Simulation in Radiology

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Departmental Simulation Officer, MGH Department of Radiology
I have no conflicts of interest to disclose.
Agenda

• Outline the basic components of a successful medical simulation program
• Describe the need for medical simulation in radiology
• Provide an overview of the MGH Department of Radiology contrast and emergency management (CEM) simulation program
• Review data and lessons learned from our initial experience
• Introduce IR procedural simulators
• Highlight opportunities for future simulation initiatives in radiology
Levels of Simulation

- Low tech
Levels of Simulation

• Screen-based
Levels of Simulation

- Complex Task Trainer

Slide courtesy of Emily Hayden, M.D.
Levels of Simulation

• Simulated (Standardized) Patients

Slide courtesy of Emily Hayden, M.D.
Levels of Simulation

- High-fidelity Patient Simulators
Levels of Simulation

- Virtual Reality
# Medical simulation applications

<table>
<thead>
<tr>
<th>Table 3. Potential applications for simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing aptitude</td>
</tr>
<tr>
<td>Developing basic skills before patient contact</td>
</tr>
<tr>
<td>Developing advanced skills before performing complex</td>
</tr>
<tr>
<td>procedures on patients</td>
</tr>
<tr>
<td>Maintaining skills</td>
</tr>
<tr>
<td>Training for teamwork</td>
</tr>
<tr>
<td>Training for management of critical and rare events</td>
</tr>
<tr>
<td>Rehearsing a procedure before performing it on a patient</td>
</tr>
<tr>
<td>Credentialing and certification</td>
</tr>
<tr>
<td>Developing new or advanced skills among experienced</td>
</tr>
<tr>
<td>practitioners</td>
</tr>
<tr>
<td>Inventing new procedures</td>
</tr>
<tr>
<td>Evaluating new technologies or procedures</td>
</tr>
<tr>
<td>Conducting research in human performance, pedagogic</td>
</tr>
<tr>
<td>methods, etc</td>
</tr>
</tbody>
</table>

Source: Dawson [23].
Why do simulation?

• Improved knowledge retention
  – Reading/Hearing 6 week retention rate: 10-20%
  – Simulation 6 week retention rate: 80%

• Knowledge retention increases when the learning experience is similar to the clinical scenario

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2 Hallinan JT. Why we make mistakes. New York: Broadway Books 2009
Necessary components of simulation*

- Course logistics/scheduling
- Simulation case development
- Assessment instruments
- Course evaluation
- Debriefing after simulation exercise
  - Reflecting on one’s own practice is critical to experiential learning
  - Allow participants to explain, analyze, and synthesize information to improve performance
  - Debriefing with good judgment developed and taught by the Institute for Medical Simulation in a one week course
  - Simulation without debriefing increases confidence but not skill

*Adapted from the Institute for Medical Simulation Instructor Training Course ©Cambridge, MA

Medical simulation has become increasingly routine in Anesthesiology and Critical Care, Obstetrics/Gynecology, Surgery, Emergency Medicine, and Pediatrics.

How many of you have been involved in medical simulation exercises within radiology?
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Simulation in Radiology

- PACS simulators with immediate feedback on cases to trainees
- Screen-based virtual reality simulator for assessment of trainee preparation prior to overnight call
- Simulation-based training for ultrasound-guided procedures
- Endovascular procedure simulators – novice and expert level
- Mannequin-based simulation for contrast reactions and emergency management (CEM) preparedness
Adverse reactions to contrast media

- **Iodinated contrast**
  - Less common with newer agents
  - Incidence ranges from 0.2-0.7%

- **Gadolinium**
  - Lower frequency than iodinated contrast
  - Incidence ranges from 0.02%-2.4%

- **Treatment**
  - 41% of patients received treatment
  - 1% of patients receiving treatment developed complications
  - 8/15 patients treated with epinephrine received the incorrect dosage of epinephrine (3 with cardiac sequelae)

CEM education before simulation

- Annual live lecture to trainee physicians during orientation
- Annual live lecture to attending physicians during a risk management conference
- Transition to online modules in 2009-2010
- “On the job” experience
### Effectiveness of CEM didactic education

<table>
<thead>
<tr>
<th>How comfortable do you feel treating a patient with an anaphylactoid reaction to contrast media?</th>
<th>Pre Module</th>
<th>Post Module</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comfortable n (%)</strong></td>
<td>Comfortable n (%)</td>
<td>Not comfortable n (%)</td>
</tr>
<tr>
<td>Physician*</td>
<td>144 (59%)</td>
<td>100 (41%)</td>
</tr>
<tr>
<td>Nurse*</td>
<td>51 (73%)</td>
<td>19 (27%)</td>
</tr>
<tr>
<td>Technologist*</td>
<td>98 (54%)</td>
<td>84 (46%)</td>
</tr>
<tr>
<td>Total (n = 522) *</td>
<td>303 (58%)</td>
<td>219 (42%)</td>
</tr>
</tbody>
</table>

Niell et al. JACR 2014;11:185
Contrast and emergency management simulation in Radiology

- To date, several small simulation programs in radiology departments have focused on resident education.

Residents who underwent simulation reported improved performance compared to didactic instruction alone.

Simulation following didactic instruction improved performance compared to simulation alone in radiology residents.
What about simulation for technologists?

Simulations with teams of radiology residents and technologists demonstrated similar knowledge improvement for both role groups and emphasized importance of communication.
Communication and Teamwork

- 43% of safety events involve poor communication
- Teamwork and communication failures are the **strongest** predictor of surgical errors

### Table II. Summary of multiple regression analysis using flow disruptions to predict surgical errors

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized coefficients</th>
<th>Standardized coefficients</th>
<th>95% confidence interval for B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Standard error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>.531</td>
<td>.1067</td>
<td></td>
</tr>
<tr>
<td>Teamwork</td>
<td>.935</td>
<td>.170</td>
<td>.692</td>
</tr>
<tr>
<td>External</td>
<td>.338</td>
<td>.253</td>
<td>.021</td>
</tr>
<tr>
<td>Training</td>
<td>.360</td>
<td>.259</td>
<td>.190</td>
</tr>
<tr>
<td>Resources</td>
<td>-1.280</td>
<td>.652</td>
<td>-.283</td>
</tr>
<tr>
<td>Equipment</td>
<td>-.307</td>
<td>.320</td>
<td>-.126</td>
</tr>
</tbody>
</table>

Note: $R^2 = .627$; Adjusted $R^2 = .533$; $P < .001$. 

Interventional Radiology Suites

- Prone to the same types of errors, including communication errors, associated with traditional operating rooms
- MGH Department of Radiology
  - 17 interventional suites
  - Approximately 18,000 interventional procedures annually
  - ~ 2,000 of which require anesthesiology support
- Procedure complications account for approximately 1/3 of malpractice allegations against radiologists
  - Second only to allegations of “failure to diagnose”
- Given the growth of IR interventions, the need for team training has never been more apparent.

Spring and Tennenhouse. Radiology 1986;159:811
MGH IR TEAM Program

Training – 6 IR divisions (2009)
Staff training – ~600 people to date
Observer training – direct observations of staff quarterly

Data management

Contract with Subject Matter Experts
  - Live training annually
  - Observer training quarterly
  - Staff survey q 18 months
We’ve trained Mass General Hospital, the YMCA and Partners Healthcare.
(We’re great at push-ups now.)

Effective corporate training without feeling weird.
After controlling for baseline differences, the 74 trained facilities experienced a significant decrease of 18% in observed mortality (RR, 0.82; 95% CI, 0.76-0.91; P<.01). Mortality decreased by 7% (RR, 0.93; 95% CI, 0.80-1.06; P=.59) in the nontrained facilities.
MGH Department of Radiology committed resources to develop and implement a simulation curriculum for contrast and emergency management with an emphasis on team training beginning in Spring 2012.

Overall program goals:

1) Improve the ability of MGH Radiology personnel to manage the first 5-10 minutes of a radiologic emergency, such as an adverse contrast reaction, while awaiting the arrival of help

2) Encourage Team Training skills among physicians, technologists, and nurses
The MGH Simulation Community of Practice

The unified simulation community of practice across MGH includes a hospital Division of Medical Simulation and training activity across departments and services. The central Learning Laboratory in the Treadwell Library is a shared facility that fosters collaboration among a network of MGH-affiliated simulation labs, including:

- Institute for Patient Care/Patient Care Services Knight Simulation Program Labs (Founders Building, Professional Office Building)
- Vincent Memorial Hospital Obstetrics and Gynecology Simulation Suite (Founders Building)
- General Surgery Skills Lab and Surgical Research Suite (White Building, Thier Building)
- Cardiac Surgery Research and Skills Lab (Edwards Building)
- Center for Medical Simulation (Landsdowne Street/Cambridge)
- MGH Institute of Health Professions (IHP) Clinical Simulation Lab (MGH Charlestown)
- MGH-affiliated Simulation Training in Emergency Resuscitation (MASTER) Lab (Zero Emerson Place)
- Center for Integration of Medicine and Innovative Technology (CIMIT) (Landsdowne Street/Cambridge)
- Dr. Dinesh Patel Arthroscopic Learning Lab (175 Cambridge Street)
- Anesthesia Clinical Research and Skills Lab (White Building)
- Ophthalmology Skills Lab at Massachusetts Eye and Ear Infirmary (MEEI)
- In-situ laboratories within MGH hospital units, wards, and operating suites

Slide courtesy of James Thrall, M.D.
Summer – Fall 2012

• Collaborators from the MGH Learning Laboratory, Anesthesia, Emergency Medicine, and Allergy

• Two steering committees within Department of Radiology
  – Technologist supervisors, nursing supervisors, interventional radiology technologist supervisors
  – Resident physician (chief resident), junior attending physicians, Division Head representative, QA Chair, senior attending physicians

• Project manager support to address scheduling logistics, data collection, and myriad program management needs

• Two attending radiologists and one nurse attended the week long Institute for Medical Simulation Comprehensive Instructor Workshop in Medical Simulation (October 2012)
Simulation pilot study in Sept 2012

• Technologist, nurse, and physician feedback from pilot sessions was incorporated to improve program
  – Tech expectations in the setting of an emergency (e.g. drawing up medications)
  – Tech suggestion to insert tech as role player/actor into simulation scenarios
  – Tech suggestion to acknowledge that techs are most familiar with their imaging suite and equipment, which is different by site and in simulation lab (potential need for standardization)
Simulation logistics

- Program completion
  - Participants expected to complete pre-simulation didactic instruction
  - Staff excused from clinical work with coverage provided by Department
  - Goal is education - No evaluation of individual competency

- Continuing education credits for techs, nurses, and physicians
GOAL: All MGH imaging personnel (~450 persons) through simulation exercises within 12 months

- **WHO**
  - MGH Imaging physicians, nurses, and technologists

- **WHAT**
  - Two cases uniquely targeted to contrast reaction management

- **WHERE**
  - MGH Learning Laboratory (2nd floor Treadwell)

- **WHEN**
  - Wednesday afternoons 1-3 and 3-5pm
  - First session: October 24, 2012

- **HOW**
  - 8 participants per 2 hour session (4 physicians + 4 techs for most sessions)
  - 60 sessions
  - 2 sessions per Wednesday afternoon
  - ≥30 weeks
Scheduling Clinical Personnel

- Trainee physicians scheduled before attendings (first physician responders in our clinical practice)
- Technologists – mix of CT, MRI, and IR for each session
- Nurses – not every session had a nurse (similar to our clinical practice)
- Attending physicians – across divisions
## Completion of simulation exercises

<table>
<thead>
<tr>
<th>Role</th>
<th>Year One</th>
<th></th>
<th>Year Two</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eligible</td>
<td>Completed</td>
<td>Eligible</td>
<td>Completed</td>
</tr>
<tr>
<td>Technologists</td>
<td>192</td>
<td>159 (83%)</td>
<td>194</td>
<td>147 (76%)</td>
</tr>
<tr>
<td>RN, NP, PA</td>
<td>46</td>
<td>26 (57%)</td>
<td>42</td>
<td>16 (38%)</td>
</tr>
<tr>
<td>All Physicians</td>
<td>208</td>
<td>184 (88%)</td>
<td>206</td>
<td>183 (89%)</td>
</tr>
<tr>
<td>Residents</td>
<td>38</td>
<td>33 (87%)</td>
<td>39</td>
<td>37 (95%)</td>
</tr>
<tr>
<td>Fellows</td>
<td>55</td>
<td>41 (75%)</td>
<td>60</td>
<td>54 (90%)</td>
</tr>
<tr>
<td>Attendings</td>
<td>115</td>
<td>110 (96%)</td>
<td>107</td>
<td>92 (86%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>446</strong></td>
<td><strong>369 (83%)</strong></td>
<td><strong>442</strong></td>
<td><strong>346 (78%)</strong></td>
</tr>
</tbody>
</table>
Schedule on day of simulation

- 12:45 – 1:00 pm Complete pre-simulation paperwork
- 1:00 – 1:05 pm Welcome and Introductions
- 1:05 – 1:20 pm Course orientation
- 1:20 – 2:05 pm Case followed by a debriefing
- 2:05 – 2:40 pm Second case followed by a debriefing
- 2:40 – 2:45 pm Closing comments
- 2:45 – 3:00 pm Group 1: Complete post-simulation questionnaire and CME evaluation forms
  Group 2: Complete pre-simulation paperwork
Pre and post simulation questionnaires

*You are evaluating an adult patient who received intravenous contrast media for an imaging study. The patient complains of mild to moderate shortness of breath, and you notice diffuse hives on physical examination. You believe these symptoms are consistent with a reaction to the contrast media. **What is the preferred route of administration of epinephrine?**

- Subcutaneous
- Intramuscular
- Intravenous
- Oral

*Simulation Training made me feel more comfortable with the management of contrast media induced anaphylactoid reactions.*

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*How comfortable do you feel administering intramuscular epinephrine to an adult with a contrast media induced anaphylactoid reaction?*

<table>
<thead>
<tr>
<th>Not at all Comfortable</th>
<th>Not Comfortable</th>
<th>Somewhat Uncomfortable</th>
<th>Somewhat Comfortable</th>
<th>Comfortable</th>
<th>Very Comfortable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Intra-simulation data collection

**CEM Program - Intra Simulation Survey**

- *Was epinephrine administered?*
  - [ ]

  If used, how long into the simulation case was the first dose of epinephrine administered?
  - Minutes: [ ]
  - Seconds: [ ]

- If used, what was the epinephrine type?
  - [ ]

  If Autoinjector administered, answer the following two questions:

  - If Autoinjector administered, were all 6 steps performed correctly?
    - [ ]

  - If Autoinjector administered, was it injected into either the lateral thigh or arm?
    - [ ]

  If IM or IV epinephrine administered, answer the following two questions:

  - If IM or IV epinephrine administered, was the correct dose administered?
    - [ ]

  - If IM or IV epinephrine administered, was the correct dilution administered?
    - [ ]

**Other Medications**

- *What other medications were administered?*
  - [ ] No Other Medications were administered
  - [ ] Oxygen
  - [ ] Albuterol Neb
  - [ ] Benadryl
  - [ ] Atropine
  - [ ] IVF
  - [ ] Other, please specify: [ ]
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To the best of my knowledge, no published studies in the radiology literature have described or evaluated
  • Simulation-based training for attending radiologists, radiology fellow physicians, or radiology nurses
  • Simulation-based inter-professional team training
Our results from the first year

We sought to understand whether implementation of a simulation-based training program impacted two skill sets:

1) Participants’ abilities to manage an adverse reaction to contrast media
2) Participants’ abilities to function as effective team members
Knowledge improvement following simulation

19% improvement in the mean number of correctly answered knowledge based questions (paired t-test p < 0.00001)

Stratified analyses by role group (paired t-tests p < 0.01)
Participants’ perceptions following simulation

- Significant improvement in ability to manage an anaphylactoid reaction (p-value < 0.00001)
- Significant improvement in ability to work as an effective team member (p-value < 0.001)

<table>
<thead>
<tr>
<th>How comfortable do you feel working in a team during a medical emergency?</th>
<th>Pre Simulation</th>
<th>Post Simulation</th>
<th>p-value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfortable n (%)†</td>
<td>Not comfortable n (%)‡</td>
<td>Comfortable n (%)†</td>
<td>Not comfortable n (%)‡</td>
</tr>
<tr>
<td>Physicians</td>
<td>135 (90%)</td>
<td>15 (10%)</td>
<td>145 (97%)</td>
</tr>
<tr>
<td>Resident/fellow physicians</td>
<td>55 (92%)</td>
<td>5 (8%)</td>
<td>58 (97%)</td>
</tr>
<tr>
<td>Attending physicians</td>
<td>80 (89%)</td>
<td>10 (11%)</td>
<td>87 (97%)</td>
</tr>
<tr>
<td>Nurses</td>
<td>19 (90%)</td>
<td>2 (10%)</td>
<td>21 (100%)</td>
</tr>
<tr>
<td>Technologists</td>
<td>94 (80%)</td>
<td>23 (20%)</td>
<td>114 (97%)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (60%)</td>
<td>2 (40%)</td>
<td>5 (100%)</td>
</tr>
<tr>
<td>Total (n = 293)</td>
<td>251 (86%)</td>
<td>42 (14%)</td>
<td>285 (97%)</td>
</tr>
</tbody>
</table>
Frequency of Re-Training

- **All respondents**
  - 56 (19%): 6 months
  - 158 (52%): 12 months
  - 70 (23%): 2 years
  - 9 (3%): other
  - 9 (3%): no repeat

- **Technologists**
  - 19 (16%): 6 months
  - 29 (25%): 12 months
  - 63 (54%): 2 years
  - 2 (2%): other

- **Attending Physicians**
  - 46 (51%): 6 months
  - 23 (26%): 12 months
  - 14 (16%): 2 years
  - 4 (4%): other

Large volume of personnel → Annual re-training currently
Frequency of Re-Training

- Data extrapolation from studies on CPR
- Loss of knowledge begins at 2 weeks
- Skill level might be maintained for up to 6 months
- Published studies suggest repeat training at 6 months
Lessons learned from years 1 and 2

- An effective simulation-based training program for contrast reactions should include technologists, nurses, and attending physicians, rather than restricting participation to residents.
  - Technologists are our first responders

- Team-training simulation programs are as relevant to radiology as they are to other clinical departments.
Challenges - Sustainability

- Debriefing expertise developed from within rather than contracted from outside
- Administrative support
- Should simulation exercises mix new staff with previously trained staff?
- Inter-professional education requires cultural change
- Expectation for increasing clinical volume competes with educational/training initiatives
- Financial challenges
Cost estimates of simulation

- \( n = 23 \) residents with two residents per simulation
- Actual simulation time was 2.5 hours
Cost includes personnel time away from clinical schedule

Working on and around stairways and ladders is hazardous. Stairways and ladders are major sources of injuries and fatalities among construction workers for example, and many of the injuries are serious enough to require time off the job. OSHA

Safety and Health Program Management Guidelines
Effective management of worker safety and health protection is a decisive factor in reducing the extent and severity of work-related injuries and illnesses and their related costs. In fact, an effective safety and health program forms the basis of good worker protection and can save time and money—about $4 for every dollar spent—and increase productivity and reduce worker injuries, illnesses and related workers’ compensation costs.
Do our personnel believe that CEM simulation is a valuable use of time?
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Ultrasound Simulators

The Full-Torso Mannequin is designed to be utilized with the following Educational Modules: Abdomen, Obstetrics, Gynecology, Transvaginal-Gynecology, Transvaginal-Obstetrics, Breast and Emergency Medicine. It has a soft, pliable, rubber surface that covers a foam belly representative of a late-first or early-second trimester pregnancy.

The Upper-Torso Mannequin is designed to be utilized with the following Educational Modules: Vascular and Neck. It has a soft, pliable, rubber surface covering the upper abdomen and the thorax, which extends around the neck area allowing for Color Doppler examination of the vertebral and carotid arteries.

By Specialty - Radiology

Vascular Access  Renal Biopsy  Transvaginal  FAST Trauma

Amniocentesis  Soft Tissue Biopsy  Lumbar Puncture and Spinal Epidural Training Model  Cardiac

Paracentesis  Thoracentesis  Regional Anesthesia  Scrotal

Abdominal Aorta  Thrombosis  Doppler  Foreign Body ID

Figure 5. Statistical significance in improvement in procedure performance from pretraining to posttraining.

Blue Phantom™, MedSim, and Mendiratta-Lala et al. Acad Radiology 2010;17:535
Endovascular Simulators

MENTICE®
Endovascular Simulators

- Radiology residents
  - Decreased fluoro time
  - Decreased major errors
  - Improved procedural skill
- Experienced interventionalists
  - Decreased procedure time
  - Less radiation
  - Improved procedural skill

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before Training</th>
<th>After Training</th>
<th>Percentage Improvement</th>
<th>P Value for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean fluoroscopy time (sec)</td>
<td>179 (70)</td>
<td>143 (39)</td>
<td>20% less time</td>
<td>.05</td>
</tr>
<tr>
<td>Mean task time (sec)</td>
<td>449 (73)</td>
<td>293 (73)</td>
<td>35% less time</td>
<td>.001</td>
</tr>
<tr>
<td>Mean contrast medium volume (mL)</td>
<td>30 (7)</td>
<td>29 (4)</td>
<td>3% less contrast medium used</td>
<td>.64</td>
</tr>
<tr>
<td>Mean number of major errors by candidates</td>
<td>1.2 (1.3)</td>
<td>0.5 (0.9)</td>
<td>58% fewer errors</td>
<td>.02</td>
</tr>
</tbody>
</table>

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Future Directions for Simulation

1. Build a library of diverse simulation cases
   - Procedural emergencies in an interventional radiology suite
   - Handoffs between IR and other medical services
   - Pediatric algorithms for trainee physicians and pediatric radiologists

2. In situ simulation exercises
   - Occur in the clinical work environment (CT, MRI, IR)

3. Expand procedural simulation initiatives

4. Multi-disciplinary collaboration (e.g. Anesthesia or vascular surgery)
Dept of Radiology Simulation Team

Joanne Forde, RTR (CT)

Alexandra Penzias, RN, MEd, MSN

Shawn Bonk, MHM

Gloria Salazar, MD

Bethany Niell, MD, PhD
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  - Tanya Milosh-Zinkus
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- James Gordon
- Margaret Sande
- Dushyant Sahani
- Steve Dawson
- Rebecca Minehart
- Cristy Savage
- Peter Mueller
Thank you for your time!

bniell@partners.org
Please comment on the strengths or weaknesses of this experience and any recommendations for improvement.