation experience was significantly associated with higher comfort levels in performing procedures, whereas lack of simulation experience was associated with lower comfort levels ($P < 0.001$).

simulation experience was associated with lower comfort levels ($P < 0.001$) (Fig 2). Increasing comfort levels were also seen with increasing level of participation in procedures ($P < 0.001$). There was a trend toward higher comfort levels with increasing postgraduate year (Fig 3).

Presence of a Dedicated Simulation Center

Out of 353 (56%), 196 respondents reported the presence of a dedicated simulation center at their institution. Out of 353 (18%), 63 respondents did not have a dedicated simulation center and 94 (27%) were unsure. Residents that came from larger programs were more likely to have a dedicated simulation center (Fig 4).

Discussion

Despite numerous studies demonstrating the benefits and feasibility of simulation, our study found that nearly 40% of radiology residents who responded to the survey have not been provided simulation as part of their procedural training. Of those residents who have used simulation, most did not do so until after already performing procedures on patients, foregoing several of the demonstrated positive effects of simulation training.⁹⁻¹² Regardless of the timing of simulation training, residents with simulation training had higher comfort levels than those without such exposure. These results confirm several prior studies that have also found increased procedural self-confidence after simulation.^{11,14-16}

Despite an association with higher comfort levels after using procedural simulation, most residents did not report simulation to be "very helpful" or "essential." The residents that did find simulation "essential" were all PGY-2. Two prior radiology

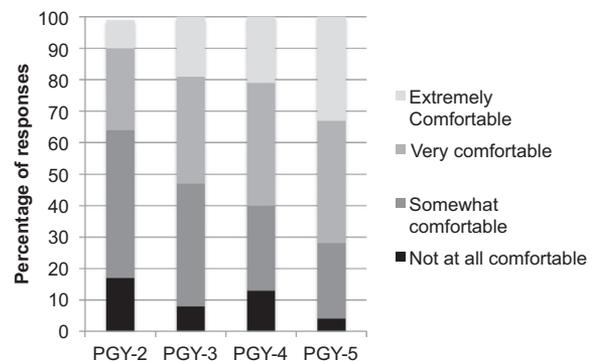


FIG 3. Comfort level by postgraduate year. Higher procedural comfort levels with increasing postgraduate year.

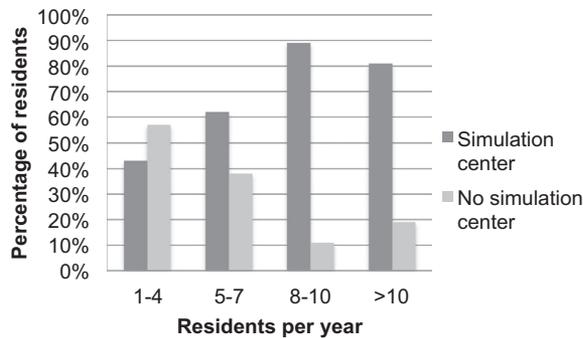


FIG 4. Presence of a simulation center by residency size. Residents from larger programs were more likely to have a dedicated simulation center.

simulation studies by Mendiratta-Lala et al¹⁰ and Ahmad et al¹⁴ also found higher levels of satisfaction of simulation use among junior residents compared to senior residents. These results suggest that perceived helpfulness of simulation may be forgotten or overcome as residents progress through their careers, advocating for earlier use of simulation during residency. In addition, pre-evaluations and post-evaluations for procedural simulations may be critical in examining the benefits of procedural simulation. These results could be shared with residents to show them their progress and improvements in skill with simulation.

Over one-third of residents do not receive any simulation training, which may be related to many potential barriers that hinder the universal adoption of procedural simulation, including access to and cost of materials needed and instructor availability and training.^{1,5} Simulation centers provide the resources to overcome several of these obstacles, such as instructor training, support staff, and availability of equipment. Radiology residency programs should attempt to seek out assistance from these specialized centers or faculty (even outside of radiology) with specialized teaching in simulation whenever possible to reduce the potential burden of implementing such training.

There was little use of simulation within VIR, despite the fact that nearly all residents report hands-on exposure to procedures within this division. This is likely multifactorial, due to complex vascular anatomy and physiology, as well as the dependence on fluoroscopy for imaging guidance, most simulation trainers currently feasible for VIR procedures are commercial, use expensive virtual reality technology to reduce radiation exposure to trainees, and require a significant monetary investment, costing as much as \$250,000.^{1,23-26} Future studies should create and evaluate inexpensive programs to aid residents in obtaining these types of procedural skills.

In other radiology department divisions, expensive equipment may not be necessary. For ultrasound, several studies have described cost effective “homemade” gelatin phantoms or using turkey breasts or bovine and porcine organs that can be purchased in the supermarket, with costs ranging from \$5-\$40.^{11,27-30} These less expensive phantoms are most amenable to ultrasound-guided biopsy or aspiration, compatible with the finding that the highest use of simulation is currently within the abdominal and breast divisions where these types of procedures are more common.

Limitations

One limitation of this study is our inability to determine the survey response rate, as survey distribution was at the discretion of chief residents and program directors to forward the original e-mail. This method was chosen, as there is currently no consistently updated and public database of radiology resident e-mail addresses. However, the total number of responses to this survey

was comparable to or higher than previous survey-based studies within radiology.^{5,31,32} For example, survey studies by Lam et al³¹ and Hoffmann et al³² used similar methodology and obtained 345 and 217 resident responses, respectively. Additionally, to maintain the greatest degree of anonymity and improve response rate, residents were not asked to state which program they were from. Although approximately 190 programs are represented by the APDR and A3CR2, it was not possible to know how many actually forwarded the survey to their residents.

It is possible this study overestimates the true use of simulation within radiology residency education, as more than 90% of responses came from residents in programs with five or greater residents per year, which had overall higher rates of simulation centers. Additionally, most respondents reported that they plan to perform procedures in their future careers, raising the possibility of response bias.

Conclusion

Despite existing evidence that simulation training improves patient safety and is associated with higher resident comfort levels in performing procedures, there is currently no mandate by the Accreditation Council for Graduate Medical Education or radiology governing bodies to provide simulation training during radiology residency and there is variable and suboptimal use in radiology resident training. Programs should attempt to seek help from faculty or centers with simulation experience when possible and should consider earlier implementation of procedural simulation during training and provide residents pre-evaluations and post-evaluations to illustrate their progress and areas for improvement.

Future studies should continue to evaluate objective outcomes of simulation training, such as patient satisfaction, dose rates (for computed tomography and fluoroscopic procedures) and complication rates of resident-performed procedures, which would further support the use of adding simulation training to residency education.

Appendix. Survey questions

1. What is your current level of training?

- PGY-2
- PGY-3
- PGY-4
- PGY-5

2. What is your age?

- < 25
- 25-29
- 30-34
- 35-40
- > 40

3. What is your sex?

- Female
- Male
- Other

4. What is the size of your residency?

- 1-4 residents/year
- 5-7 residents/year
- 8-10 residents/year
- > 10 residents/year

5. What is the location of your residency?

- Northeast US

- Southeast US
 Midwest US
 Northwest US
 Southwest US
6. At what level of training do you begin to get hands-on exposure to radiologic procedures on patients (eg, tunneled line placement, arthrogram, breast biopsy)?
- PGY-2
 PGY-3
 PGY-4
 PGY-5
7. As a resident, in which sections do you get hands-on exposure to radiologic procedures on patients? (select all that apply)
- Abdominal
 Breast
 Chest
 Emergency
 Musculoskeletal
 Neuro
 Pediatrics
 Vascular
 Other
 None of the above
8. Are you planning on performing procedures during your career?
- Yes
 No
 Undecided
9. On average, what is your level of participation in radiologic procedures?
- Observation only
 Assist the attending by performing a few steps of procedure
 Perform most steps of procedure with attending assist
 Perform the procedure entirely with attending supervision
10. Have you participated in procedure simulation (eg, ultrasound-guided phantom biopsies) during residency?
- Yes (move on to questions 11–16)
 No (skip to question 17)
11. How many procedure simulation sessions have you had during residency?
- 1
 2–5
 5–9
 ≥10
12. Which imaging modalities have you used during simulation? (select all that apply)
- Fluoroscopy
 Computed tomography
 Ultrasound
 MRI
13. In which sections have you participated in procedure simulation? (select all that apply)
- Abdominal
 Breast
 Chest
 Emergency
 Musculoskeletal
 Neuro
 Pediatrics
 Vascular
 Other
14. Select the earliest year that you participated in procedure simulation.
- PGY-2
 PGY-3
 PGY-4
 PGY-5
15. Did you have procedure simulation prior to performing procedures on patients?
- Yes
 No
16. On a scale of 1–4, how helpful have you found hands-on procedure simulation?
- Not at all helpful
 Somewhat helpful
 Very helpful
 Essential
17. On a scale of 1–5, how likely would you be to participate in simulations if they were available to you?
- Very unlikely
 Somewhat unlikely
 Neutral
 Somewhat likely
 Very likely
18. To your knowledge, does your hospital or academic center have a simulation center?
- Yes
 No
 Unsure
19. How comfortable would you feel performing procedures independently with attending supervision only?
- Not at all comfortable
 Somewhat comfortable
 Very comfortable
 Extremely comfortable
20. Did the availability of procedural simulation influence your radiology residency program ranking?
- Yes
 No
 I was not aware of procedural simulation when making ranking decisions
21. Are you planning on performing procedures during your career?
- Yes
 No
 Undecided
-

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