Simulation-based Research in Orthopaedic Surgery

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Overview

- Who am I? My journey
- Historical perspective
- Surgical education
- What is simulation?
- Simulation training
- Simulators: fidelity vs realism
- Simulation-based research
Objectives

∗ Analyze why surgical education is changing
∗ Evaluate what simulation brings to medicine
∗ Compare different simulators
∗ Explain why skills training is important
∗ To review examples of education research projects
Who am I?
Who am I?

- Associate Professor of Orthopaedic Surgery/arthroscopist/teacher/mentor
  - Shoulder reconstructive surgery
  - Sports
- Roth-McFarlane Hand and Upper Limb Centre (HULC)
Who am I?

- Fellow at the Centre for Education, Research & Innovation (CERI)
- MHPE (University of Illinois at Chicago)
My journey...

What am I doing here???
2009: Suggestion to do more teaching/educational work (division and department chairs)

2009: MHPE at UIC, Chicago

2009-now: 8 research grants

Total 456,000$
My journey

2011:
- Academic Medical Organization of Southwestern Ontario (AMOSO) Opportunities Fund, “Fostering the Future of Simulation-Based Surgical Training: The Simulation-based Educator and Researcher in Surgery (SiBERS)”

2012
- Physicians’ Services Incorporated Foundation grant, “Observational learning strategies in simulation-based arthroscopic surgical training”
What am I doing?

- Simulation-based research in orthopaedic surgery
  - Arthroscopy
  - Basic skills
- Development of simulators and metrics for training and assessment in arthroscopy
What am I doing?

Research projects:
Stay tuned… it’ll come later tonight!
What are the meanings of:

“endoscopy”

“laparoscopy”

“arthroscopy”?
Endoscopic surgery began when...

1585 – Aranzi (Italy)

1st endoscopic nasal cavity procedure
1853 – Desormeaux (France)

“Father of endoscopy”
Urologic examination
1868
Dr Kussmaul
(Germany)
1901 – Kelling (Germany)

1st “organoscopy (laparoscopy)
Then

Now
The evolution of surgery

**Large incisions** for access / visibility
- Increased post-operative pain
- Slower recovery

**Smaller incisions / minimally invasive**
- Less dissection
- Less pain
- Faster recovery
Fundamental issues of training in endoscopy are not speed but quality of surgery and preventing accidents.

Surgeons who regularly perform a specific procedure have better outcomes than those who perform it sporadically.
What does a surgical resident need to learn?

1. Learn *when* to operate
   * Textbooks
   * Clinics
   * Hospital ward work

2. Learn *how* to operate
   * In OR with live patients
   * Many problems with this approach
Trainees are more likely to make technical errors
- Many post-operative complications are direct result of intra-operative technical errors

Trainees increase operative times
- Longer operative times = increased complications
- Wound infection and post-operative sepsis rate increase with longer operative time
Adequate training can minimize the complication rate

Complications are seen in the early part of the learning curve
Challenge of laparoscopy ...
Challenge of arthroscopy …
- Arthroscopy = complex
- Hard to teach
- Hard to learn
- Restrictions work hours
- Very steep learning curve
Learning curve = rate of learning

Principle that more one does something the better one gets at it

Shows the rate of improvement in performing a task as a function of time
Steep learning curve

- I'm not even trying
- I'm doing my best
- I made it my life's purpose
- Effort

Understanding
Why does surgical education have to change?
Why does surgical education have to change?

- New paradigm in training 80 hours/work week:
  - Decreased number of complex cases a resident will see by 40%
  - Decreased percentage of cases followed through to discharge by 56%
Why does surgical education have to change?

- Time constraints (trainees increase operative times)
- Financial pressure (time is money)
Why does surgical education have to change?

* Medical-legal concerns (trainees more likely to make errors)
Why does surgical education have to change?

- Rapidly changing surgical technology (both surgeon and trainee are learning)
Why does surgical education have to change?

- Increased complexity of tertiary cases
- Patient pressure / expectations
- Drive to decrease morbidity and mortality
OR is an inefficient classroom
Apprenticeship model

Model of Deliberate Focused Practice
Deliberate practice

* Skills training prior to undertaking procedure could:
  - minimize learning curve
  - improve skills
  - reduce morbidity / mortality
What is “Simulation”
What is “Simulation”
What is "Simulation"
What is “Simulation”
What is simulation?

the imitation of the operation of a real-world process or system over time (Wikipedia)
When did it all start?

* **Antiquity**: stone/clay representations
* **1947**: 1st simulation game, missile fired at a target
* **1960’s**: astronauts, simulator must be mastered first
* **1980’s**: computers → Nintendo, 1985
* **1989**: 1st surgical simulator
How far behind are we?

Table 1. Attitudes in Aviation and Healthcare: A Survey of 31,033 Pilots, Surgeons, Nurses, and Residents

<table>
<thead>
<tr>
<th>Question</th>
<th>Pilots Who Answered Yes</th>
<th>Surgeons, Nurses, and Residents Who Answered Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does fatigue negatively impact your performance?</td>
<td>74%</td>
<td>30%</td>
</tr>
<tr>
<td>Do you reject advice from juniors?</td>
<td>3%</td>
<td>45%</td>
</tr>
<tr>
<td>Is error analysis system-wide?</td>
<td>100%</td>
<td>30%</td>
</tr>
<tr>
<td>Do you think you make mistakes?</td>
<td>100%</td>
<td>30%</td>
</tr>
<tr>
<td>Easy to discuss/report mistakes?</td>
<td>100%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Why use simulation in medicine?

- Training
- Assessment
- Accreditation
What does simulation add?
Potential Benefits of Simulators in Surgical Residency

- Decrease costs associated with resident training
- Volume of real surgical cases less crucial
- Stress-free training in controlled environment for focused deliberate practice
- Reduce surgical morbidity and mortality
- Objective assessment of resident surgical skills
What simulation adds

Boeing pilot training studies show simulator based training improves pilot training by teaching the WHY and not just the WHEN and WHAT of airplane operations.
The Cone of Learning

I see and I forget.  
I hear and I remember.  
I do and I understand.  
— Confucius

After 2 weeks,  
we tend to remember ...

10% of what we READ
20% of what we HEAR
30% of what we SEE
50% of what we SEE & HEAR
70% of what we SAY
90% of what we SAY & DO

Source: Edgar Dale (1969)
Simulation training

- Growing body of evidence:
  
  - Research has validated simulation as an effective learning tool (McGaghie, 1999; Issenberg et al., 2001; ACS, 2013; RCPSP, 2013)

  - Simulation technology provides a safe and effective mechanism to educate and assess professionals (Tekian et al., 1999; RCPSC, 2013; ACS, 2013)
Simulation training

* Simulation-based skills training is transferrable to the OR (Windsor, 2012; Sturm, 2008; Stefanidis, 2012)
Simulation technologies to complement, NOT to replace traditional teaching
Simulators: fidelity vs realism

* Simulators compared to live actor-patients have equivalent results in prompting critical actions (Gillet et al, 2008)

* Aviation: a proper training program is essential to realizing the potential training value of a device, regardless of its realism (Caro 2012)
Simulators: fidelity vs realism

- Each simulator has strengths and weaknesses
- Low-fidelity models as efficient as higher-fidelity models for certain types of training (Hill et al, 2012)
- More fidelity required for more advanced skills (Hill et al, 2012)
Simulators: fidelity vs realism

- Low-fidelity physical models
- High-fidelity physical models
- Virtual-reality simulators
- Animal models/Cadavers
Low-fidelity physical simulator

Urethra = Penrose drain

Bladder dome = Inverted cup

Ureters = 8 mm embedded straws

Bladder base = Molded latex in portable plastic case
Low-fidelity physical simulator

**Advantages**
- Inexpensive (20 $)
- Reproducible
- Portable
- Effective

**Disadvantages**
- Simplistic
- Non-anatomic
High-fidelity physical simulator
Our model

Real patient

High-fidelity trainer
High-fidelity physical simulator

**Advantages**

- Less expensive than computer-based simulators (3700 $)
- Portable
- Effective

**Disadvantages**

- More expensive than low fidelity models
- “Only” equally effective as low fidelity model
Virtual-reality simulator
Virtual-reality simulator

**Advantages**

* Immediate feedback, objectives measures
* Haptics
* Numerous modules/procedures

**Disadvantages**

* $$$, needs updates
* Learning curve, even for experts
* Need for validation
Ideally actual patient data could be *uploaded* to simulate actual case prior to embarking on procedure.
Advantages:

* Less expensive than high-fidelity models and virtual reality simulators (300-800 $)

* Anatomically may be similar to the human

* Bleeding and respiratory movement occurs

* Haptic feedback similar to human tissue

* Effective
Disadvantages:

* More expensive than low fidelity models
* Risk for disease transmission
* Lack of proper scientific assessment
Interestingly...
The right technology...
Ultimately...

Patient-specific VR Trainer

Database

Patient images
What about here in London?
Research questions: then

* Using the technology available at CSTAR, what basic arthroscopic simulator can we develop for the training of the residents?

DEVELOPMENT

* What are the basic skills that constitute the fundamentals skills of arthroscopy surgery?

research
How can I influence the learning on surgical simulators?
- Amount/quality of information, feedback, observation, etc.

How do we process the information we get from our hands and eyes when we learn arthroscopy?
What do I do with Simulations?

- Simulation-based research (physical and VR):
  - CERI
  - Brain and Mind Institute (BMI)
  - Roth-McFarlane Hand and Upper Limb Centre (HULC) mechatronics laboratory
  - Canadian Surgical Technologies and Advanced Robotics (CSTAR)
What do I do with Simulations?

* Development (physical and VR):
  * CSTAR
  * HULC
Measuring performance and training progress

![Image of a computer screen and a man manually adjusting a knob]

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**Overall Score**

- **Weeks of training completed**
- **Percentage change in Overall Score from prior week**
- **Final Overall score** (week 10)
- **% change (baseline to week 8)**

<table>
<thead>
<tr>
<th>Week</th>
<th>Median</th>
<th>Min</th>
<th>Baseline Simulator Overall score</th>
<th>Weeks of training completed</th>
<th>Percentage change in Overall Score from prior week</th>
<th>Final Overall score (week 10)</th>
<th>% change (baseline to week 8)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>67%</td>
<td>44%</td>
<td>8</td>
<td>10</td>
<td>12% 5% 4% 4% 2% 1% 1% 1% -1%</td>
<td>88%</td>
<td>13%</td>
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* scores includes all 17 exercises
Motion + Force sensing
Training: what should we do?

- Determine the educational needs
- Design a curriculum (Kern)
- Find the right technology
- Decompose/deconstruct surgeries
- Schedule of practice
- Assessment
Ultimate intended Benefits/Outcomes of Simulation Training in Surgery

- Better training for better surgeons
- Better surgical outcomes
- Reduced health care costs
- Less complications
- Shorter post-operative hospital stay
- Speedier recovery
- Quicker return to workforce
Conclusion

- Simulation will never replace real life experience
- Focus on reliable and valid tools (simulators, metrics): development + research
- Expert mentors will always be needed
  - Verify performance
  - Judge simulator’s in vivo fidelity
Lots of work to do in this field!

* Curriculum design

* Standardization of simulation training

* Research

* Development
Thank you!

**Student Pilot Crashes Simulator**

3 Bubs, Kris Shaley from England who was training for the first officer position, and the instructor who sat behind the plane at his own station in the completely enclosed cockpit.

"Lucky no one was seriously injured," said Butler County emergency responder Horace Masters. "But all 3 were pretty shaken up because they weren't wearing their seatbelts during the estimated 10 feet fall."

No one really knows why the simulator topped over; but from his hospital bed the instructor told FAA officials that Bubs had been known to override the simulator into some pretty wild gyrations, and that today was no different. He is reported to have said, "Personally, I wouldn't let Bubs pull my kids' wagon."

"I don't think we will ask him (Bubs) to come back," said James Tavera bitterly. "We all liked him; he was a real gentleman with a great sense of humor. But basically we at SimFly are not 2.5 million dollars because the Faa was not insured. Who pays insurance for a simulator?"

And that may not be all of Bubs's troubles. The FAA, the NTSB and Homeland Security have become involved because Bubs allegedly wired "Ai-Yi-Yi" as the simulator crashed, the cry of terror as they anticipate martyrdom and the 14 virgin, or 14 Bubs young boys with the grace of gasolene, awaiting them in Paradise. Homeland Security is now concerned that Bubs may have been training for a terrorist attack using a simulator.

"Can you imagine the damage that one of these simulators could do if it were loaded with explosives?" said one Homeland Security official.

Bubs was quickly whisked off to the Guantanamo Bay detention center where Guantanamo prison personnel will be able to write a letter to him in 3 years.

The FAA has issued a directive for the SimFly simulator effectively grounding the entire fleet until the cause of the crash can be determined.