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AOA Critical Issues in Education

A Curricular Model for Simulation Within Orthopaedic Residency Training

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Introduction: American Board of Orthopaedic Surgery/American Council on GraduateMedical Education Residency Review Committee training requirements have necessitated the need for the adoption of simulation education into existing programmatic requirements. Current guidelines focus only on interns at a potentially significant cost to programs; both in total dollar amount and time.

Methods: The authors aim to provide a model that can maximize utility for all resident levels, manage cost by maximizing the use of cadaveric material, and allow integration of varied industry support.

Results: The Oregon Health & Science University Orthopaedic education program has developed a high-fidelity training curriculum that (1) is applicable to both junior and senior residents (2) has minimized the cost per resident with the reuse of cadaveric specimens and (3) has nurtured partnerships with industry stakeholders to reduce bias in training by collaborating with most major industry representatives.

Conclusion: The simulation curriculum outlined in this manuscript may serve as a reference for other programs and institutions to develop their own residency educational curriculum models.

Introduction

Rules surrounding work hours and the clinical environment, along with variations in clinical experiences, have driven the growth of simulation's role in clinical education[1]. Both faculty and resident-level surgeons have voiced discomfort with the decreased clinical hours and increased number of handoffs[2,3]. Simulation training offers a consistent supplemental education experience in a low-risk environment that ensures the learners are prepared to deliver high-quality, patient-centric care in the context of more varied and restricted clinical experiences[4-7].

In 2013, the American Board of Orthopaedic Surgery (ABOS) and American Council on Graduate Medical Education

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Residency Review Committee (ACGME RRC) introduced simulation training as a formal intern-year requirement for orthopaedic surgery residents. This change was driven by the desire to ensure early acquisition of surgical skill and training required in the initial management of orthopaedic patients[8].

The ABOS provided a modular curriculum to meet their 2013 ABOS/ACGME RRC residency training requirements. Programs interested in creating a simulation program that satisfies all the guidelines and optimizes learning opportunities might encounter the familiar challenges of cost and time: Even a basic system can cost upward of $350 per resident using readily available materials[9]. The limitation of such academic models is that they generally lack the realism of virtual reality or cadaveric donor models, especially if more senior learners are to be involved[8-11]. In addition, clinical experiences and work hour restrictions limit the time available for education-focused simulation[12]. Consequently, program directors are left to determine their institutions' priorities around clinical vs. simulation education experiences.

The authors aim to present an educational model that can maximize utility for all resident levels, manage cost by increasing uses of cadaveric material, and balance bias through the involvement of many major industry supporters.

Methods

IRB review and approval were not required because this article is a description of an educational endeavor rather than a scholarly study.

OHSU Simulation Objectives and Curriculum

Oregon Health & Science University's (OHSU) Orthopaedics and Rehabilitation department formalized the program's core curricular objectives in 2013 based on the ABOS modules for Post-Graduate Year (PGY)-1 residents seen in Table I. Objectives were fully implemented in 2014 as OHSU began hosting simulation laboratory test results and vetting further programmatic growth with support from the OHSU Simulation Steering Committee and guidance from both orthopaedic residents and faculty. Program leadership has since elevated the previously existing dry laboratory experience with the integration of cadaveric tissue–based simulations described below.

Core curricular content is scheduled through once- or twice-monthly cadaveric or Sawbones model–based training hosted at the VirtuOHSU Simulation and Surgical Training Center (VSSTC). Curricular details can be seen in Table II: Topics that most closely adhere to the ABOS guidelines such as arthroplasty (Fig. 1) and arthroscopy (Fig. 2) are repeated annually, whereas topics that are more broadly represented (for example, the various regions of spine surgery: cervical, thoracic, and lumbar) are repeated once every 3 years. The objective of clinical education at OHSU is to supplement the historic apprenticeship model with simulation training[13].

As of 2023, this current curricular series consists of 18 Friday morning sessions hosted twice monthly for 6 months of the academic year and once monthly during the training review block during the other 6 months of the year. The simulation frequency is reduced to once-monthly sessions to accommodate for the protected education time in preparation for the American Association of Orthopedic Surgeons Orthopaedic In-Training Examination and during the anatomy block of the curriculum, which involves once-weekly dissections and surgical approaches on an embalmed specimen.

A 3-year rotating curriculum was developed through the collaboration of the associate program director and a senior resident as a quality initiative, then vetted through the faculty surgeons and the education committee (residents and faculty surgeons). This curriculum is developed to maximize resident exposure to a diverse range of topics and approaches and maximize relevance for all levels of training.

Training Outside of the Regular Friday Curriculum

The core curriculum involving the entire resident group covers 13 of the 17 ABOS Modules. Modules not covered in the Orthopaedic Residency curriculum include Module 1: Sterile technique/operating room (OR) setup, Module 6: Traction, Module 16: Joint aspiration and injection, and Module 17: Patient safety, team training, and obtaining consent. Module 1 is skipped because it is sufficiently covered in the residents' intern year while rotating with general surgery and participating in their simulation experiences. A separate training for rising and graduating interns at the start of the year covers Modules 6, 16, and 17, the traction and joint aspiration/injection modules and consenting module, as well as other skills believed to be imperative for fielding orthopaedic consults[13].

Microvascular surgery and arthroscopic surgery are more advanced skills that our residents experience later during their dedicated rotations[14]. Junior residents (PGY-3) on upper extremity rotation are guaranteed protected time in a weekly 3-hour microvascular curriculum in which they practice vascular anastomosis with a live rat model[15]. The PGY-5 residents on the rotation are also welcome to attend these microvascular sessions, for instance, if pursuing specialization in upper extremity and microvascular surgery.

Finally, junior and senior residents on the sports rotation participate in weekly arthroscopy laboratory test results involving surgery of the knee, shoulder, and hip. See the Appendix, http://links.lww.com/JBJSOA/A605 for example curricula for supplemental simulation training during the upper extremity and sports rotations.

VirtuOHSU Simulation and Surgical Training Center

OHSU's Orthopaedics and Rehabilitation resident simulation training program is a collaborative partnership between VSSTC, the OHSU Body Donation Program (BDP), industry stakeholders, and faculty and staff of the Department of Orthopaedic Surgery. Simulation of OR and clinical scenarios are provided in-house on OHSU campuses within the VSSTC training facility. VSSTC was built and partially funded by the Office of the Provost to dedicate toward simulation and education efforts throughout the OHSU campus. Ongoing educational efforts continue to be prioritized by the Office of the Provost.

TABLE I American Board of Orthopaedic Surgery Surgical Skills Modules for PGY-1 Residents*

Module 1 sterile technique-operating room setup	Module 2 suturing and knot tying
Module 3 microsurgical suturing technique	Module 4 soft-tissue handling and dissection
Module 5 casting and splinting: splints, casts, and removal	Module 6 traction techniques
Module 7 compartment syndrome. Diagnosis and treatment	Module 8 bone handling techniques—osteotomy
Module 9 fluoroscopic knowledge and skills	Module 10 K-wire techniques
Module 11 techniques basic to internal fixation of fractures	Module 12 principles and techniques of fracture reduction
Module 13 basics techniques in external fixation	Module 14 basic arthroscopy skills
Module 15 basic arthroplasty skills (TKA and THA)	Module 16 joint aspiration and injection
Module 17 patient safety, team training, and obtaining consent	

*PGY = Post-Graduate Year; TKA and THA = Total Knee Arthroplasty and Total Hip Arthroplasty.

Equipment and instrumentation for simulation activities in VSSTC are provided through a combination of in-house and industry-sponsored in-kind donations. Fluoroscopic imaging using a C-arm stored in VSSTC is undertaken onsite by residents with appropriate protection and orthopaedic faculty guidance.

Grant Request Process from Industry

The Department of Orthopaedics and Rehabilitation requests grant and in-kind support for specific courses within the core curriculum. Industry partners have electronic request forms for educational grant requests. These processes vary but are generally posted on the industry sponsor's web site and are readily available by contacting local industry representatives.

The grant process is variably successful because of different companies' commitment to education as a budgetary line item. As a result, some industry stakeholders are more frequently represented within the core curriculum on this basis. This limits the ability to realize our goal to completely equalize the residents' exposure to various options for their surgical procedures.

Once grant funding is secured, administrators and faculty work with local distributors to acquire specific instrumentation. Confirmation of deliverables is communicated by the local industry partner. If standard grant processes are not available or are not successful from their corporate headquarters, local distributorships are sometimes willing to fill the role with enough advance notice and discussion.

Integration of Industry Support Into the Educational Curriculum

Programs seeking industry partner involvement to supplement training instrumentation and equipment should aim to incorporate as broad a range of training equivalents as possible. This serves to optimally prepare residents for the multitude of clinical options available in practice. However, the inclusion of external partners may pose some ethical dilemmas. OHSU has addressed this concern in 2 ways. First, through the involvement of as many major industry companies as possible and second, by hosting all training events within the neutral training environment of VSSTC. Inviting all industry partners to support the educational objectives of the program with in-kind donations allows for broad exposure to each individual product line. Residents otherwise only gain exposure to a subset of the many available industry products and tools used by their faculty in the clinical space. Industry partnerships represent a means to broaden resident exposure and maximize support.

Tissue Procurement and Preparation

OHSU BDP staff are present for all cadaveric laboratory test results. Duties include (1) donor specimen preparation, (2) positioning and mounting assistance, and (3) biologic management and removal for final processing. The tissue preparation process is standard for all fresh uses. Donor preparation includes metal detection of specimens to ensure no previous surgeries in the areas of interest. For each course in the 25-resident core curriculum, 4 specimens are provided.

Maximize Use and Reuse of Cadaveric Donor Material

The costs of cadaveric donor specimens are further reduced because initial tissue mapping is coordinated with BDP and orthopaedic faculty in advance of course dates. This advanced planning allows for the coordinated reuse of cadaveric donor material to be used and refrozen for future courses focusing on different anatomical areas of interest. For example, 4 pelvis through toes specimens are used for pubic symphysis Open Reduction Internal Fixation, then hemisected to provide 8 hemipelvis through toes specimens that can be used twice more in total (but may be sectioned to allow separate uses of foot/ankle vs knee, etc). OHSU has found that cadaveric models can undergo up to 3 freeze/thaw cycles before cremation with acceptable muscle degradation that maintains educational viability[16].

Simulation Curriculum Outcomes

Reduction of Cost

The specific cost of our simulation program is an elusive data point for several reasons. An example invoice is included in the Appendix, http://links.lww.com/JBJSOA/A605. As shown on the invoice, $1806.25 for facility laboratory space, $1,175.00 for OHSU laboratory instruments and cleaning, and $1,560.00 for

TABLE II 3-Year Rotating Core Curriculum

Month	Year	Subspecialty	Laboratory	Modules
July A	1	Trauma/UE	BB forearm ORIF (basic plating/fracture reduction skills for new residents—include closure if wet lab)	2, 4, 11, 12
	2	Trauma/UE	BB forearm ORIF	2, 4, 11, 12
	3	Trauma/UE	BB forearm ORIF	2, 4, 11, 12
July B	1	Trauma	External fixation	13
	2	Trauma	External fixation	13
	3	Trauma	External fixation	13
August (OITE)	1	UE	Ulnar shortening osteotomy, PRC, and ulnar tunnel release	4
	2	UE	Finger procedures (CRPP, plating, amputations, and flaps)	9, 10, 12
	3	UE	Wrist fusion, carpal fusion, and carpal tunnel release	4
Sept (OITE)	1	Peds	CRPP supracondylar humerus fx and ORPP lateral condyle fx	4, 9, 10, 11, 12
	2	Trauma/UE	Proximal humerus and humerus shaft ORIF	4, 11, 12
	3	Trauma/UE	Olecranon and distal radius ORIF	4, 11, 12
Oct (OITE)	1	UE/trauma	Distal humerus ORIF	4, 10, 11, 12
	2	UE	TSA	4
	3	UE	Clavicle/scapula ORIF	4, 11, 12
Nov A	1	Spine	Pedicle screw placement and lumbar decompression	4
	2	Spine	Cervical fusion (ACDF/posterior fusion)	4
	3	Peds	Scoliosis instrumentation and VEPTR	4
Nov B	1	Peds	Distal femur/proximal tibia epiphyseodesis	8
	2	Sports/joints	HTO/DFO	4,8
	3	Trauma/tumor	Tibial IMN	11, 12
Dec A	1	Trauma/tumor	Acetabular fracture ORIF	4, 11, 12
	2	Trauma	ORIF pubic symphysis	4, 11, 12
	3	Trauma	Percutaneous SI fixation/triangle SI fixation	9, 10
Dec B	1		Musculoskeletal ultrasound	
	2		Musculoskeletal ultrasound	
	3		Musculoskeletal ultrasound	
Jan A	1	Trauma/tumor	Cephalomedullary femoral fixation/femoral IMN	11,12
	2	Peds	Proximal femoral osteotomy	8
	3	Trauma	Supracondylar femur ORIF	4, 11, 12
Jan B	1	Sports/UE	Shoulder arthroscopy (SAD, biceps tenotomy/tenodesis, and distal clavicle resection)	2, 14
	2	Sports/UE	Shoulder arthroscopy (SAD, biceps tenotomy/tenodesis, and distal clavicle resection)	2, 14
	3	Sports/UE	Shoulder arthroscopy (SAD, biceps tenotomy/tenodesis, and distal clavicle resection)	2, 14
Feb (anatomy)	1A	Joints/tumor	THA	4, 8, 15
	1B	Anatomy		
	1C	Anatomy		
	1D	Anatomy		
	2A	Joints/tumor	THA	4, 8, 15
	2B	Anatomy		
	2C	Anatomy		
	2D	Anatomy		

continued

TABLE II (*continued*)

Month	Year	Subspecialty	Laboratory	Modules
	3A	Joints/tumor	THA “tumor/megaprosthesis”	4, 8, 15
	3B	Anatomy		
	3C	Anatomy		
	3D	Anatomy		
March (anatomy)	1A	Trauma	Tibial plateau ORIF, compartment monitoring, and release	7, 11, 12
	1B	Anatomy		
	1C	Anatomy		
	1D	Anatomy		
	2A	Trauma	Tibial IMN, compartment monitoring, and release	7, 11, 12
	2B	Anatomy		
	2C	Anatomy		
	2D	Anatomy		
	3A	Trauma	Tibial plateau ORIF, compartment monitoring, and release	7, 11, 12
	3B	Anatomy		
	3C	Anatomy		
	3D	Anatomy		
April (anatomy)	1A	FA/trauma	Ankle and pilon ORIF	4, 11, 12
	1B	Anatomy		
	1C	Anatomy		
	1D	Anatomy		
	2A	FA/trauma	Hindfoot procedures (calcaneus, talus ORIF, and subtalar fusion)	4, 11, 12
	2B	Anatomy		
	2C	Anatomy		
	2D	Anatomy		
	3A	FA	Midfoot/forefoot procedures (bunion, LisFranc, etc.)	4, 8
	3B	Anatomy		
	3C	Anatomy		
	3D	Anatomy		
May A	1	Sports	Knee arthroscopy (meniscus and ACL)	14
	2	Sports	Knee arthroscopy (meniscus and ACL)	14
	3	Sports	Knee arthroscopy (meniscus and ACL)	14
May B	1		Open session*	
	2		Open session*	
	3		Open session*	
June A	1	Joints/tumor	TKA	4, 8, 15
	2	Joints/tumor	TKA	4, 8, 15
	3	Joints/tumor	TKA	4, 8, 15
June B	1		Open session*	
	2		Open session*	
	3		Open session*	

*Open sessions are available for visiting professors or faculty requests. ACDF = Anterior Cervical Discectomy and Fusion; ACL = Anterior Cruciate Ligament; BB = Both Bone; HTO/DFO = High Tibial Osteotomy/Distal Femoral Osteotomy; IMN = Intramedullary Nail; OITE = Orthopaedic In-Training Examination; ORIF = Open Reduction Internal Fixation; PRC = Proximal Row Carpectomy; SAD = Sub Acromial Decompression; TSA = Total Shoulder Arthroplasty; TKA = Total Knee Arthroplasty; UE = Upper Extremity; VEPTR = Vertical Expandable Prosthetic Titanium Rib.

Fig. 1
Residents practicing arthroscopic surgical techniques during the annual orthopaedic arthroscopy bootcamp.

anatomical services, including tissue specimen ×4, for a total price of $4,541.25 estimated for a particular laboratory session. This results in a cost of $181.65 per resident per laboratory session.

The estimated invoice is provided to the industry partner for the specific course to provide in-kind equipment and products in addition to the financial support. Grant funding through

Fig. 2
Residents actively engaged during a hip arthroplasty, which is a Friday core curricular event.

industry sponsorship, when available, can supplement the overall cost to host resident education courses. Grant application processes vary per industry sponsor and typically need to be arranged well in advance of a course. We are fortunate to have a provost who has made simulation education an institutional priority, and if an industry partner grants a funding amount less than what is requested, the remaining costs can often be absorbed by the institution's simulation budget.

OHSU's Department of Orthopaedics and Rehabilitation reduces the educational simulation expenditure by partnering with VSSTC and BDP, which are both 501c3 nonprofit institutions. Simulation activities are hosted on-site within VSSTC, a multidisciplinary simulation center at OHSU, which offers a relatively reduced rate. Offsite locations typically incur increased costs from the transportation of residents to and from the facility, hosting and facility fees, and separate donor preparation and processing fees. Because of the partnership with OHSU and BDP, disarticulated shoulder or knee specimens, for example, involve a reimbursement rate between $500 and $600. Compared with the $350 per individual resident represented from Lopez et al. (estimated to equal $450 in 2023 dollars), the cost of cadaveric material becomes more approachable when specimens are used on a recurrent basis[9]. And finally, we partner whenever possible with other services to share cost: For example, the plastic surgery team can follow an extremity procedure and practice flap coverage of a wound, and the general surgeons can practice their procedures on the thoracic cavity and abdomen of a specimen intended for scoliosis surgery.

Increased Utility for Senior Residents

Compared with modalities that use dry tools and models, cadaveric specimens allow for enhanced anatomical reality and allows more opportunities for senior residents to assume a teaching role for junior residents while still gaining a rich educational experience for their own purposes. Each resident assumes more responsibility in a simulated environment: Junior residents get more autonomy to practice procedures that might be more observational at their level, and senior residents can add to the procedure in ways they might avoid clinically (i.e., directly visualize a neighboring neurovascular structure that is typically left undisturbed, to completely understand its proximity and precise location).

Viable Options for Assessing Resident Skill Level

A challenge discussed in depth later in this article is the conversation surrounding the prioritization of assessment vs. education given time constraints. Although this program prioritizes education over testing, portions of our simulation efforts have developed potential avenues for resident evaluation with specific clinical implications.

Rose et al. (2017) used wearable inertial sensors to objectively quantify the performance of orthopaedic residents while performing a diagnostic knee arthroscopy[14]. This study indicated that level of expertise correlated with patterns such as increased shoulder abduction and forearm pronation and shows promise as a metric of arthroscopic skill acquisition. Studies are ongoing to examine whether improvement in arthroscopic skill can be quantified on an objective basis.

Ko et al. (2015) used a validated Global Rating Scale to demonstrate that PGY-3 residents participating in weekly microvascular laboratory exercises improved both time to completion and quality of the procedure during their upper extremity rotation[15,17].

The senior author (JMB, Brady et al. 2021) developed the Orthopaedic Intern Skills Assessment (OISA) for evaluating the skills of junior residents[13]. In a limited cohort study of OHSU learners, participants were evaluated on their ability to complete 11 skills in a simulated environment that had applicability to on-call procedural skills. We concluded that OISA was responsive to the level of training, was easily reproducible, and could be modified to specific training scenarios. This assessment process has become an annual credentialing process at OHSU to ensure that the rising PGY-2 residents are safe in the hospital for indirect supervision during the night float rotation.

Discussion

Current curricula for simulation exercises are associated with significant costs to orthopaedic programs, both in total dollar amount and time. With the prevalence of dry-only Sawbones models and rudimentary task-specific alternatives designed primarily to target junior residents, the authors propose a curricular model for more globally applicable simulation within orthopaedic residency training to expand on recent ABOS requirements.

Educational learning outcomes are maximized through the integration of an extensive cadaveric-based curriculum in combination with the representation of most major industry partners' in-kind donation of instrumentation, equipment, and disposables. By inviting all major industry partners, residents can increase their exposure to varied product lines and techniques.

The cost barrier for integrating such a curriculum into an individual's program can be mitigated through the repeated use of disarticulated fresh-frozen specimens. The advantage of this is not only a richer educational experience, with learning outcomes applicable to both senior residents and faculty, but it also serves as a more holistic simulation experience that puts surrounding anatomical structures into the context of the course objective.

Cumulatively, this model approach to integrating simulation into residency education aims to supplement learning objectives, both for our individual residency program and the ABOS modules for simulation training, and prepare residents to deliver high-quality care to our patient community.

Limitations

Exposure

This article is a description of a single institution's experience, and our resources and educational environment may not match that of other orthopaedic residency programs.

Duty Hours

Each program striving to implement a simulation curriculum must balance duty hours and the ability to capture as many resident learners as possible. Although duty hour restrictions are a 20-year-old requirement implemented in 2003, this constraining feature is still relevant to educational curriculum and course series design. With increasing subspecialization and rapidly evolving technology, the conversation around whether the clinical hours are sufficient remains relevant. Protected time was approved by our faculty and education committee on Friday mornings because they are not typically days recognized by the hospital to have a late start for clinical activities. Residents start the simulation session at 6:30 AM and are permitted to miss the first hour of clinical work to complete their session by 8:30 AM.

Education vs. Assessment

Assessment has become an important part of resident advancement through their training programs, as well as invaluable proof that simulation activities are effective at improving clinical skills and patient safety. However, attempts at real-time assessment in a simulation environment can result in threats to the educational experience itself because of time constraints. The authors have settled on level of comfort to minimize interruptions of the simulation laboratory test results for the whole resident group. In 3 instances, the authors have made strides on credentialing and objective evaluation in real time: (1) intern testing[13], (2) motion patterns as a marker of arthroscopic skill[14], and (3) microvascular surgery training[15]. Our institution endeavors to recruit an in-house expert in competency-based assessment as it thinks critically about the staffing of the VirtuOHSU laboratory, to improve the assessment of resident skill across specialties without disrupting the educational experience.

Conclusion

To address the growth of simulation's role in clinical education, the OHSU Orthopaedic education program has developed a high-fidelity training program that (1) is applicable to both junior and senior residents, (2) has minimized the cost per resident with the reuse of cadaveric specimens, and (3) has nurtured partnerships with industry stakeholders to reduce bias in training by collaborating with most major industry representatives. We propose that the discussion outlined in this article acts as a reference for other programs and institutions to develop their own residency educational curriculum models, as well as develop ways to assess their learners' progress in real time.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSOA/A605). This content was not copyedited or verified by *JBJS*. ■

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