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of Harvard Medical School

Simulation in Radiology

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GENERAL HOSPITAL
IMAGING

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

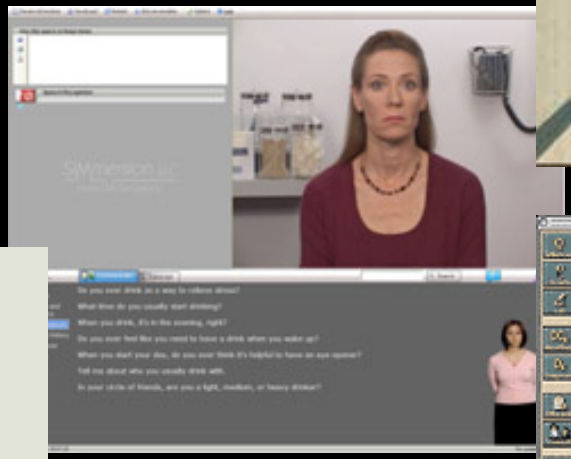
Levels of Simulation

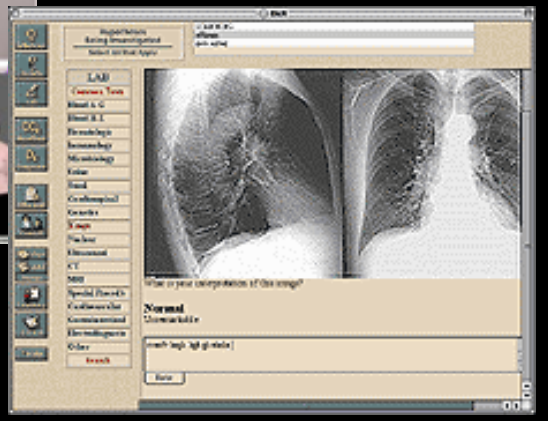
- Low tech

Slide courtesy of Emily Hayden, M.D.

Levels of Simulation

- Screen-based





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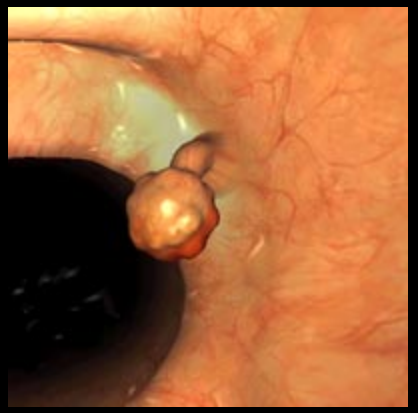
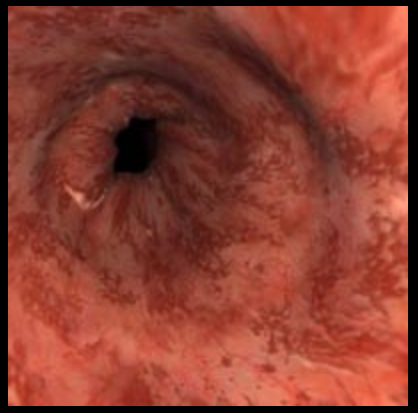
Levels of Simulation

- Complex Task Trainer





Slide courtesy of Emily Hayden, M.D.

Levels of Simulation

- Simulated (Standardized) Patients

Slide courtesy of Emily Hayden, M.D.

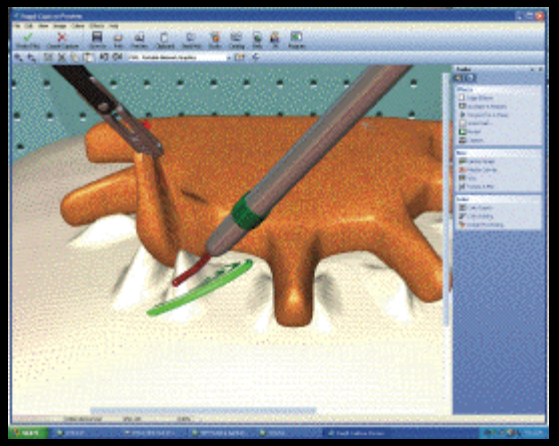
Levels of Simulation

- High-fidelity Patient Simulators

Slide courtesy of Emily Hayden, M.D.

Levels of Simulation

- Virtual Reality



Slide courtesy of Emily Hayden, M.D.

Medical simulation applications

Table 3. Potential applications for simulation

Testing aptitude
Developing basic skills before patient contact
Developing advanced skills before performing complex procedures on patients
Maintaining skills
Training for teamwork
Training for management of critical and rare events
Rehearsing a procedure before performing it on a patient
Credentialing and certification
Developing new or advanced skills among experienced practitioners
Inventing new procedures
Evaluating new technologies or procedures
Conducting research in human performance, pedagogic methods, etc

Source: Dawson [23].

Sabir et al. *JACR* 2014; 11:512 and Dawson *JVIR* 2006;17:205

Why do simulation?

- Improved knowledge retention [1]
  - 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 [2]

[1] Edgar D. Audiovisual methods in teaching. Hinsdale, IL: Dryden Press 1954

[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 [1]
  - Simulation without debriefing increases confidence but not skill [2]

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

[1] Rudolph et al. Anesthesiology Clinics 2007;25:361 and [2] Marteau et al. BMJ 1990;300:849

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

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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)

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Wang et al. *AJR* 2008; 191:409-415 and ACR Manual on Contrast Media © 2013

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

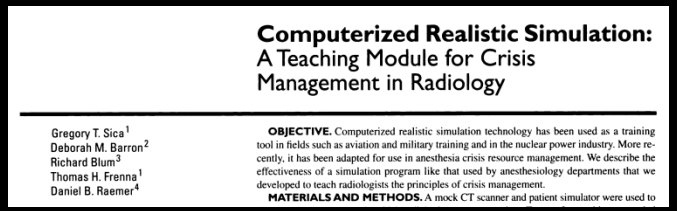
Effectiveness of CEM didactic education

	Pre Module		Post Module	
How comfortable do you feel treating a patient with an anaphylactoid reaction to contrast media?	Comfortable n (%)	Not comfortable n (%)	Comfortable n (%)	Not comfortable n (%)
Physician*	144 (59%)	100 (41%)	209 (86%)	35 (14%)
Nurse*	51 (73%)	19 (27%)	65 (93%)	5 (7%)
Technologist*	98 (54%)	84 (46%)	134 (74%)	48 (26%)
Total (n = 522) *	303 (58%)	219 (42%)	425 (81%)	97 (19%)

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

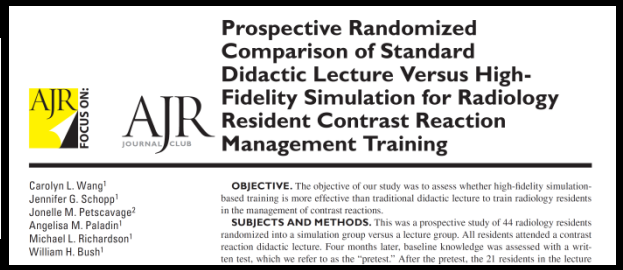


Computerized Realistic Simulation: A Teaching Module for Crisis Management in Radiology

Gregory T. Sica[1] Deborah M. Barron[2] Richard Blum[3] Thomas H. Frenna[1] Daniel B. Raemer[4]

OBJECTIVE. Computerized realistic simulation technology has been used as a training tool in fields such as aviation and military training and in the nuclear power industry. More recently, it has been adapted for use in anesthesia crisis resource management. We describe the effectiveness of a simulation program like that used by anesthesiology departments that we developed to teach radiologists the principles of crisis management.

MATERIALS AND METHODS. A mock CT scanner and patient simulator were used to



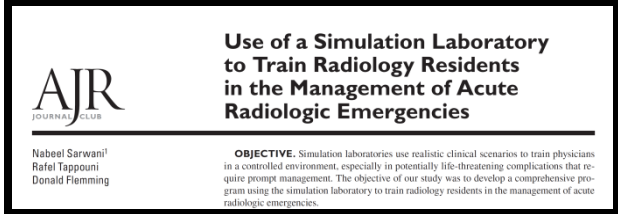
AJR FOCUS ON: AJR JOURNAL CLUB

Prospective Randomized Comparison of Standard Didactic Lecture Versus High-Fidelity Simulation for Radiology Resident Contrast Reaction Management Training

Carolyn L. Wang[1] Jennifer G. Schopp[1] Jonelle M. Petscavage[2] Angelisa M. Paladin[1] Michael L. Richardson[1] William H. Bush[1]

OBJECTIVE. The objective of our study was to assess whether high-fidelity simulation-based training is more effective than traditional didactic lecture to train radiology residents in the management of contrast reactions.

SUBJECTS AND METHODS. This was a prospective study of 44 radiology residents randomized into a simulation group versus a lecture group. All residents attended a contrast reaction didactic lecture. Four months later, baseline knowledge was assessed with a written test, which we refer to as the "pretest." After the pretest, the 21 residents in the lecture



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Use of a Simulation Laboratory to Train Radiology Residents in the Management of Acute Radiologic Emergencies

Nabeel Sarwani[1] Rafel Tappouni Donald Flemming

OBJECTIVE. Simulation laboratories use realistic clinical scenarios to train physicians in a controlled environment, especially in potentially life-threatening complications that require prompt management. The objective of our study was to develop a comprehensive program using the simulation laboratory to train radiology residents in the management of acute radiologic emergencies.

- 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

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What about simulation for technologists?

Severe Contrast Reaction Emergencies:

High-fidelity Simulation Training for Radiology Residents and Technologists in a Children's Hospital

Nancy M. Tofil, MD, MEd, Marjorie Lee White, MD, MPPM, MEd, Matthew Grant, MD, J. Lynn Zinkan, RN, MPH, Bhavik Patel, MD, Lynsey Jenkins, BS, Amber Q. Youngblood, BSN, RN, Stuart A. Royal, MD

TABLE 1. Demographics of Radiology Residents and RTs Regarding Experience with Codes and Contrast Reactions

Variable	Residents*	RTs
Postgraduate year (residents)		
2	5 (26%)	
3	4 (21%)	
4	5 (26%)	
5	5 (26%)	
Experience (RTs) (y)		13 ± 6.5
Number of codes experienced		
0–2	15 (79%)	6 (66%)
2–5	1 (5%)	1 (11%)
6–10	2 (10%)	1 (11%)
>10	1 (5%)	1 (11%)
Number of potentially life threatening contrast reactions		
0–2	19 (100%)	6 (66%)
2–5	0 (0%)	3 (33%)
Certifications		
BLS	13 (68%)	9 (100%)
ACLS	19 (100%)	0 (0%)
PALS	0 (0%)	0 (0%)

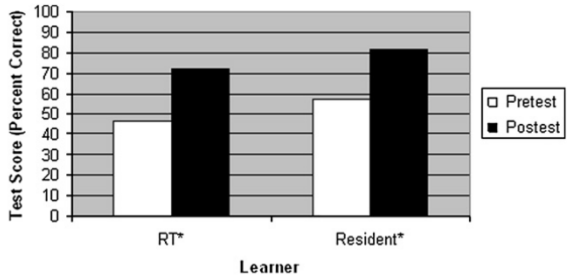

Figure 1. Radiology residents and radiology technologists' (RTs) knowledge improvement during simulated contrast emergencies. *$P < .01$.

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

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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

	Unstandardized coefficients		*Standardized coefficients*			*95% confidence interval for B*	
Model	*B*	*Standard error*	*Beta*	*t*	*P value*	*Lower bound*	*Upper bound*
(Constant)	531	1.067		.497	.623	−1.668	2.729
Teamwork	.935	.170	.692	5.506	.000	.585	1.285
External	.038	.253	.021	.152	.881	−.482	.559
Training	.360	.259	.190	1.393	.176	−.172	.893
Resources	−1.280	.652	−.283	−1.963	.061	−2.623	.063
Equipment	−.307	.320	−.126	−.958	.347	−.966	.353

Note. $R^2 = .627$; Adjusted $R^2 = .553$; $P < .001$.

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Gawande et al. *Surgery* 2003;133:614 and Wiegmann et al. *Surgery* 2007;142:658

Slide from Gloria Salazar, M.D.

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.

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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

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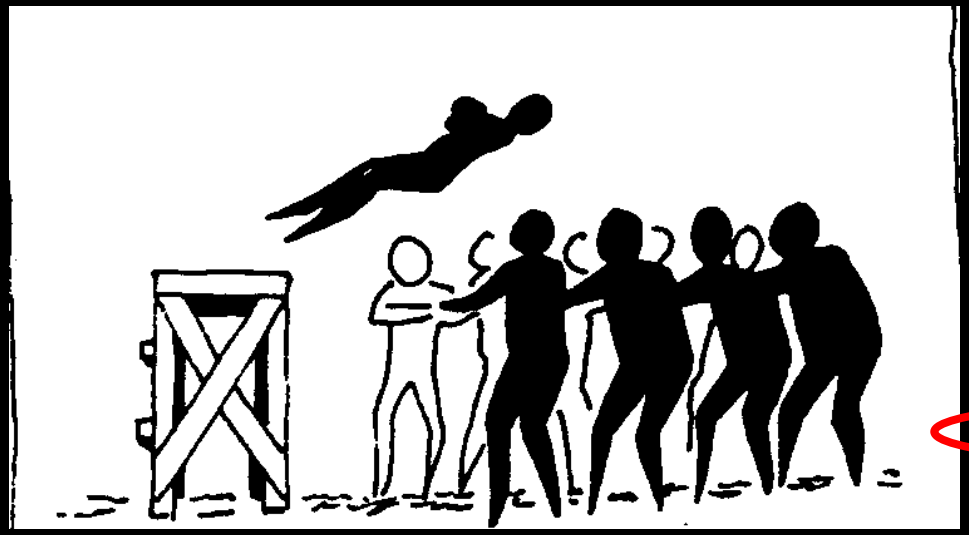
Slide adapted from Karen Miguel, R.N.

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“Team Training? Do I have to?”

ORIGINAL CONTRIBUTION

Association Between Implementation of a Medical Team Training Program and Surgical Mortality

Julia Neily, RN, MS, MPH
Peter D. Mills, PhD, MS
Yinong Young-Xu, ScD, MA, MS
Brian T. Carney, MD
Priscilla West, MPH
David H. Berger, MD, MHCM
Lisa M. Mazzia, MD
Douglas E. Paull, MD
James P. Bagian, MD, PE

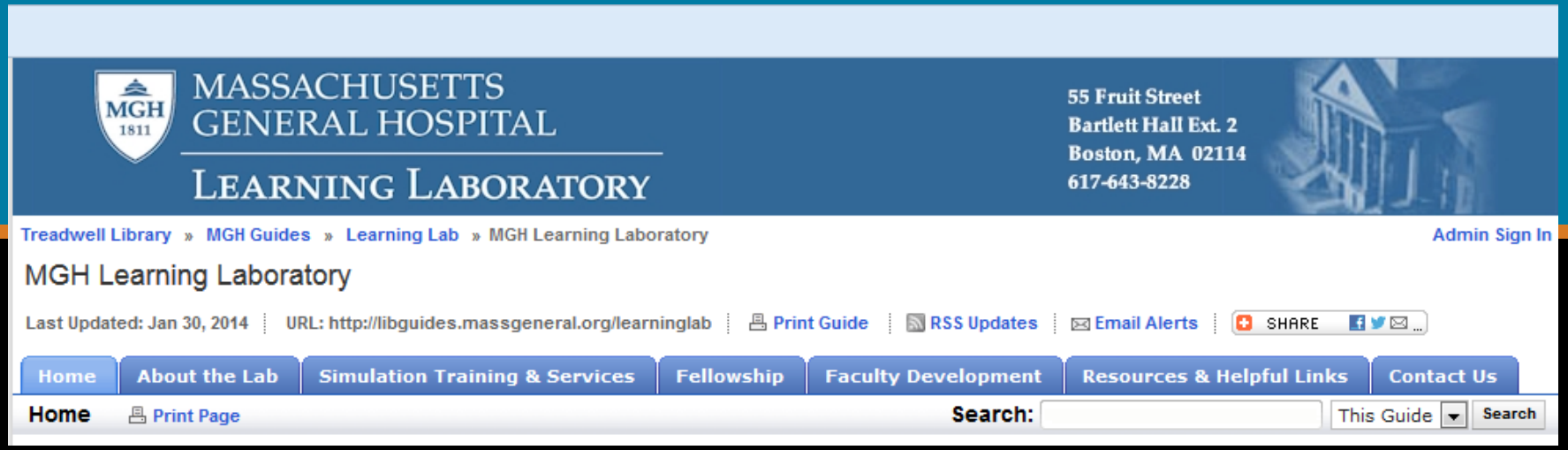
After controlling for baseline differences, the 74 trained facilities experienced a significant decrease of 18% in observed mortality (RR, 0.82; 95% CI, 0.76-0.91; $P=.01$). Mortality decreased by 7% (RR, 0.93; 95% CI, 0.80-1.06; $P=.59$) in the nontrained facilities.

Neily et al. JAMA 2010;304:1693

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

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- 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)

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IMAGING

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)

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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

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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

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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

	Year One		Year Two	
Role	**Eligible**	**Completed**	**Eligible**	**Completed**
Technologists	192	159 (83%)	194	147 (76%)
RN, NP, PA	46	26 (57%)	42	16 (38%)
All Physicians	208	184 (88%)	206	183 (89%)
Residents	38	33 (87%)	39	37 (95%)
Fellows	55	41 (75%)	60	54 (90%)
Attendings	115	110 (96%)	107	92 (86%)
Total	**446**	**369 (83%)**	**442**	**346 (78%)**

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


Marshall


Adult
//24/2013 01:36 PM
reds
ECG Leads Off
Touch when leads attached
HR
-?-
SpO2
-?-
SpO2 No Sensor
NBP Manual
NBP No Cuff
Touch when cuff attached
Pulse
-?-
awRR
-?-

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.**

Strongly Disagree	Disagree	Somewhat Disagree	Somewhat agree	Agree	Strongly Agree
◯	◯	◯	◯	◯	◯

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

Not at all Comfortable	Not Comfortable	Somewhat Uncomfortable	Somewhat Comfortable	Comfortable	Very Comfortable
◯	◯	◯	◯	◯	◯

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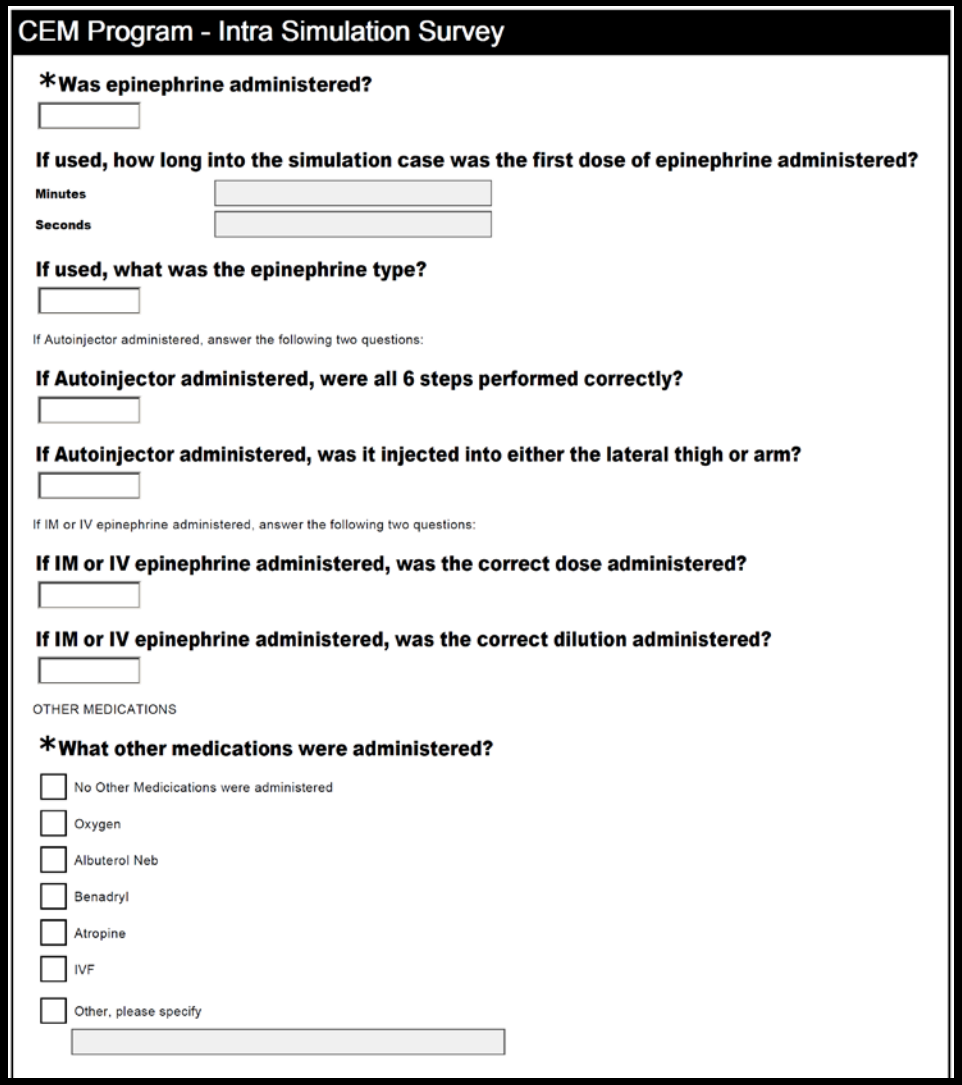
Intra-simulation data collection



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 Medicications 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

Prospective analysis of an interprofessional team training program using high-fidelity simulation of contrast reactions

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Taj Kattapuram, MD[1]

Elkan F. Halpern PhD[1, 3]

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Shawn S. Bonk, MHM[1]

Joanne C. Forde, RT(R)(CT)[1]

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Margaret Sande, MD, MS[2, 4,5]

Rebecca D. Minehart, MD[2, 6]

James A. Gordon, MD, MPA[2, 4]

- 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

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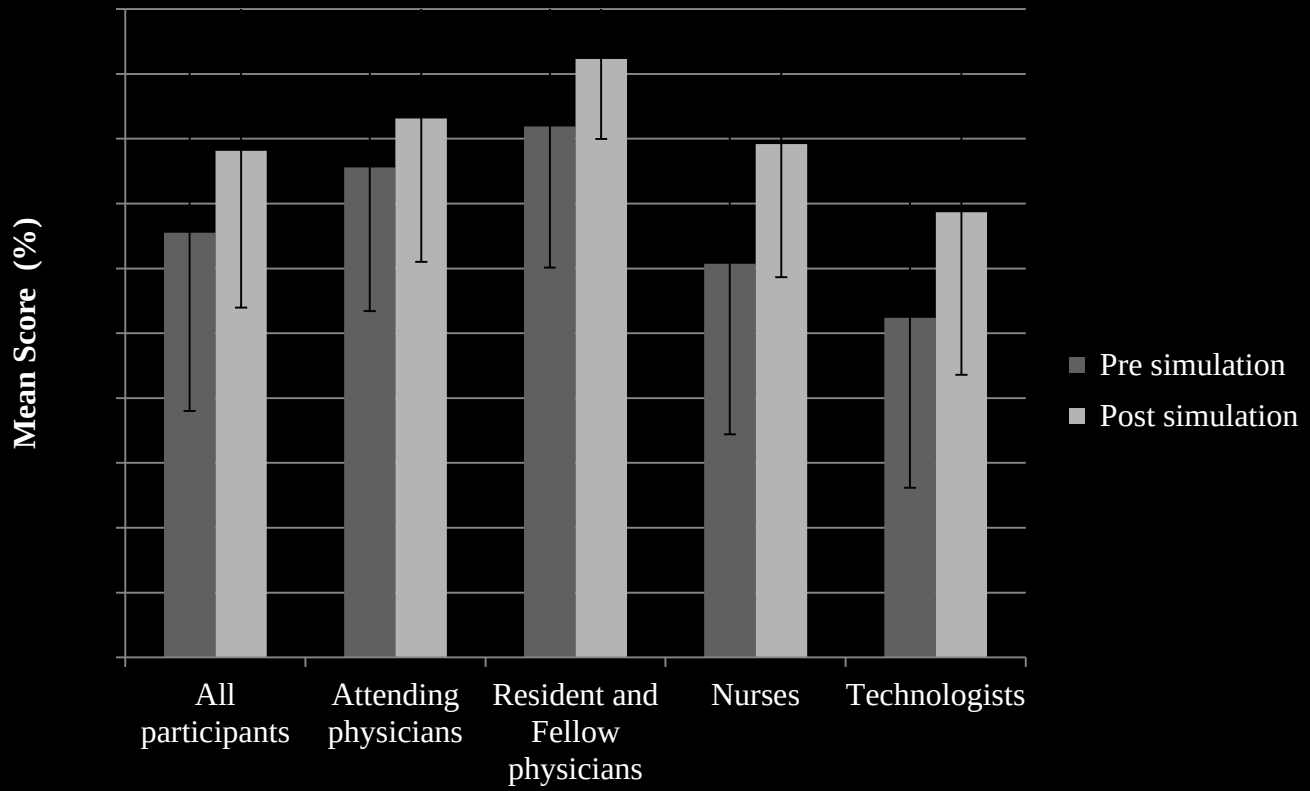
Niell et al. *American Journal of Roentgenology AJR* (in press)

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)

	Pre Simulation		Post Simulation		
How comfortable do you feel working in a team during a medical emergency?	Comfortable n (%)†	Not comfortable n (%)‡	Comfortable n (%)†	Not comfortable n (%)‡	p-value *
Physicians	135 (90%)	15 (10%)	145 (97%)	5 (3%)	0.003
Resident/fellow physicians	55 (92%)	5 (8%)	58 (97%)	2 (3%)	
Attending physicians	80 (89%)	10 (11%)	87 (97%)	3 (3%)	
Nurses	19 (90%)	2 (10%)	21 (100%)	0 (0%)	0.5
Technologists	94 (80%)	23 (20%)	114 (97%)	3 (3%)	<0.00001
Other	3 (60%)	2 (40%)	5 (100%)	0 (0%)	NA
Total (n = 293)	251 (86%)	42 (14%)	285 (97%)	8 (3%)	<0.00001

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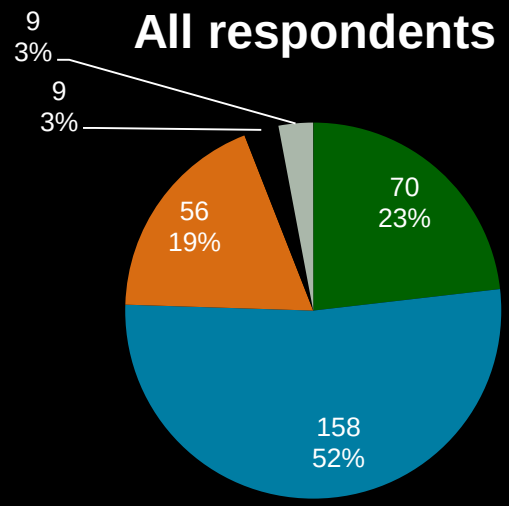
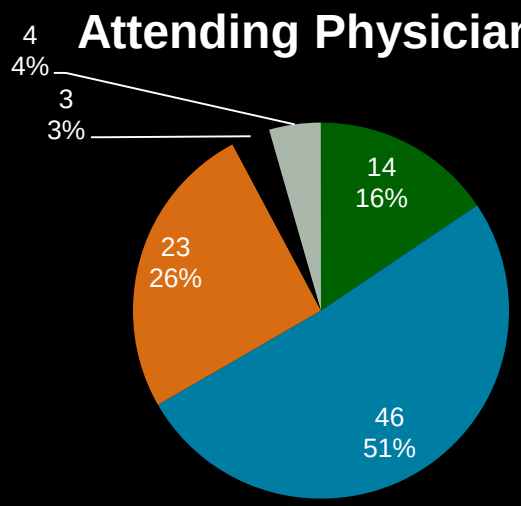
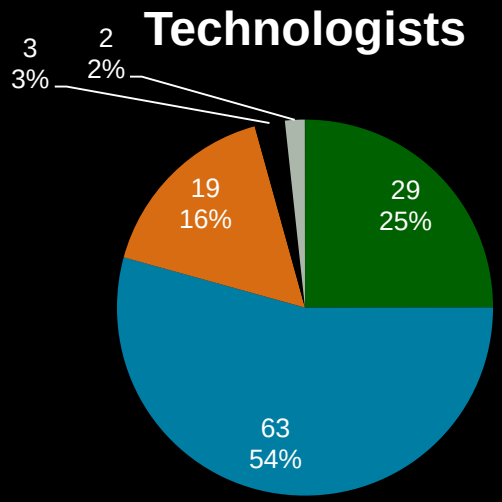
Frequency of Re-Training







Large volume of personnel → Annual re-training currently

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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

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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

TABLE 5. Summary of Cost Differences Between the Two Groups

	Lecture Curriculum		Simulation Curriculum	
Analysis Item	Setup Cost	Recurring Cost	Setup Cost	Recurring Cost
Faculty time (academic days)	2	1	7	5
Resident time (h:min)	1:10	1:10	3:30	3:30
Financial cost (per resident)	<$5	<$5	$259.76	$203.46

- n = 23 residents with two residents per simulation
- Actual simulation time was 2.5 hours

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Petscavage et al. Academic Radiology 2011;18:107

Cost includes personnel time away from clinical schedule

eTraining, Inc.

Certificate of Completion

This certifies that

Fred Neill

has received the proper training for successfully completing

Introduction to Stairways and Ladders

November 13, 2013 Certificate Number: 31760

eTraining, Inc.

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Fall Protection

OSHA Subpart M 1926.500-503

November 22, 2013 Certificate Number: 32005

www.etraintoday.com

Niall O'Malley, President

Larry A. Baylor, VP Content Development

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.

https://www.osha.gov/Publications/osha3124.pdf

Do our personnel believe that CEM simulation is a valuable use of time?

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
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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.

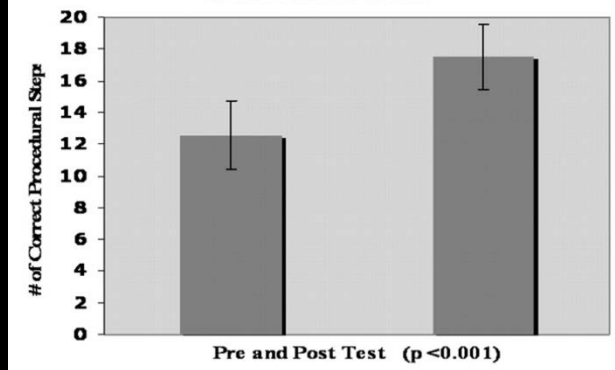


Figure 5. Statistical significance in improvement in procedure performance from pretraining to posttraining.

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

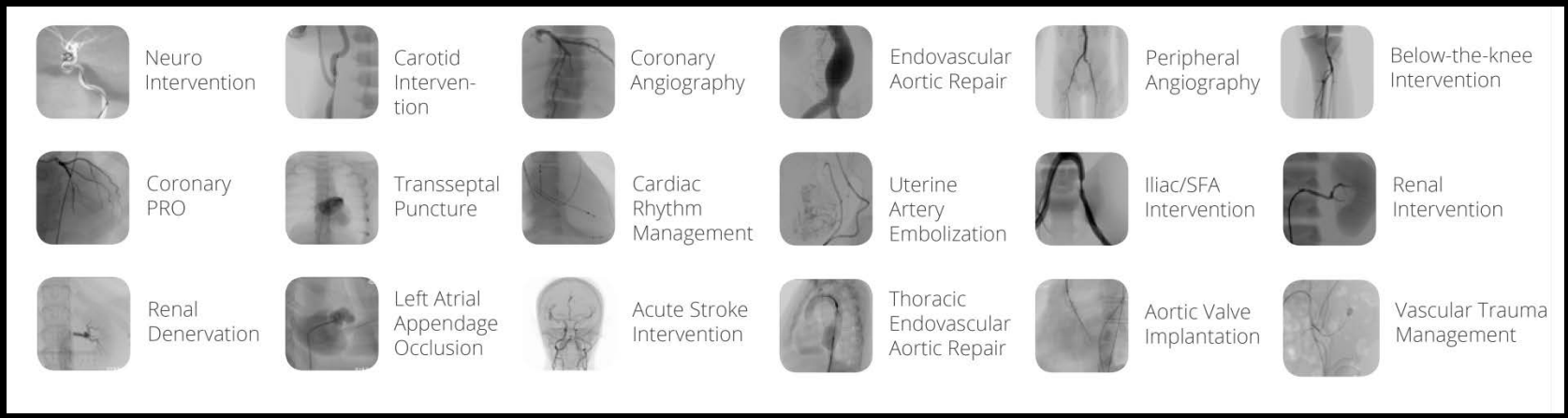

Thrombosis


Doppler


Foreign Body ID

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

Endovascular Simulators



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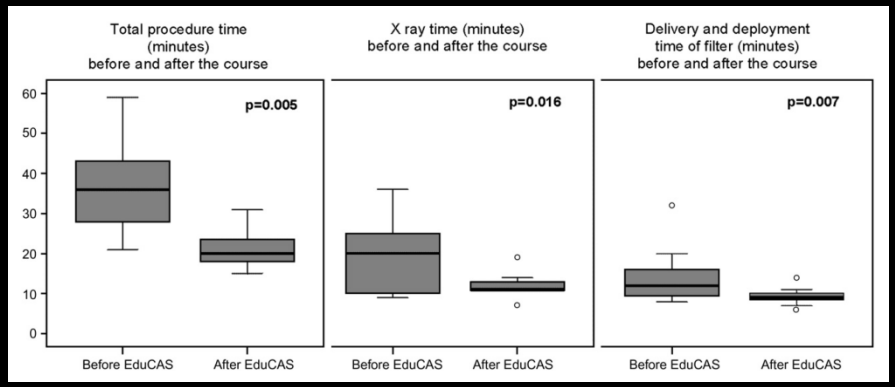
MENTICE®

Endovascular Simulators

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

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



Coates et al. *JVIR* 2010; 21:130 and Van Herzeele et al. *Eur J Vasc Endovasc Surg* 2007;35:541

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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)

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Thank you for your time!

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