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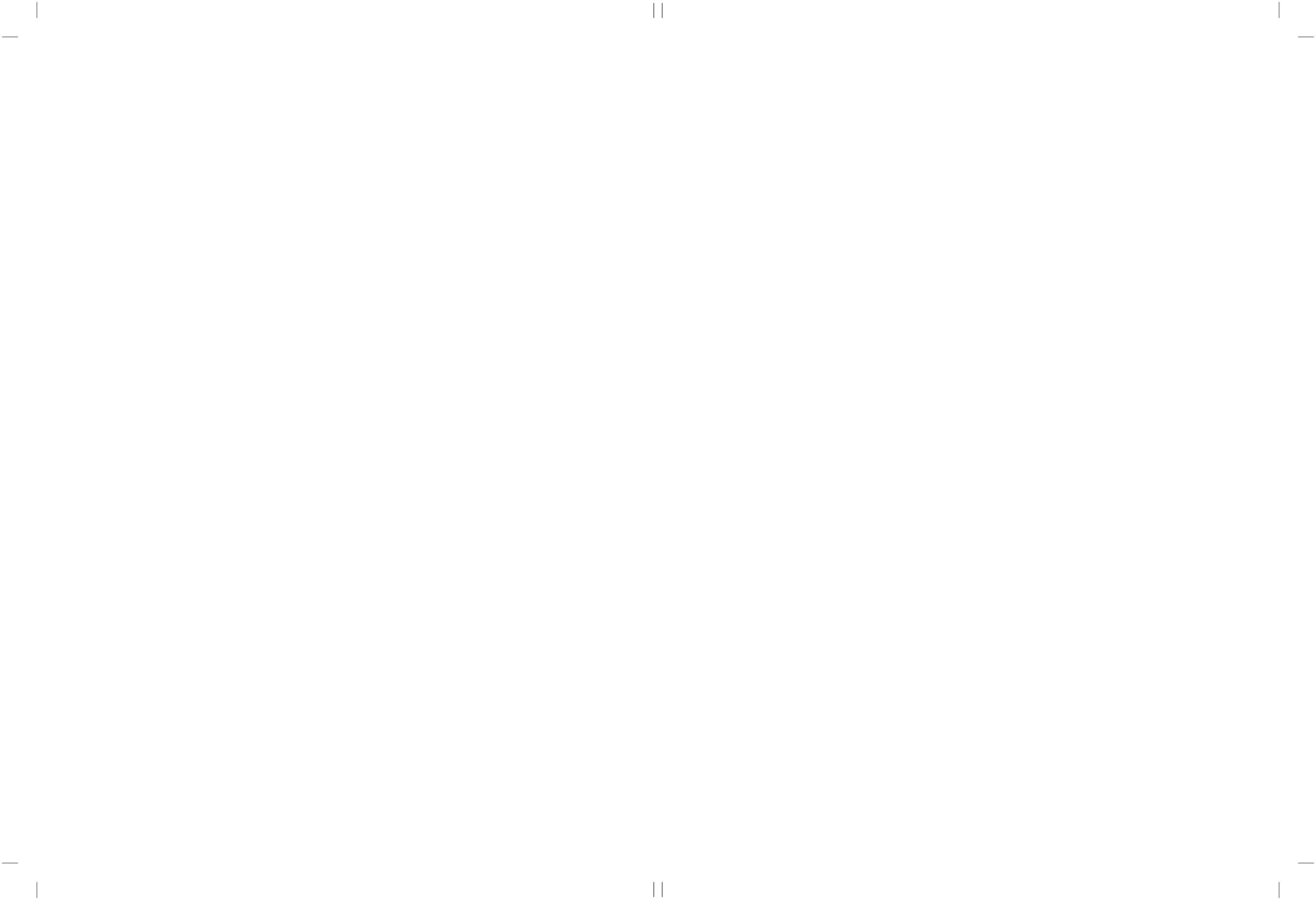
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Learning in the AO: Looking Back and Moving Forward

Guest Editors:

Greg Berry, MD, Wael S. Taha, MD, and Chitra Subramaniam, PhD

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AO North America

The views and opinions expressed in this issue are those of the authors and do not necessarily reflect the views of the editors of
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Contents

SDC Supplemental digital content is available for the article.

Articles

- Si Introduction**
Greg Berry, Wael S. Taha, and Chitra Subramaniam
- S1 The Journey to Competency-Based Education**
Urs Rüetschi, Michael R. Baumgaertner, Amy S. Kapatkin, Kodi E. Kojima, and Teija Lund
- SDC S5 Designing and Implementing a Harmonized Evaluation and Assessment System for Educational Events Worldwide**
Monica Ghidinelli, Michael Cunningham, Miriam Uhlmann, Alain Rickli, and Urs Rüetschi
- S11 Chairperson Education Program and Its Application**
Wael S. Taha, Kodi E. Kojima, Mark Reilly, and Vajara Phiphobmongkol
- SDC S17 Faculty Coaching in Surgical Education Within the AO**
Carla S. Smith, Piet G. de Boer, Narayan Ramachandran, and Gregory Berry
- S22 The AO Trauma Competency-Based Training and Assessment Program: An Approach to Address Performance and Assessment Gaps in Surgical Training**
Roger Wilber, Chitra Subramaniam, Markku Nousiainen, and Kathrin Lüssi
- S28 Multicenter Video Recordings of Minimal Invasive Cephalomedullary Nailing of Pertrochanteric Femur Fractures for Metrics Validation Studies: Lessons Learned**
Kodi E. Kojima, Wael S. Taha, Matt L. Graves, Anthony G. Gallagher, Tracy Y. Zhu, Victor Díaz, Michael Cunningham, Monica Ghidinelli, and Alexander Joeris
- SDC S34 Effect of Cognitive Task Simulation in Transfer of Performance Skills in an AO Practical Skills Laboratory**
Chitra Subramaniam, Brett D. Crist, Hobie Summers, Jaimo Ahn, Greg Berry, Chad Coles, and James Morgante
- S42 A Biologically Friendly Wire Tensioning Technique and How a Worldwide Surgeon Education Network Can Affect Patient Care**
Kyle M. Schweser, Michael S. Sirkin, Mark C. Reilly, Karl Stoffel, Christoph Sommer, Dankward Hoentzsch, and Brett D. Crist

(continued next page)

Contents (continued)



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Introduction

Greg Berry, MD,^a Wael S. Taha, MD,^b and Chitra Subramaniam, PhD^c

(*J Orthop Trauma* 2021;Si)

Education has been at the heart of the *Arbeitsgemeinschaft für Osteosynthesefragen* (AO) mission since its founding in 1958. The founders of this organization had the foresight to recognize the importance of teaching the revolutionary fracture management principles and techniques they established through their research, implant development, and documentation of outcomes. The readers of this supplement almost to a person, should be exposed to the organization either directly, through participation in an AO course as a resident, fellow, or practicing surgeon, or indirectly through being taught by someone who attended such courses. Today, the AO is truly an international organization with 20,000 surgeon members teaching at 730 educational events and reaching 58,000 learners across the globe annually. The scope, commitment to quality, teaching, and learning all aim at ensuring that treatment of an orthopaedic injury such as an ankle fracture is the same regardless of where it is treated in the world. Given the importance and reach of the AO as a leader in surgical education, the editors of this supplement readily agreed to assemble the articles describing the past, present, and, most importantly, the future of education within the AO.

From the outset of the first AO course in 1960, the teaching methods necessary to transmit the knowledge, skills, and attitudes of successful orthopaedic trauma care were lectures, practical exercises, and group discussions (initially in the form of informal “fireside chats”). This winning formula ensured the spread of AO courses across the globe over the course of a generation. As outlined in Ruetschi et al’s article, in early 2000 curricular design based on competency-based strategies such as gap analysis and the backward planning model became an integral part of all educational offerings of the AO, undergirded by the 7 principles of adult education. Not only was the quality of the curriculum enhanced, the faculty and course chairs were also given focused training in the Faculty Education and Chairs Education Programs as described by Taha et al in their article. This ensured that those teaching at AO courses were not only content experts but were conversant and skilled in the princi-

ples and practices of learner-centered adult education. Coaching was rolled into the faculty development strategy as outlined by Smith et al whereas leadership development for the organization was ensured with the introduction of the Leadership Educators Program as described by Ruetschi et al. Together, these organizational initiatives have combined to produce high-quality design and delivery of orthopaedic surgical education.

Accompanying the increased sophistication of the educationalists and surgeon educators came a strong interest in education research. Two studies are included herein. Subramaniam et al describe a study assessing the effectiveness of a cognitive task simulation as a practice tool in surgical skills training using a randomized study design. Kojima et al outline their extensive rigorous study on the validation of performance metrics in the nailing of pertrochanteric fractures in a multicenter international study. Educational research will be an integral component of the Competency-Based Training and Assessment Program described by Wilber et al with a 5-year comprehensive program already established and ready to begin in 2021.

None of what is described in the supplement would be possible without the valuable partnerships with educationalists and researchers who have contributed to the AO in establishing evidence-based practices that ensure quality of the education delivered. Our heartfelt thanks to all of them for their support and interest in the AO.

As we continue to work toward achieving our mission to improve patient outcomes in musculoskeletal care, we hope to also contribute to evidence in medical education and surgical training. When published every other year, this supplement will serve to disseminate AO best practices, lessons learned, research findings, and AO case studies that emphasize a focus on effective ways to design, develop, deliver and assess surgical education and training. In addition, we hope to share our successes and progress on our competency-based training and assessment program through which we hope to create a learning ecosystem that supports development and use of validated performance assessment tools, comparative studies to evaluate different learning interventions and teaching methods.

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The Journey to Competency-Based Education

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Kodi E. Kojima, MD, PhD,^d and Teija Lund, MD^e

Summary: In the middle of the 20th century, orthopaedic trauma patients were inadequately treated because of limited knowledge of bone-healing biology and fracture fixation procedures. The OTA/AO was established as an association in 1958 by a group of orthopaedic surgeons with the mission to improve patient outcomes through research, development, documentation, and education. Education has been recognized by the founders as a means to disseminate fracture fixation principles and techniques. Starting from just 69 learners at the first AO course in 1960, AO reached globally more than 50,000 learners in 2019. This achievement was possible because the AO improved its educational offerings and integrated evidence-based practices in medical education. Since its beginning, AO used simulations in combination with other educational methods, such as lectures and small group discussions. Around the year 2000, competency-based curriculum development was introduced and became a core tenet of AO education. AO's educational design today uses evidence-based concepts in needs analysis, planning and design of learning, faculty development, and assessment. In addition, the AO contributes to the medical education research with emphasis on measuring the impact of education, simulation, and development of performance assessment metrics.

Key Words: CPD, CME, evidence-based education, competency-based education

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During the past 30 years of the 20th century, the widespread adoption of the AO method of surgical management of acute orthopaedic trauma dramatically improved patient outcome with a huge economic impact.^{1,2}

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How did an academically unaffiliated group of 13 Swiss surgeons with interest in acute fracture surgical fixation in the late 1950s evolve into a global network that currently includes 14,000 faculty surgeons who provide direct education to more than 55,000 learners every year? Collaborating as a club-like organization, the Arbeitsgemeinschaft für Osteosynthesefragen (AO) was organized in 1958. Roughly translated as a “*Fellowship of purpose based on friendship*” this group sought to advance surgical care of fractures by building 4 critical workstreams as follows: developing a coordinated system of instruments and implants, researching the process of fracture healing, collecting and documenting clinical outcome data, and directly teaching the principles and techniques to surgeons wishing to use the method.³

EVOLUTION OF EDUCATION IN THE AO

The first face-to-face course occurred in 1960, and continued annually, in Davos, Switzerland. Lectures highlighting surgical principles combined with hands-on exercises on human specimens provided the new knowledge and technical skills for attendees to improve. Evening “fireside chats” with case presentations and analysis honed decision-making skills. This blend of educational formats was enthusiastically endorsed by an expanding group of surgeons, requiring courses to be offered elsewhere in Switzerland, then Germany, and across Europe by 1970.⁴

In 1972, AO International was formed to administer the expanding educational mission and creating a standardized AO Trauma “Basic Principles” and “Advances” course offering lectures, surgical simulation, and small group discussion. AO courses were delivered in the America and across Asia, with content and quality like the original Swiss programs. Forward thinking surgeons in other specialties appreciated that the techniques and instrumentation developed for use in human long-bone fractures could be of great value for them. Responding to this interest, between 1969 and 1981, AO sections in veterinary, craniomaxillofacial, and finally spine surgery formed to provide modified instrumentation and specialty-specific educational programs.⁵

Twenty-five years after its creation, the AO had grown exponentially in size and clinical scope, and its original administration was dissolved in 1984 to create the AO Foundation. Governance was by an executive committee that reported to a global elected board of trustees. Research along with clinical documentation and an education service unit provided support for their respective programs. Face-to-face teaching expanded to include a range of target audiences from operating room personnel and junior residents to established subspecialist experts. These programs triggered a continued need

for a library of linked enduring material (published monographs, guidelines and manuals, videos, journals, and web sites). In 1989, the AO Alumni Association (AOAA) was established to promote continued engagement of surgeons who had been AO fellows or served as faculty. With newsletters, social events at courses, and a triennial meeting, this represented the first efforts toward faculty professional development.

From CME to CPD—the Shift to Continuous Connected Learning Opportunities that Facilitate Behavior Change

The mindset of the medical education community changed during the years leading up to 2000. Driven largely by the American Medical Association (AMA), focus shifted to the needs and practice gaps of the physicians⁶ and awareness of the impact of external forces and the health systems linked to medical education.

The AO Education Commission, a governance body that advised AO International (the operating educational arm of AO) and oversaw the development in surgical education started consultations with and in the United States and United Kingdom academic experts in medical education. In the early 1990s, AO began to offer educational seminars for faculty who were especially interested in the principles and concepts of medical education and were motivated to strengthen their competencies as teachers.

This new approach of bringing educationalists from academia together with surgeon content experts involved in educational design intensified with the shift from Continuing Medical Education to Continuing Professional Development (CPD) as described in the 2003 AMA book publication “The Continuing Professional Development of Physicians.”⁷

In 2004, AO invited a group of the education consultants to partner with a group of AO surgeons involved and highly interested in education to write a dedicated textbook for the global AO faculty outlining the “AO Principles of Teaching and Learning.”⁸ The goal was to achieve a global quality standard in the delivery of education. The book, published in 2005, focusses on different competencies covering lecturing, small group discussion facilitation, guiding and managing simulations, and providing participant feedback. In parallel, AO established its first structured faculty educational program for teachers under the brand name “Tips for Trainers.” Over the ensuing decade, the AO Principles of Teaching and Learning book was given away to more than 3000 faculty globally as part of their development pathway as AO teachers.

The book represented a milestone for the shift to competency-based curricula development and the further design of the AO Faculty Development Program to support CPD. It also triggered the AO to actively engage in medical education research projects and to become active contributor to the leading associations and societies in CPD, surgical simulation, and faculty development.

Quality Medical Education

In the past decades, demands for high-quality education with measurable outcomes have increased because of rapid

scientific advancements in medicine and changing expectations from patients, health care providers, and societies alike. Since 2008, a collaborative effort by surgeon faculty together with professional educationalists has ensured that AO Foundation education remains relevant and effective; from 2010 onward, these efforts have been initiated and coordinated by the AO Education Institute replacing the former AO International activities as an organizational center of excellence.

For best-quality education a paradigm shift was introduced to the whole educational process from planning through execution to assessment and evaluation. Today, all AO Foundation educational events are built around 7 principles of adult education deemed important for continuous professional development of musculoskeletal surgeons (Table 1). Educational events are designed based on a standardized needs assessment protocol identifying gaps in the knowledge and/or performance of the participants.⁹ The backward planning process is then applied to the educational program development to address the practice and performance gaps of the learners to achieve the best possible outcome of patients.¹⁰ Performance gaps are analyzed and translated into the competencies needed by the potential learners. The competencies are deconstructed into knowledge, skills, and attitude components and trigger the development of learning objectives and the instructional design of activities. The execution of AO Foundation educational events has shifted from passive teacher-centered setups toward a learner-centered focus with more interactive formats ensuring ample possibilities for feedback and reflection. In this supplement, Wilber et al¹¹ provide a comprehensive description of the AO Trauma Competency-Based Training and Assessment Program as an example of the innovative educational activities within AO Foundation.

The AO Foundation conceptual framework for quality education consists of 4 overlapping areas around physician competencies: curriculum planning and design, faculty development, assessment and evaluation, and development of resources. AO Trauma launched the first global competency-based curricular events (Basic Principles and Advanced Principles Courses) using fixed core content allowing for adaptation to local needs. The first fully backward planned standardized curriculum in orthogeriatrics was introduced by AO Trauma in 2010¹² with a point-of-care learning app as additional resource.¹³ A long-term goal for AO Foundation has been the implementation of a standardized framework for evaluation and assessment of all educational activities. The relevance of our offerings as well as the faculty performance has been measured extensively.¹⁴ However, as medical education should lead to measurable changes in practice, mere evaluation of participation or participant satisfaction is not enough; education providers are expected to provide data on the value of their offerings on the participants’ practices and patient health outcomes. Measuring the effect of an individual educational event on patient or community health is demanding at best and would require the use of local, national, or international registry data. To gather information on the effect of our educational offerings on the participants’ practice the Commitment-to-Change

TABLE 1. Seven Principles of Quality Education—Planning, Execution, and Evaluation

1. Based on Needs
2. Motivates to learn
3. Relevant
4. Interactive
5. Provides feedback
6. Promotes reflection
7. Leads to verifiable outcomes

tool has been used.¹⁵ In this article, the participants are asked whether they intend to change anything in their practice as a result of the educational event; a 3-month follow-up assesses the status of the intended changes. Several barriers have been identified that prevent surgeons from implementing what they have learned, and the Commitment-to-Change has given us information on those barriers for further use when planning future education.¹⁶ A more complete illustration of the design and implementation of the AO Foundation evaluation and assessment framework will be provided by Ghidinelli et al in this supplement.

Faculty Development as Driver of Change

The AO faculty role has always been a volunteer position. Teaching is the major reason why surgeons engage in AO. In a recent worldwide AO faculty survey, 59% of the responders indicated interest in teaching was the most important reason they joined. Interest in faculty training to teach was important to 34% of the survey participants. The paradigm shift from being a teacher to learner centric organization meant that AO needed an evidenced-based program to train faculty in how to deliver content by a variety of educational methods with the goal of achieving measurable outcomes in surgical management of trauma and musculoskeletal disorders. The 3-tiered progression, faculty education program (FEP), chairperson education program (CEP), and leader education program (LEP) were developed to accomplish this mission.

The AO FEP concentrates on competencies that enable faculty to deliver high impact lectures, lead interactive small group discussions, and to effectively teach surgical skills in simulations. The AO CEP teaches curriculum design and management. The program reinforces using best practices in education to select content, choose learning methods, manage faculty conduct evaluation, and provide feedback. The AO LEP teaches relevant leadership skills to faculty who are likely to be elected to important governance positions in the organization. Participants in this program learn about self-assessment of their leadership behavior, they apply models of behavior to build and lead teams, facilitate change, and to be an advocate for continued improvement in education and leadership. All the faculty development courses are delivered by 5 weeks of online self-directed learning with a 1.5 to 2-day face-to-face interactive program. The program is taught by educational specialists and AO faculty surgeons trained in the regional education team training (RETT) program.

The coaching training program was started by AO Trauma in 2012. The goal was to train regional and experienced faculty to assume a dual role of being a teaching faculty and a faculty coach in real time. The program includes a precourse online self-assessment, readings, and discussions. The structural training sessions occur before an AO teaching event, and the coaching skills are practiced on site during the course. Coaching is different than teaching or mentoring; peer coaching at AO courses helps each faculty get immediate feedback on what they did well and what they may choose to do differently in their next teaching assignment. Peer coaching is effective in improving teaching skills, strategies, and improves teacher satisfaction.¹⁷

By the end of 2019, AO has trained 3675 individuals in the FEP, 1350 in the CEP, and 270 in LEP worldwide. The program is required for any faculty member seeking a successful career path at AO. It ensures delivery of consistent quality educational events. Besides a continual need to train new faculty, additional training will be required to develop synchronous and asynchronous online teaching competencies as well as those needed to educate in virtual environments and to guide learners through simulations remotely. Online learning requires similar education approaches but different methods of communication and platforms.¹⁸ Technologies are expanding and changing rapidly. Interactive webinars are already part of clinical divisions teaching portfolio. Blended formats of education became a necessity due to COVID-19 travel and social restrictions and have been implemented successfully.

Surgical Simulation—AO's Approach

AO pioneered a blend of surgical simulation, lectures, and case discussions for the first time in 1960. At that time, AO used human bones to simulate fracture fixation with screws, plates, and nails.⁴ Over time, the use of real bones became problematic and “low fidelity” plastic bones were produced and used to simulate fracture fixation. This allowed for full global scaling of courses.¹⁹

Currently, the highest fidelity simulation available are human anatomical specimens or living animal models. AO uses anatomical (sometimes prefractured) specimens for the education of experienced surgeons, where soft-tissue awareness and handling drives a clinical outcome, and it is educationally worthwhile to use these complex and expensive simulation methods.²⁰

AO uses simulations also to teach biomechanical and surgical concepts normally difficult to explain through conventional lectures. Examples include how much torque the surgeon can tighten a screw before it fails, inadvertent soft-tissue penetration differences when using sharp and blunt drills, reduction techniques, and biomechanical variations of plate and nail fixation. To better teach these concepts, AO developed the “Skills Lab” that consists of 10 unique interactive stations to simulate different surgical scenarios. These stations allow handling of instruments and implants to provide surgeons feedback to improve their knowledge and skill. The “Skills Lab” strives for surgical competence, a higher level of educational outcome than typically can be achieved with didactics alone.²¹

The goal of AO is to provide evidence-based education and simulation environments that lead to measurable improved surgeon performance, demonstrated by better outcomes for their patients. This requires not just surgical competence but proficiency in their practices. Therefore, the AO and its education institute embraced the concept of proficiency-based progression.^{19,22} To demonstrate that proficiency-based progression will be effective, AO is doing its own series of studies to characterize surgical procedures and define observable metrics. Currently, procedural simulations are available on the app-based platform “Touch Surgery.”²³ Full virtual reality simulations with limited haptic feedback and hybrid augmented/virtual reality simulations are being developed to teach procedures to the surgeons, allow for deliberate practice, and measure proficiency. These exciting new technologies, when guided by proven educational principles and evidence-based methodologies, may well transform the surgical education initiated by AO 60 years ago.

After 60 successful years, AO’s education journey continues. As learners needs evolve, learning technologies get smarter, and the environments require us to think of how to teach health care providers to learn faster and better. AO will continue to evaluate its educational approaches to provide the most effective opportunities for its learners.

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Designing and Implementing a Harmonized Evaluation and Assessment System for Educational Events Worldwide

Monica Ghidinelli, PhD, Michael Cunningham, PhD, Miriam Uhlmann, PhD, and Alain Rickli, MA, AO Education Platform, and Urs Rüetschi

Summary: To determine the effectiveness of educational events and improve the quality of continuing medical education (CME), course providers and medical faculty instructors must have access to structured and consistent collection and reporting of evaluation and assessment data. In 2012, the AO Foundation (Switzerland) used a wide range of evaluation questions and processes that were inconsistent across various clinical areas. With AO's 700 educational events delivered annually in multiple geographical regions, it was therefore challenging to determine overall education effectiveness and to identify and compare trends and topics based on individual course data. This led to a decision by AO to update, align, and harmonize the various questions and processes to create a new streamlined and consistent evaluation and assessment system. A series of expert advisory group sessions and consensus meetings were convened over a 3-year period, and feedback from 8 stakeholder groups was incorporated. AO developed processes and online tools that were piloted in several educational events and then implemented worldwide. Faculty and course organizers were trained to gather and apply the information. In 2019, this new course evaluation and assessment system was applied to more than 70% of AO's yearly educational events. The generated reports have helped faculty to adjust educational events to meet the needs of participants. The new system has also helped committees and regions to plan future educational events and to improve the quality of CME on an ongoing basis.

Key Words: evaluation, assessment, CPD, CME, evaluation design
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INTRODUCTION

Continuing medical education (CME) and continuing professional development (CPD) are designed to help participants to close knowledge gaps or improve clinical

performance for better patient outcomes.¹ To determine if an educational activity achieves these goals, information from the collection of evaluation and assessment data is essential. This information also guides course providers when making decisions and taking actions regarding future educational activities.²

Evaluation is a process of observing and measuring for the purpose of judging and of determining “value,” by comparison to a benchmark or standard. Evaluation refers to a program, course, or institution, whereas assessment refers to an individual.³

The AO Foundation, based in Switzerland, is a medically guided, nonprofit organization that delivers more than 700 face-to-face and online educational events around the world annually, supported by nearly 14,000 volunteer medical faculty and attended by more than 55,000 participants in many clinical areas. The AO's educational activities are designed using a competency-based approach through backward planning⁴ and follow Kern's 6-step model for curriculum development. Kern recommends assessment for planning and evaluation as a driving force for continuous improvement.³

In 2003, the AO implemented a structured evaluation system focused on the relevance of educational activities and the performance of faculty instructors. Evaluation data were summarized by the course organizer and provided to the appropriate course chairperson in preparation for the following year's events. Evaluations were limited to a small proportion of the courses (mostly international), and the data from these evaluations were not fully used. In addition, every AO clinical division (CD) and region was using different evaluation methods and tools. The uncoordinated application of evaluations was possibly the result of the insufficient tailoring of questions to the specific needs of the user.⁵ Faced with this inconsistent data collection, planning committees were unable to properly apply the program evaluation findings to make decisions regarding course planning and improving the curricula. At the same time, CME providers were increasingly pressured by leaders in medical education, governments, health authorities, and accrediting bodies to provide evidence of educational outcomes.^{3,6–9} Providers were asked to perform and document needs analyses (gap analyses), to define learning objectives, demonstrate independence of education, show ongoing improvement, and collect data on the changes (outcomes) that result from educational interventions. It was therefore essential that providers have access to structured and consistent collection and reporting of

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evaluation and assessment data to enable accurate analysis and to optimize planning decisions.

For these reasons, the AO decided in 2012 to update and align all the questions and processes for gathering and reporting data before and after educational events. The AO instituted the new system in 2016. This article describes the process that was used to design, develop, and implement a more effective evaluation and assessment system for educational events worldwide.

METHODS

Based on the intended use of the course data, an Evaluation for Quality Improvement, characterized by intensive stakeholder engagement,¹⁰ was the best suited approach. A series of expert advisory group sessions and consensus meetings were convened over a 3-year period. Methods included literature review,^{4,11–13} evidence gathering, consensus-building debates, and meetings with stakeholders to ensure that contributions reflected the various perspectives and that all aspects were relevant to end users. The process consisted of the following 5 phases:

Phase 1: Planning

1. A steering team was formed from a group of experts in medical education and evaluation and a plan of action (goals, contributions, timeline) was established.
2. Through an interview process, stakeholders were identified and asked to define the factors that contribute to the success of educational activities and the level of outcomes⁴ they wanted to assess. A list was collated, and the highest scored factors were combined with existing educational program evaluation frameworks^{4,11–13} to create a proposed set of data collection areas.
3. The proposed stakeholder groups and data collection areas were confirmed at the AO Education Platform annual meeting where all AO clinical divisions (CD) are represented.
4. The CD representatives shared the proposal with the respective CD, and feedback was integrated in the proposal.

Phase 2: Question Development

1. The steering team compiled a list of questions for each of the data collection areas, combining previously used questions, input from stakeholders, and evidence from the literature.^{11–14} The guiding principles for each question were that they must be clearly understood by an international audience, provide a sociodemographic profile of the responders, provide quantifiable and actionable information, and be answered in a short amount of time.
2. The list was reviewed by members of the CD and feedback was integrated (see questions and descriptions in **Appendices 1–3, Supplemental Digital Content 1**, <http://links.lww.com/JOT/B301>, <http://links.lww.com/JOT/B302>, <http://links.lww.com/JOT/B303>).

Phase 3: Report Design and Action Collection

1. A proposal for report content, format, and timing was prepared by the steering team.
2. The proposal was reviewed and consolidated during the AO Education Platform annual meeting according to priority and resource availability.
3. Reports were piloted at the AO Davos Courses in 2013 and feedback from faculty and chairpersons regarding quality, thoroughness, and potential actions were collected and integrated (see sample reports and descriptions in **Appendices 1–3, Supplemental Digital Content 2**, <http://links.lww.com/JOT/B301>, <http://links.lww.com/JOT/B302>, <http://links.lww.com/JOT/B303>).

Phase 4: Development of Online Tools and Workflow

1. A proposal for tools and workflow was created by the steering team and eLearning/IT experts.
2. The proposal was discussed with the CD, and agreement was reached about content, timing, and roles.
3. IT interfaces and automation for the process were developed.

Phase 5: Implementation

1. A rollout plan was developed by the steering team.
2. In 2015, the pilot was tested at AO Dubai's regional courses and AO Davos' international courses, followed by final adjustments.
3. A communication plan was developed and outreach to the AO community began.
4. Training was organized for data collection staff and report recipients.
5. Support was established and an online guide was created.
6. Translations of questions and reports were prioritized based on the need.
7. A cost–benefit analysis was made of all the required changes to the existing evaluation system.

Data Collection and Management

Data collection, handling, and management were conducted according to General Data Protection Regulation (GDPR) standards. Participant data were anonymized and available only in aggregate form. The applications used were SurveyMonkey (to collect data via questionnaires) and Tableau (to analyze and visualize data). A custom-built and automated system controlled the time-sensitive workflows for the distribution of questionnaires and reminders, and the management of collected data for reporting.

RESULTS

The overarching goals for the creation of an evaluation and assessment system for the AO were to (1) measure the impact of educational activities on the competence of the surgeon learners and the faculty, (2) measure the effectiveness of planning decisions and achievement of learning outcomes, and (3) inform future iterations of educational activity planning and meet new or updated needs.

The first step was to identify and engage all the groups that might be interested in the results. Eight

stakeholder groups were identified: participants, faculty, chairperson(s) (course chairperson, coaches, educators, supervisors), curriculum developers (faculty, taskforces, educators, staff), management, boards/councils (involved in strategic decisions for educational activities), funding bodies and partners, and CME accrediting authorities. The stakeholders then defined the factors for successful educational activities: (1) participants demonstrate improved knowledge, skills, or attitudes and a change in practice or behavior, (2) faculties are well prepared and effective, and (3) content is relevant and commercially unbiased. These success factors represented the basic principles that were used in combination with the literature to specify the 7 data collection areas and the 19 questions (7 pre-event and 12 post-event questions) that constitute the standard data set. These are used in all regions and surgical specialties with available adaptation to clinical areas and serve the minimal reporting requirements. The standard questionnaire can be expanded with 5 optional set of questions.

Data Collection Areas

Area 1: Demographics

Demographics data provide information about the level of experience and expertise of participants and their backgrounds (specialties or subspecialties and type of practice) (see **Appendix 1, Supplemental Digital Content 3**, <http://links.lww.com/JOT/B301>). This is relevant for chairpersons and faculty before the educational event and for all the stakeholders to effectively compare course results with each other.

Area 2: Motivation

Motivation is the fundamental precondition for successful learning and is based on needs.¹⁵ Motivational data are collected before and after the event to measure possible changes in needs of certain competencies.¹⁴ To estimate motivation, the gap (difference) between self-reported desired level of expertise and current level of expertise is calculated for each defined event competency (or learning objective).^{14,15} An optional addition is an objective measure using 2 multiple-choice questions (MCQs) for each competency. This enables detection of areas where actual needs differ from the perceived ones¹⁴ (see **Appendix 1, Supplemental Digital Content 4**, <http://links.lww.com/JOT/B301>). Knowledge of motivation is essential for faculty before the educational event, chairpersons and management for future event planning, curriculum developers when making adjustments, and CME accreditation authorities.

Area 3: Faculty Performance

Faculty performance must be good for the successful rating of an educational activity. The standard data set can be extended to faculty performance for each lecture, discussion, and practical exercises (collected during the event with paper and pencil) (see **Appendix 2, Supplemental Digital Content 5**, <http://links.lww.com/JOT/B302>). This information can be applied by the faculty to assess their own performance and to help chairpersons with future faculty selection for similar educational activities.

Area 4: Event Key Performance Indicators

Event key performance indicators (KPIs) like venue/location, communication, and perceived commercial bias of the event are important factors to consider after the event by management (especially course organizers), chairpersons, and CME accreditation authorities. These factors may influence participants' recommendation of the course (see **Appendix 2, Supplemental Digital Content 6**, <http://links.lww.com/JOT/B302>).

Area 5: Outcome Participation

Outcome participation represents the number of participants progressing through each stage of the participation funnel, for example, how many registered, showed up at the event, attended all the sessions, and completed evaluations.^{4,16} This information is essential after the event for management (especially course organizers) and curriculum developers. These data are collected without asking direct questions of participants (see **Appendix 2, Supplemental Digital Content 7**, <http://links.lww.com/JOT/B302>).

Area 6: Outcome satisfaction

Satisfaction measures the degree to which the expectations of the learners about the educational activity were met.⁴ These measures are used by chairpersons, curriculum developers, management (especially course organizers), and CME accreditation authorities. An option is available to expand the data set and rate the relevance of the content for each lecture, discussion, and practical exercises (see **Appendix 2, Supplemental Digital Content 8**, <http://links.lww.com/JOT/B302>).

Area 7: Outcome Learning, Competence, and Performance

Achieving an increase in competence and performance is the gold standard in today's medical education.⁴ This information is relevant for all the stakeholders, especially chairpersons, management, curriculum developers, and CME accreditation authorities.

To estimate learning, participants are asked to self-report knowledge gain. An optional objective measure is available of a set of 2 MCQs for each competency and are comparable to the pre-event questions (see **Appendix 2, Supplemental Digital Content 9**, <http://links.lww.com/JOT/B302>).

To estimate an increase in competence, participants are asked to describe 1 to 3 specific changes they intend to make in their clinical practice and relate them to competencies. This provides an opportunity for self-reflection, which in itself promotes learning.¹⁷ In addition, self-reported current level of ability for each competency was compared with the one provided before the activity.¹⁸ As an expanded option, to estimate change in performance, a Commitment to Change follow-up questionnaire 3 months after the event is available.¹⁹ Participants are also asked to self-report the implementation status of the intended changes and barriers (see **Appendixes 2 and 3**,

Supplemental Digital Content 10, <http://links.lww.com/JOT/B302>, <http://links.lww.com/JOT/B303> respectively).

The layers of data collection allow for adaptation to different needs and offer different options for assessment, which increase reliability and outcome levels (Table 1).

The 19 standard and 5 optional questions were used to generate 2 standard and 4 optional reports aimed at different recipients (Table 2) (see **Appendices 1–3, Supplemental Digital Content 11**, <http://links.lww.com/JOT/B301>, <http://links.lww.com/JOT/B302>, <http://links.lww.com/JOT/B303>). Additional reports based on needs can be generated on demand by aggregation of different data sets.

IT infrastructure and a highly automated workflow were developed and piloted in 2015 for the entire evaluation and assessment process to collect, combine, and analyze data for one event (Fig. 1) or several events over time. An option for the collection of data with paper was also provided to respond to regional needs and to increase the response rate. The standard set of question and reports were initially provided only in English and then translated into Spanish, Portuguese, Chinese, Russian, French, German, Italian, Japanese, and Korean.

In 2016, chairpersons, faculty, and staff in each region were informed about the new system, and course organizers and report recipients were trained on how to apply the information. In particular, in the chairperson education program (CEP), chairpersons were trained on the use of pre-event participant data reports to adjust course content to participant levels and to share the data with faculty during the precourse meeting (see **Appendix 4, Supplemental Digital Content 12**, <http://links.lww.com/JOT/B304>). They also learned how to analyze all the other report types.

In mid 2017, all CD and regions were asked to fully implement the pre- and postevent reports as standard for all face-to-face events and to adapt them for online activities (webinars, webcasts, etc.). The other report types remained optional depending on local needs and resources.

In October 2018, the new evaluation system was mandated for all courses and seminars, and in 2019, it was implemented in more than 70% of AO Trauma educational events globally.

DISCUSSION

The AO created a highly automated workflow for structured and consistent collection and reporting of evaluation and assessment data. The mix of multiple-choice and open-field questions provides quantitative and qualitative data that can be used for course improvement and research studies.

This agile process, together with the engagement of stakeholders during development, helped to ensure the commitment in using the reports and in taking action on findings.²⁰ The event reports are used by chairpersons and faculty to adjust individual events and meeting the needs of participants. All groups can use these reports to monitor the overall success of the educational activity for improved competence and performance. In addition, course organizers can easily meet the standard for reporting to the CME accrediting authorities.

When monitoring and planning educational events, most stakeholders compare reports over time or with similar events. For example, curriculum developers regularly use aggregated data to monitor new curriculum performance and implementation.¹⁸ This is of particular interest to global providers because the AO faces the additional challenges of different health care systems and sociocultural environments.²¹ Furthermore, curriculum developers use the data to identify trends, new or changed participant needs, and to adapt or develop new curricula.¹⁹ An emerging trend of courses based on curriculum development is that they are rated higher in content usefulness and participant satisfaction than those that do not. Boards, councils, and management use the aggregated data for planning purposes focusing on the impact of education by course type, by region, or over time.

Recently, the increased demand for online education to address the restrictions in conducting face-to-face events because of the Covid-19 virus pandemic highlights the value of having baseline data. The use of these data enables any organization to effectively evaluate adapted course delivery through online or blended educational methods compared with their existing standards.

Challenges in the implementation of the new evaluation system were predominantly faced during the early stage. The main obstacle was language, with questions and reports first

TABLE 1. Assessment Options Available

	Pre-event	Post-event	Outcome Level
Standard	Self-reported level of ability of each competency (or objective)	Self-reported level of ability of each competency (or objective) + Commitment to change	Self-reported Learning and competence
Additional options			
1	Set of 2 MCQs for each competency (or objective)		
2		Set of 2 MCQs for each competency (or objective)	
3	Set of 2 MCQs for each competency (or objective)	Set of 2 MCQs for each competency (or objective)	Learning and competence
4		Three mo commitment to change follow-up	Performance

TABLE 2. Report Types

	Report type	Release Time	Recipients
Standard	Preevent participant data report	20, 10, 3 days before	Chairperson(s), curriculum developers, management
Standard	Postevent evaluation report	16, 30 days after	Chairperson(s), CME accrediting authorities, curriculum developers, management
Optional	Content and faculty report (confidential)	16 days after	Chairperson(s)
Optional	Individual faculty reports	16 days after	Individual faculty members
Optional	CME report	16 days after	CME accreditation body
Optional	Commitment to change outcome report	105 days after	Chairperson(s), curriculum developers

administered only in English. Translations increased usage of the evaluation system. Interpretation of the data was not always straightforward because benchmarks were not provided, and each group needed to set them by reviewing data over time and with comparisons of similar events. This was required because interpretation must always consider the language of the questions compared with the fluency of the

responders, the culture within the country or subspecialty, and the overall context of the educational event. An additional challenge that is still partially present is that content and faculty ratings by lecture are collected on paper during the event and are then manually reported on the database. Although this ensures a high response rate, it requires the event organizer’s added time and resources.

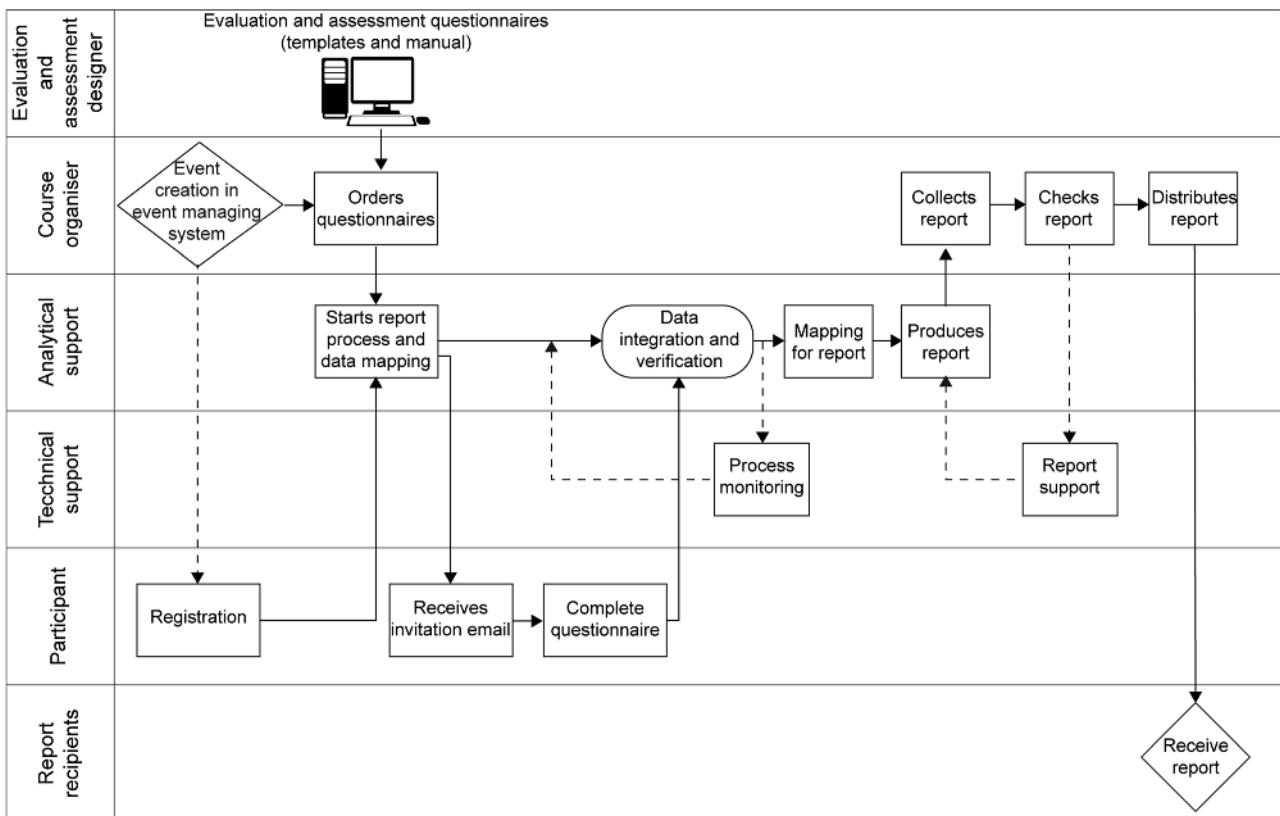


FIGURE 1. The course chairpersons request an online evaluation. The course organizers select the appropriate reports in the event managing system. Registered participants receive invitations and reminders with the SurveyMonkey link for the pre-event questionnaire by email on predefined dates. Data from registration and SurveyMonkey are stored in a database and processed. The course organizer receives and distributes the pre-event reports. During the event, faculty performance and content usefulness for each lecture, discussion, and practical exercise are collected on paper (reported manually in the database). After the event, the participants receive the pre-event questionnaire by email (SurveyMonkey link). The course organizers receive and distribute the pre-event reports. Technical and analytical support are constantly provided.

The limitations of this new evaluation system include a lack of completion by participants in some events, especially in regards to the 3-month follow-up reports, single source feedback, and possible inflexibility because of selected technical solutions and software in an area that is constantly changing, and the time and costs required for any changes. In addition, our data collection strategy is prone to voluntary response bias (eg, people with strong opinions are more likely to respond to a poll) or nonresponse bias.²²

Future enhancement of this evaluation and assessment system would be to automate the generation of yearly reports, to consider integrating alternative assessment techniques to MCQs and commitment to change (eg, case reviews, script concordance tests), and to integrate a more reliable measurement instrument for faculty performance.

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Chairperson Education Program and Its Application

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Summary: AO educational events have been recognized for the quality of education and faculty that run these events. Therefore, a formal faculty development program has been a priority for foundation. The Chairperson's Education Program was developed to meet an identified need to support the AO faculty in designing, organizing, and running AO educational events. The program curriculum was designed using a backward planning approach in which gaps in the chairperson's practices in running educational events were identified. Specific competencies were developed from which an educational plan was designed. Chairs are engaged in a comprehensive blended learning experience where they are equipped with the skills and tools needed to design, plan, and run educational events. Application of the concepts discussed in the Chairperson's Education Program to accomplish the goals of the AO Davos Trauma courses, a flagship event, has shown a steady increase in course ratings from 4.20 in 2015 to 4.90 in 2019.

Key Words: education, faculty development, faculty education, AO course, organizing AO education event, course chair

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INTRODUCTION

The AO was established in 1958 by a group of surgeons with a mission to improve patient care through research, development, documentation, and education. The first AO course took place in Davos in 1960. The program was composed of lectures that emphasized the AO principles of fracture fixation and practical sessions on cadaveric bones to illustrate the techniques and surgical skills needed to fix fractures. Since then, the course has been running on an annual basis. In 1965, the first course was conducted outside of Switzerland in Freiburg, Germany. By 1972, the course had spread globally, and the AO was converted into AO International.

Two types of courses were developed by 1972, the basic principles course and the advanced principles course. Both had an almost standard program, however, as the

courses became more popular and started to be taught in different regions. The programs also started changing based on the course chairperson's perception of what needed to be taught. Although the principles were included in all the courses, it was the topics of the anatomical regions that were variable. By the year 2000, a new level of courses addressing surgeons with experience started to become more popular. These "Master" level courses were designed by senior surgeons based on their experience and understanding of what needed to be taught. These courses became very successful and started attracting a new cohort of surgeons.

It was common to find differences between these courses, unless chaired by the same surgeon. Although this created diversity in the topics delivered, at the same time, it created some inconsistency in the subject matter and instruction delivered. In some instances, this was perceived as an advantage, especially when acknowledging regional variabilities. However, the question arose: how can we consistently assure that we are meeting the real needs of the learners?

Another issue that started to be recognized was the selection of teaching methods for the different courses. The main teaching methods were lectures, practical simulations, and small group discussions. These were used extensively with other methods such as panel discussions and debates. Many of the chairs had some experience in choosing the correct method; however, it was also noticed that some of the chairs and faculty were not always using the appropriate method to achieve a specific objective.

New Paradigm in AO Education

With the turn of the millennium, a new concept in AO education started developing, greatly influenced by reports from the American Medical Association emphasizing the importance of identifying gaps in physicians' practice as a way of optimizing medical education.^{1,2} As a result, the AO started working more closely with educationalists. This led to the development of the first faculty development activity in the AO which was titled the "Tips for Trainers course." This was a 2-day face-to-face program in which the faculty were taught and coached on the skills of lecturing, facilitating small discussions, and running practical simulation. Simultaneously, a book on teaching methods used in AO educational events was published and made available to the AO faculty community.³

By the year 2009, the AO Trauma Education Commission was formed and consisted of a group of surgeons representing the different geographical regions, as well as representatives from the AO Education Institute. One of the first priorities for the group was to develop a comprehensive faculty development program. This was recognized as an

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urgent and important need to address many of the issues regarding surgeon education with the aim of supporting the delivery of high-quality education based on evidence to the orthopedic community.

The Faculty Development Task Force, consisting of a group of surgeons and educationalists, was established and mandated to create such a comprehensive faculty development program. The group developed 2 important concepts on which all programs were to be built: the 7 principles of adult learning (Table 1) and building curricula based on identified competencies. These were the framework on which the faculty development program was constructed, as well as the development of educational curricula, resources, and assessment and evaluation tools (Fig. 1).

Faculty Education Program

One of the important principles that the different educational task forces rely on during development of any of their programs, is the feedback from the learners. This has been a valuable resource in making changes to programs developed.

Based on the feedback from faculty, a new program was developed to teach skills used in AO educational events. This was called the “Faculty Education Program” or FEP which is a blended activity with online components and a face-to-face component. As this program was rolled out globally and feedback from faculty was received, the need for a program to help chairs organize and run educational events became evident. This led to the development of another blended program which included a 4-day face-to-face course. The program initially concentrated on developing skills in curricula development, faculty management, and some leadership issues. However, as more feedback was received, it was realized that the 4-day course was challenging to many of our participating faculty because of the time commitment needed and the many topics that were covered. So a decision was made to split this course into 2 courses. One of the courses would be entirely devoted to helping chairpersons prepare, organize, and run their educational events, and the other course would be devoted to leadership skills. This led to the development of the Chairperson Education Program (CEP) and the Leader Education Program. Another consequence of this was the development of a coaching program from the CEP. To facilitate the ability of surgeons to give and elicit feedback from other surgeon chairpersons and faculty, coaches were trained in a separate program to prepare them to support chairs in giving faculty feedback that would help them improve their teaching skills.

TABLE 1. AO 7 Principles of Adult Education

1	Based on Need
2	Motivates to learn
3	Relevant
4	Interactive
5	Provides feedback
6	Promotes reflection
7	Leads to verifiable outcomes

Two optional programs were developed; the first was the Regional Education Training program in which regional faculty are trained to teach on the FEP. The other was the Education Advisor program in which the faculty are trained on how to evaluate an educational event (Fig. 2).

The Chairperson Education Program

As with all of our educational programs, a needs assessment was performed on which the curriculum was developed. This was also supported by feedback received from faculty running courses locally and also those who attended the FEP. This information was used to identify gaps in the chair’s practice, from which the competencies were then outlined. The performances needed to address these gaps were then identified which helped in developing the competencies needed to design the education plan for the CEP (Table 2).

Based on these competencies, a program was developed that consisted of 3 main parts. The first part was a precourse online discussion forum that reviewed many of the concepts taught in the FEP and served also as an introduction to the many concepts that would be discussed in the face-to-face program. The second part is a 2-day face-to-face event in which the participant is engaged in an interactive discussion of different topics. After the face-to-face course, participants are engaged again in a 2-week after course online discussion.

On program completion, participants can apply the key principles of curriculum design and management. They will base their design of instruction for the course on problem identification, needs assessment of target learners, learning objectives, educational methods, evaluation, and feedback. Having learned educational principles and best practices, CEP participants are well placed to succeed as chairpersons of AO educational events.

Quality Education

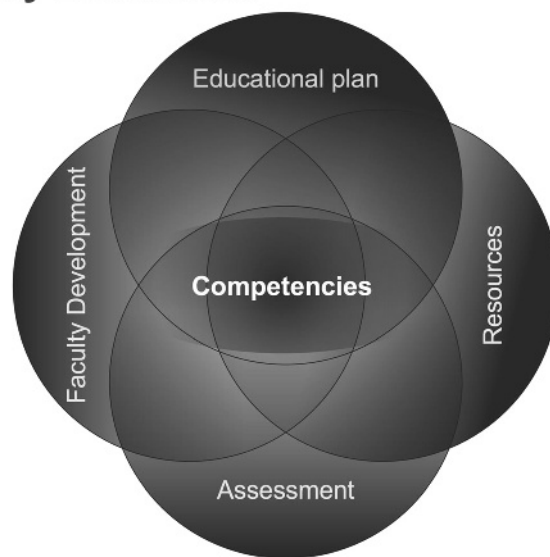


FIGURE 1. AO framework for quality education.

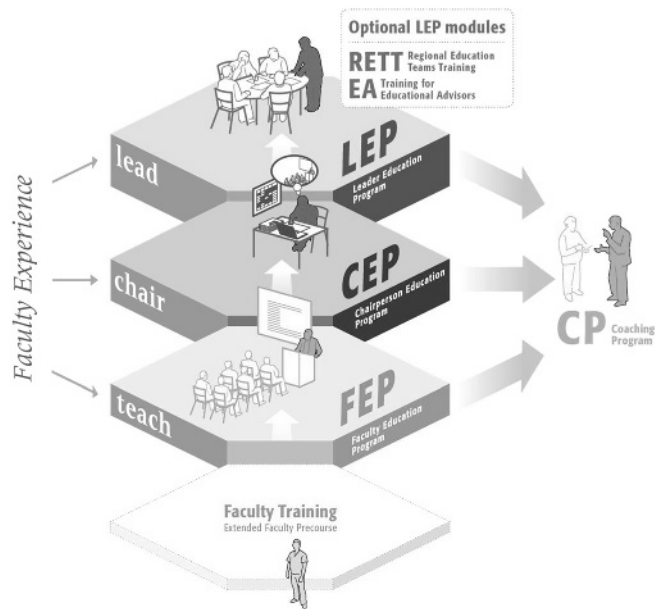


FIGURE 2. Faculty development pathway.

Precourse Online Component

During this portion of the program, the participant is asked to do a precourse self-assessment.⁴ This is subsequently used by the faculty of the CEP to identify gaps in the participants knowledge so modifications to the program can be made before the face-to-face event. The participants are then engaged in several online discussions that include how to conduct assessments and how to evaluate them and make changes to the educational program accordingly. The following module discusses teaching methods, how they differ, and when they are used based on specific competencies and objectives identified. This is followed by a discussion on the role of the chairperson during an educational event, how to develop the program, and utilization of available resources (Table 3).

Face-To-Face Component

This is a 2-day event in which the participants and the faculty further discuss topics that were addressed in the online portion as well as addressing new topics. On day 1, the AO evaluation and assessment framework is reviewed leading to a discussion regarding the interpretation of the results of self-assessments to identify gaps in the learner’s practice in order to develop and modify the curricula.²

The participants are then taken through the process of curriculum development. This is accomplished by using information from needs assessments and feedback to identify gaps in physicians’ practice and applying the concept of backward planning to identify competencies needed to address the gaps identified (Table 4).

Based on the competencies, the chairperson is then shown how to develop learning objectives specific for these competencies, and how they are broken down to the 3 main domains of learning: cognitive, psychomotor, and affective.

TABLE 2. Chairman Education Program Competencies

Assessment & evaluation	<ul style="list-style-type: none"> 1.1 Use previous assessment and evaluation data to improve current event 1.2 Analyze data about learners’ level of expertise and practice setting 1.3 Identify motivation and competency gaps of learners and make this information available to faculty and learners 1.4 Apply the available measurement instruments to evaluate your event 1.5 Analyze the evaluation data
Program planning	<ul style="list-style-type: none"> 2.1 Ensure that education promotes high-quality learning according to the OTA/AO principles of education 2.2 Use backward planning to design and/or modify an educational event based on competencies 2.3 Select and match teaching methods to optimize learning according to needs and desired outcomes 2.4 Assign faculty based on their clinical and educational expertise 2.5 Adjust content to address learners gaps and on the basis of the expertise/practice setting data
Manage faculty	<ul style="list-style-type: none"> 3.1 Resolve any disclosed conflict of interest 3.2 Provide support and make decisions that promote interaction, motivation, and feedback as part of the teaching/learning process 3.3 Plan and conduct precourse activities including early communication with faculty 3.4 Prepare and collaborate with moderators and practical directors 3.5 Share and act on precourse-assessment data with faculty 3.6 Address any problems during educational event eg, absent faculty, badly prepared faculty, and inappropriate/biased content
Event organization	<ul style="list-style-type: none"> 4.1 Use the available tools and processes to plan, organize, and direct the educational activities 4.2 Plan for an optimal physical learning setting
Collaboration	<ul style="list-style-type: none"> 5.1 Lead and manage educational activities in a collaborative way ie, sensitive to cultural and organizational aspects 5.2 Work effectively with advisory bodies, planning committees, and organizers in all phases of the educational event

The learner is then engaged in a discussion to choose the most appropriate teaching method for a specific domain.

In module 3, the course logistics and budgets are discussed with the participants addressing organization of the event as well as identifying the necessary resources

TABLE 3. Topics Discussed in the Precourse Online

Introduction	Get to know each other Build trust among the group Identify own gaps by completing the self-assessment Refresh your knowledge of “how people learn”
Assessment & gaps	Describe feedback rules and concepts Describe how OTA/AO’s assessment toolkit works Appreciate the importance of the assessment report Develop strategies that assess and affect learners’ motivation to learn about specific topics and engage in specific learning activities Describe OTA/AO’s evaluation process and instruments
Teaching methods	Refresh your knowledge on “giving a lecture” Refresh your knowledge on “running a practical exercise” Refresh your knowledge on “facilitating small group discussions” Refresh your knowledge on “moderating and debating”
Role of chairperson	Describe the role of a chairperson and list their responsibilities and tasks Exchange views on what the main challenges of being a chairperson are and how they can be addressed Be aware of possible conflict of interest issues
Program planning	Appreciate existing materials provided by your clinical division based on your event topic Outline a draft of your educational event program Recognize your own expectations of the face-to-face event

needed for the course and for the practical exercises. In module 4, faculty management is discussed, which covers choosing appropriate faculty, distributing workload, organizing precourse meetings, and the management of faculty during the course. A great part of this module is also centered around giving the faculty feedback during the event.

On day 2 of the face-to-face event participants are given the opportunity to reflect on the concepts discussed on day 1 and then engage in a discussion regarding their AO roles and responsibilities as chairs. The participants are given an opportunity to work on their individual programs and then present their work based on what was taught in the course. This gives them opportunities to learn from feedback from their peers and from the CEP faculty.

Postcourse Online Component

Participants are asked to complete a postcourse self-assessment and also engage in a discussion on what went well during the course and what can be performed differently next time. This is a very important component as it helps the

Start with the end in mind —identify desired results (outcomes) early

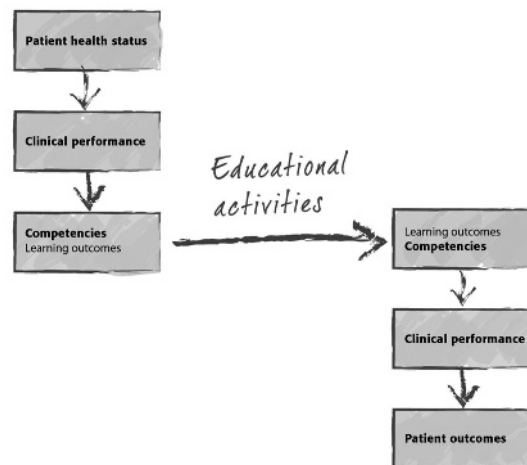


FIGURE 3. Backward process for curriculum development.

organizers of these courses make changes to the course to meet the real needs of our participants.

Special Concepts

Pre-course Assessment Tool

This is a tool that is used in most of our educational events and in all of our faculty development courses. It is made up of 2 parts. In the first part, the participants are asked to rate their perceived level of knowledge in relation to the competencies for this educational event on a Likert scale. Then they rate where they would like to be at the end of the course on the same Likert scale. The difference in the score gives an idea about the degree of motivation to learn among the participants. This is then supplemented by a test, based on the course competencies developed to assess the level of knowledge of the participants. This will help identify if the participant has correctly rated themselves in regard to their perceived level of knowledge regarding the competencies.^{2,4}

The chair uses this information to make adjustments to the curriculum. This Gap Analysis tool is used in all of our educational events and in the faculty development courses.²

Backward Planning

This is the method of curriculum development that is adopted by the AO. It depends on identifying gaps in the

TABLE 4. Face-To-Face Topics

Introduction	Principles of quality education
Module 1	Assessment and evaluation
Module 2	Program development
Module 3	Logistics and relationship with industrial partners
Module 4	Faculty management
Module 5	Individual program planning

learner’s knowledge and practices. Performances needed to address these gaps are then identified. From these performances, competencies are defined. These competencies are a unique set of knowledge, psychomotor skills, and attitudes. These are then broken down into learning objectives so the appropriate teaching method can be selected and a program can be developed (Fig. 3).⁵⁻¹⁰

Continuity, Sequence, and Integration

This is a concept that is discussed thoroughly in the face-to-face component.

Continuity is the concept of a specific idea being discussed and addressed over and over again throughout a curriculum in different formats.

Sequence refers to the importance of having the proper sequence and flow of topics and educational methods when developing the program to have the maximum educational benefit. For example, in residents’ courses, we start with delivering knowledge followed by training psychomotor skills then addressing attitude in discussion groups. However, this is reversed in master level courses as we start with discussion groups to challenge ideas and make a change in attitude, then end by lectures presenting evidence.

Integration refers to the importance of integrating different ideas together and using different educational methods to help translate them to the real world.

Application of the CEP

The Davos annual courses are the flagship events for the AO Foundation. The AO Trauma division has established in recent years a special meeting for the chairs of the Davos trauma courses based on the CEP program. The chairs of the Davos courses are chosen 18 months before the event, and there are 12–14 courses that run annually. Each course has 2 chairs. In recent years, the chairs have to have completed the FEP and preferably should have completed the CEP as well. They are given the task of developing a program as well as selecting faculty, and then

they are invited to a face-to-face 2-day event in which they are given the opportunity to work on their course program and finalize issues in regard to faculty management and logistics. The chairs meet and work to develop the competencies and learning objectives for their courses as well as work on faculty selection. The faculty are proposed from the regions, and the chairs have the opportunity to discuss the faculty with each other and then a final list is submitted to the course organizers to sort the faculty out and make sure there are no overlaps.

At the end of day 1, the chairs are engaged in a social activity with the aim of enhancing a team working environment between the different chairs and the course organizers.

On day 2, the chairs are given the opportunity to discuss their needs with the course organizers, curriculum developers, and industrial partners. Resources needed for practical exercises and anatomical specimen labs as well as other logistical issues are identified and discussed. They are asked to submit a preliminary program, finalize their faculty list and their simulation requirements. They are also given a timeline for delivering other requirements for the course. After this face-to-face event, opportunities for online meetings are made available for the chairs so that they can meet with their faculty to finalize their program.

Since starting this meeting in this format for the Davos course, which is based on the CEP, we have identified a clear and constant improvement in the outcome of the Davos courses evaluations, as can be seen in Figure 4. This has encouraged many regions to follow a similar approach for their major regional education events and has shown very similar outcomes.

CONCLUSION

The chairmen’s Education Program was developed to support the chair of the different AO educational event design programs that will meet the specific needs of participants based on established concept in curriculum design such as backward planning and precourse and postcourse assessments. It also equips the chairs with the tools and skills that

AOTrauma aggregated ratings 2006 - 2019
(all AOTrauma Davos Courses)

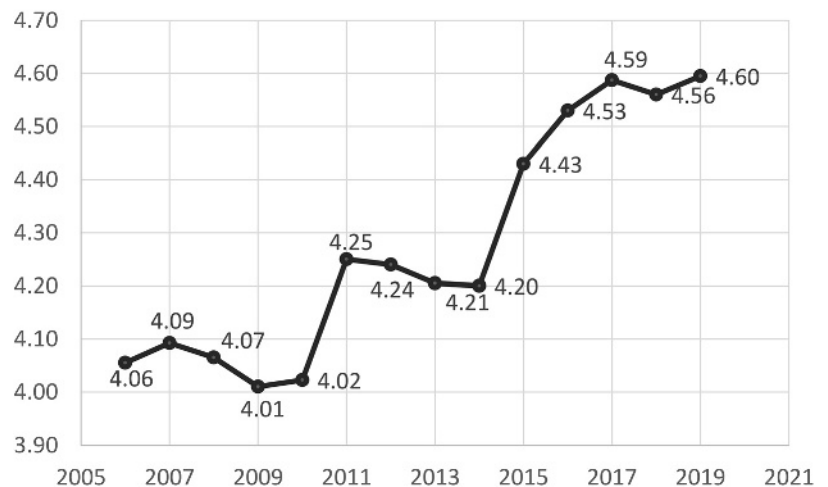


FIGURE 4. Postcourse evaluation Davos.

support his role in managing his faculty, ranging from faculty selection, assignments, and coaching. The application of these tools has reflected positively on the outcome of our educational events through better satisfaction from both the participants and faculty.

ACKNOWLEDGMENTS

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Faculty Coaching in Surgical Education Within the AO

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Summary: Faculty development is considered a key element in the effectiveness of teaching and adaptation to innovation in medical education. Within an orthopedic curriculum, participant evaluations improved with redesign that incorporated specific faculty training. One of the components of this training was the use of peer coaching specifically designed toward the objectives of the educational content. We describe here the coaching program, its evolution over time, and evaluation in 3 large geographical regions (Europe, Middle East, and North America).

Key Words: faculty education, coaching, orthopedic education

(*J Orthop Trauma* 2021;S17–S21)

INTRODUCTION

The AO Foundation has provided medical education in the management of orthopedic trauma for the past 60 years. It is currently one of the leading providers of Continuing Medical Education in orthopedic trauma, veterinary surgery, craniomaxillofacial, and spine surgery.¹ In 2005, a deliberate approach to improving surgical education was undertaken, guided initially by the 4 theoretical principles driving motivation, which include gap, instrumentality, expectancy, and valence.² These have been described in detail in the Learning Assessment Toolkit, which illustrates how practical application of educational theory leads to the improvement of learning outcomes with the ultimate goal of improving patient care.³ Other literature supports the idea that relevance to practice is an important consideration in reducing barriers to implementation of learned material.⁴

The role of the faculty in achieving good outcomes from surgical education is critical. It is no longer sufficient to be a content expert to be an effective educator. Faculty development is recognized as a key factor in teaching effectiveness.⁵ Toward this end, the AO began restructuring its courses in 2005, and by 2009, it widely incorporated a “Train the Trainers” model, which ultimately became the Faculty Educators Program.

Measures of learner perception of usefulness, relevancy of course content, and faculty performance improved as a result of the curriculum redesign. Faculty training appeared to be a very strong contributor to the improved scores because the faculty development was the last fully integrated component of the redesign, and it was not until full incorporation of the training that improved scores were seen.⁶

The current faculty development program includes training on all aspects of course execution; the initial module applies learning theory to lecture development and delivery, discussion group leadership, and running a practical exercise. Additional modules have been developed for chairing a course and coaching. The relevance of coaching to performance improvement has been much discussed and is thought to be a necessary component of attaining expertise.⁷ Use of coaching has been promoted in the fine arts, athletics, and operating room.⁸ The AO defined 9 key competencies necessary for successful coaching. Feedback would be given with care and attention, invited by the recipient, directly and fully expressed, uncluttered by evaluation, well timed, readily actionable, and checked and clarified.⁹ The framework for a coaching session followed the format developed by Pendleton¹⁰ and modified by Lisa-Hadfield-Law. It consists of 5 parts: (1) ask faculty what went well, (2) describe coach’s observations of what went well, (3) ask faculty what they would do differently next time, (4) confirm what coach would recommend for next time, and (5) ask faculty to identify and commit to 3 specific things to keep or change for the next time. Education and coaching guidelines reflect the need for timely and specific observation and thoughtful feedback.^{11,12} Specific tools geared to prompting the coach and faculty toward the specific elements of each educational activity are shown in Fig. 1. Coaches were chosen from the faculty pool and provided additional training while also acting as faculty. In this peer coaching model, coaches were not expected to have greater expertise than other faculty but were trained specifically in the feedback elements described above.

Evaluation of the coaching program has been undertaken in 2 ways. Previous reports indicate a strong impact of faculty performance on participant experience; therefore, a portion of the effectiveness of the curriculum can be ascribed to the improvement in faculty performance.⁶ Second, surveys of faculty were undertaken to assess the appeal and benefit of the coaching program on the faculty and are reported here for the first time.

COACHING BY REGION

Europe

Faculty Education was introduced to the AO by Lisa Hadfield Law in 1997 when the first “Tips for Trainers”

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The authors report no conflict of interest.

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AOTRAUMA

Lecture title: _____
 Faculty name: _____
 Date: _____

Checklist: Lecturer—Faculty coaching

Key Educational Principles
 1. Based on needs 2. Motivates to learn 3. Relevant 4. Interactive 5. Promotes reflection 6. Leads to verifiable outcomes 7. promotes feedback

Criteria	Went well	Next time
Engage audience early and demonstrate enthusiasm, motivation and relevance	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Clear structure with set dialogue and closure. Timing	<input type="checkbox"/>	<input type="checkbox"/>
Understand learner needs and experience	<input type="checkbox"/>	<input type="checkbox"/>
Make content meaningful pegged to learner level of experience with relevant cases and examples	<input type="checkbox"/>	<input type="checkbox"/>
Stick to 3-5 learning outcomes with evidence	<input type="checkbox"/>	<input type="checkbox"/>
Show visual aids which supported the lecture and which were clear	<input type="checkbox"/>	<input type="checkbox"/>
Demonstrate appropriate eye contact, gestures, body language and positioning	<input type="checkbox"/>	<input type="checkbox"/>
Use appropriate pace, volume, modulation and diction	<input type="checkbox"/>	<input type="checkbox"/>
Presentation was at the correct level for the course participants	<input type="checkbox"/>	<input type="checkbox"/>
Clear links to other course elements & effort to promote reflection/feedback	<input type="checkbox"/>	<input type="checkbox"/>
Finish with a clear take home message	<input type="checkbox"/>	<input type="checkbox"/>

AOTRAUMA

Discussion group title: _____
 Faculty name: _____
 Date: _____

Checklist: Discussion groups—Faculty coaching

Key Educational Principles
 1. Based on needs 2. Motivates to learn 3. Relevant 4. Interactive 5. Promotes reflection 6. Leads to verifiable outcomes 7. promotes feedback

Criteria	Went well	Next time
Optimal room setup and environment	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Understanding learner needs and experience	<input type="checkbox"/>	<input type="checkbox"/>
Clearly defined faculty roles	<input type="checkbox"/>	<input type="checkbox"/>
Enthusiastic introduction with clear definition of learning outcomes	<input type="checkbox"/>	<input type="checkbox"/>
Well selected cases which have been prepared by faculty	<input type="checkbox"/>	<input type="checkbox"/>
Clear visual aids which support the discussion group	<input type="checkbox"/>	<input type="checkbox"/>
Demonstrate appropriate eye contact, body language and positioning	<input type="checkbox"/>	<input type="checkbox"/>
Involve as many participants as possible	<input type="checkbox"/>	<input type="checkbox"/>
Appropriate open questions—closed when necessary. Focus on case objectives	<input type="checkbox"/>	<input type="checkbox"/>
Time management whilst meeting learner expectations	<input type="checkbox"/>	<input type="checkbox"/>
Clear summary with links to other course elements	<input type="checkbox"/>	<input type="checkbox"/>

AOTRAUMA

Practical title: _____
 Faculty name: _____
 Date: _____

Checklist: Practical Director—Faculty coaching

Key Educational Principles
 1. Based on needs 2. Motivates to learn 3. Relevant 4. Interactive 5. Promotes reflection 6. Leads to verifiable outcomes 7. promotes feedback

Criteria	Went well	Next time
Optimal room setup and environment. Check videos and equipment	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Understanding learner needs and experience	<input type="checkbox"/>	<input type="checkbox"/>
Creation and application of clear timetable leading to good time management	<input type="checkbox"/>	<input type="checkbox"/>
Enthusiastic introduction with clear definition of course linkage, timelines & learning outcomes	<input type="checkbox"/>	<input type="checkbox"/>
Chunking of practical with defined objectives for each case	<input type="checkbox"/>	<input type="checkbox"/>
Appropriate use of visual aids which are clear	<input type="checkbox"/>	<input type="checkbox"/>
Clear handovers to table instructors/ handle	<input type="checkbox"/>	<input type="checkbox"/>
Demonstrate control of practical ensuring attention during videos	<input type="checkbox"/>	<input type="checkbox"/>
Use appropriate pace, volume, modulation and diction	<input type="checkbox"/>	<input type="checkbox"/>
Accurate observation of practical ensuring problems are identified and solved	<input type="checkbox"/>	<input type="checkbox"/>
Clear summary with links to other course elements	<input type="checkbox"/>	<input type="checkbox"/>

FIGURE 1. A, Coaching tools for lecturer, (B) discussion group, and (C) practical director.

course was held in the United Kingdom. A key element in this course was feedback—how to give and receive it. This course was first held outside the United Kingdom in 2004, and by

2009, 1500 surgeons had taken part. These courses were the basis for the creation of the AO Textbook of teaching and learning.¹² Informal coaching of orthopedic faculty given by

Lisa started in Davos in 2001. Although the feedback given by a trained educationalist was very highly valued by the faculty, it was clear that any educationalist could not have the content knowledge necessary for optimal coaching. For example, if the problem was that the lecturer had too much information in his or her talk, the solution was to reduce the amount of content. If the coach did not have content knowledge, how could he or she advise what might be left out? This led to the question, could a surgeon with content knowledge acquire sufficient educational skills to become an effective coach? In 2010, Piet de Boer began the first peer coaching program in Europe. Assessment forms were used for the first 2 years (n = 94), but as the responses were always very positive, no further assessments of this type were carried out.

Initially, it was felt that faculty who had successfully completed the Chairman's education program would have acquired sufficient skills in giving feedback to allow them to coach without further training. A pilot coaching program was organized using graduates of the Chairman's education program as coaches. Feedback from the coaches was mixed, and observation of the coaching sessions showed that the faculty chosen did not have sufficient skills in giving feedback largely because of a lack of practice.

The first coaching course was held in Davos in 2012. Key competencies were identified, and pre- and post-course needs assessment documents were created. Precourse on-line teaching material was made available, and teaching about coaching was part of the course, but the majority of the course consisted of course participants giving coaching to the Davos faculty. All sessions were supervised by a trained coach, and feedback was given to the coaches about their performance. Ninety-eight surgeons have taken part in Davos coaching courses, and similar events have been held in all regions of the AO.

Since 2016, 30 AO Trauma Courses per year held in Europe have had a faculty coach assigned. That individual provided coaching support for the faculty and also had a small teaching role in the course itself. Thirty trained coaches exist in Europe in 2020, and there is a need to train more coaches to cover the 42 countries where AO courses are held.

North America

As a result of the success with the program globally, beginning in 2014, formalized training and implementation of a coaching program as a way to increase the desired efficiency of faculty performance and engagement was undertaken in North America. Coaching was offered to faculty on an opt in basis between 2011 and 2014 and formally offered beginning in 2014 to all faculty at Principles and Advanced Orthopedic Trauma courses in North America. Eight principles and 4 advanced principles courses are offered per year with 24 and 16 faculties at each, respectively. As of 2014, coaching was offered to faculty as "opt out" with near universal participation, which remained at high levels to the present. Courses consist of lectures, small group discussion, and practical table exercises (surgical simulation with plastic bones and actual implants). Between 2014 and 2018, coaches trained in a formal educational 6-hour session and who are also active faculty provided coaching on individual lectures (one on one coaching) and

discussion groups (once coach with 2 faculty). Assessment of the role of coaching in faculty engagement was undertaken with a simple survey taken in advance of a 1-day coaches planning program in September 2018. A total of 2048 coaching sessions over 4 years provided the basis for the survey, and 148 responses were recorded to the yes/no questions; 366 individual free-text answers were provided to the open-ended questions. Of the faculty responding, 32% had attended the Faculty Coaching Program. Overwhelmingly, the faculty thought that the coaching program was of value to coach and faculty who received coaching (Fig. 2). Narrative comments from the faculty are included in **Supplemental Digital Content 1** (see **Appendix 1**, <http://links.lww.com/JOT/B300>).

Middle East

Four coaches from the Middle East were trained at the initial Davos Coaching Course. Once approval was obtained from the AOTME Education Commission, a formal 1-day coaching program was initiated in October 2013 in Dubai, before the commencement of the Regional Courses. Six coaches were formally trained and then supervised at Principles and Advanced Courses over the following week. Based on the positive feedback received from both the coaches and the faculty, it was decided that, ideally, each country in the region should have a trained coach. Pursuant to that, a total of 28 coaches were trained between 2012 and 2018. Currently, all courses at the regional and national level have a coach assigned, who also has a limited faculty role. The format of "opt out" was adopted at all courses, and there was 96% acceptance by the faculty. There was great enthusiasm on the part of "first-time" faculty at regional courses to have a more open approach to coaching. The coaches were also encouraged to offer their expertise before the course, by way of reviewing presentations and offering feedback on effectiveness. Overall, 120 faculty who taught regionally in 2018 and 2019 were surveyed; 95% felt that coaching made a difference in their performance as faculty, and 97% would choose to be coached at their next course.

Asia Pacific

The first Coaching Course at Davos in 2012 saw 4 participants from the Asia Pacific Region. Subsequently, the region ran 4 more courses, 2 each in 2016 and 2017. To date, the region has 35 trained coaches. Coaching was formally adopted at most Regional Courses, beginning with the Chiang Mai Regional Courses. Most countries also recommend the inclusion of a faculty member who is a trained coach to offer coaching to the faculty.

Latin America

Four faculty participants from the Latin America region were trained in Davos in 2012 and ongoing training at Davos courses through 2017 has yielded 19 regional coaches, who are used on a regular basis at both the regional-level and national-level courses.

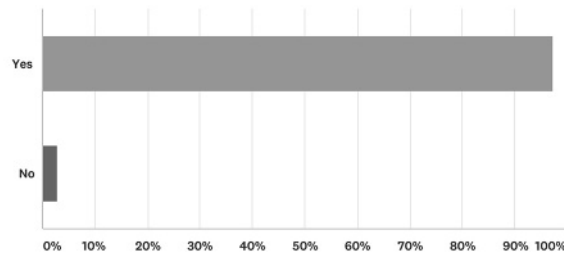
DISCUSSION

Recent literature supports the role of formal faculty development in improving the quality of orthopedic education.⁶ It is likely that such improvements are to the result of

AO North America Coaching Survey

Q Do you think the Coaching program is of value to both faculty who serve as coaches and those who are coached?

Answered: 148 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	97.30%	144
No	2.70%	4
TOTAL		148

FIGURE 2. Faculty response to value of coaching.

changes in a number of components of the curriculum, but it is reasonable to presume that improved faculty performance linked to increased relevance from the participants’ viewpoint is useful in solidifying learning. During the same period that the AO Foundation made an overhaul in its educational courses, it also introduced a series of faculty development programs, including the formal peer coaching described above. Over that same period, the value of the courses increased as measured by participant feedback and faculty ratings improved as well. The unique role that faculty coaching played is hard to differentiate from the overall changes but is likely to have contributed to the improved faculty performance.

The faculty regard coaching as a very desired and appreciated component of the larger Faculty Educators Program. Initially, when faculty had to “opt in,” it was less used, but when coaching became a normal part of all Principles and Advanced courses, it became very popular, sought out, and valued. Coaching provides direct and immediate feedback between coach and faculty and also seems to have an impact on the relationships between faculty, which is positive. Many of the free-text comments remarked upon the impact that purposeful coaching had on dialogue, familiarity among faculty, and the passion to improve all aspects of teaching. The role that understanding the science of adult learning played was also underscored as a positive contribution from both the Faculty Educators Program and the coaching.

Furthermore, the coaching program was thought to have a positive impact on the coaches and faculty as discussed at a coaches’ review in 2018. The use of coaching as a tool to foster deeper commitment and understanding between faculties using an example of the Johari window model for team communication demonstrated another positive impact that coaching had upon the group.¹³ Finally, the increasing role that surgeon coaching has had in performance

improvement has been demonstrated several times over and shown to have a positive impact on resilience, passion for performance improvement, and longevity.¹⁴ We demonstrate here that peer coaching for faculty in orthopedic surgical education is very well received, valued by the faculty, and a component of overall increase in the effectiveness of our educational offerings.

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The AO Trauma Competency-Based Training and Assessment Program: An Approach to Address Performance and Assessment Gaps in Surgical Training

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Summary: The goal of medical education is to develop disciplined, self-regulated adult learners who possess metacognitive skills and are aware of their strengths and weaknesses. Such a learner is then more open to listening, learning, and behavior change. Educational adult learning principles such as addressing the needs of the learner, translation to practice, motivation, engaging learning interactions, tactics that promote reflection and feedback, well-defined outcomes, and ways to measure it are important factors to consider when designing such education. Alignment of the learner needs to the learning outcomes, the measurement methods, and teaching formats and to the content being delivered are essential for a successful learning experience. The target audience for the AO are surgeons at various practice levels; therefore, the concepts of deliberate practice that enable the development of performance skills are integral to the overall curriculum. However, the current apprentice model and lack of robust validated performance assessment tools create challenges in residency training today. Despite significant investments into graduate training, no validated evidence exists toward the success of residency programs or a systematic approach to the design and delivery of a curriculum that is effective and helps residents achieve proficiency. The factors contributing to this situation are multifaceted further adding to the challenge. In response, AO trauma clinical division developed a plan with a team of expert surgeons and educationalists to design and implement a Competency-based Training and Assessment Program that offers a more streamlined approach to the training and assessment of residents and opportunities to practice.

Key Words: skills training, residency training, adult learning, adaptive learning competency based training

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BACKGROUND

The AO Foundation's focus for more than 60 years has been on the training and mentoring of surgeons globally.

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Currently, the organization covers the globe in 5 regions, conducting 830 educational events every year with the support of 9000 trained faculty reaching more than 58,000 participants. Its mission is to improve patient care throughout the world by using the knowledge and skills of its network of 20,000 surgeons and 215,000 health care professionals. The Foundation was established in 1958 and defined education, research, documentation, and implant development as the 4 pillars of focus for the organization. The first course in Davos, Switzerland, was held in 1960, and since that time it has and continues to offer quality educational events (AOFoundation.org). Approaching education as a discipline has become a major focus for the organization devoting resources and time to the development of the faculty as professional educators. Additional training in the Faculty Education Program, Chairman Education Program, and Leadership Education Program has become requirements for participation in most events as the understanding of modern education theory has been adopted. Changes in learning and the needs of the learners have evolved rapidly over the past decades, and it became evident that an increasing gap between the type of education available and what is needed exists and had to be addressed. The offerings, although of exceptional quality, did not allow for an individualized approach that could be tailored to the participants needs, accessed when needed using modern theories yielded from educational research. In addition, the training environment for residents and the need for a validated evaluation of performance are demanding change. Its role as an independent nonprofit entity, the number of committed faculty, and its global reach uniquely position the AO to evolve and adapt to the changing environment. The AO Foundation (AOF) has the mission, the resources, and the desire to create new methods of education and assessment of surgical training. The concept of the Competency Training and Assessment Program (CTAP) is to create a curriculum of surgical trauma education that will be individualized to the learner/resident; it includes not only knowledge-based assessments but also the possibility to evaluate the performance of Entrustable Professional Activities (EPAs) and skills training through deliberate practice. EPAs are surgical tasks that a resident is able to perform without any supervision or help. These are aligned with the milestones defined. Using validated training assessment tools, the CTAP aims to fill gaps in surgical training and establish AO as a leader in skills training and assessor of competence.

To address the constantly growing need for surgical skills training outside of the operating room (OR), the CTAP will leverage evidence-based new practices in training, coaching, and performance assessments emerging through the rapid development in augmented reality/virtual reality simulation.

Current Approaches and Challenges in Residency Training

Recent publications in the medical education literature suggest that surgical residents may graduate from their training programs without enough clinical exposure to procedures they will have to perform in practice.^{1,2} This is believed in part to be driven by duty hour restrictions, pressures to increase OR efficiency, and the ongoing development of new techniques for trainees to learn.^{2,3} In response to growing concerns with the current model of training, specialty training programs around the world are now shifting toward competency-based medical education (CBME).⁴ Unlike traditional models that focus on the time spent in training, CBME focuses on outlining the skills every surgical trainee must acquire before completion of training⁴ and shifts the focus away from what is taught toward what is learned. CBME benefits trainees by providing clearly defined learning objectives⁵ and helps training programs by providing an explicit curriculum and assessment framework to ensure that trainees have acquired all the necessary knowledge and skills they need to transition into independent practice.⁵

One essential element in trainee assessment in CBME involves the use of an EPA. An EPA represents a key task of the discipline that a resident must be observed to perform competently to progress through the training program (eg, obtaining informed consent, performing the surgical management of a hip fracture, or managing a postoperative complication).⁶ EPAs are completed by a supervising surgeon to determine trainee competence. Although being completed, a combination of summative (performance on a checklist) and formative feedback (comments on what was performed well and what can be done better next time) is provided to the trainee by the assessor. Used in aggregate, multiple EPAs reflect the competence of the trainee in managing common specialty-specific conditions. Careful integration of EPAs into an educational curriculum can help ensure that trainees are assessed in all key competencies of the specialty. When used correctly, EPAs can help identify trainees' strengths and weaknesses and focus attention where it is most needed.⁶ This process can track progress over time and identify those residents who are struggling so that timely intervention can occur. In addition, these assessments can also be used to identify the outstanding or poor assessor.

In addition to implementing explicit curriculum and assessment frameworks, many CBME initiatives have adopted the use of simulation to increase exposure to different procedures and skills.³ Simulation is an encouraging teaching tool because it provides residents an opportunity to learn new skills with no impact on patient care.⁷ Trainees can make mistakes, receive feedback, and improve performance before working with patients, without the time and safety pressures that exist in clinical teaching situations.⁷ Furthermore, the

variety of simulation materials available, including synthetic models, animal models, cadavers, and augmented and virtual reality simulators allows educators to choose models best suited for teaching specific skills. Many published studies have shown that surgical skills do improve with simulator training in the laboratory environment.^{8–10} Despite these findings, there is sparse evidence of proven skill transfer into the clinical environment.¹¹ This is mostly due to issues in the study design (ie, lack of reliable and consistent outcomes, lack of clear definitions of competence, lack of consideration of both physical and functional fidelity of simulator, lack of validation in the context in which the simulator is being used, and lack of the same aspects of performance being measured in the simulation and clinical setting).¹¹

CBME curricular and assessment plans and simulation training provide many techniques of training and assessment to enhance resident education. However, objective, valid, and reliable evaluation tools still need to be developed to determine when trainees have become competent in managing patients, particularly as it relates to the subspecialty of orthopaedic trauma. The AO CTAP project incorporates CBME principles and the intensive use of simulation in its aim to improve surgeon competence in managing orthopaedic trauma. The CTAP will provide a curriculum and assessment platform to its learners to enable them to acquire the competencies they need in managing a patient with a musculoskeletal injury. Essential knowledge in managing orthopaedic trauma conditions will be achieved through a learner-adaptive, interactive online server. Skills development will occur on low-fidelity (artificial bone models) and high-fidelity (cadavers) simulators as well as augmented and virtual reality simulators. EPAs will be used as an assessment tool. The knowledge and skills training the CTAP aims to provide its participants will supplement the training and practice that exists in residency and fellowship training programs. By developing valid and reliable assessment platforms in the skills laboratories and real-time OR environment, it aims to prove skill transfer into the clinical environment.

CTAP Learning Pathway

The AO CTAP steering committee and the AO North America (AO NA) CTAP curriculum taskforce designed the program and all the associated learning experiences based on the following principles:

1. Learners interact with an ecosystem that includes instructional elements and interactions that allow construction of knowledge and skills, along with assessment, feedback, and continuous engagement.
2. Interactions and assessments are adaptive and accommodate the different levels of the learners.
3. Repurposable content delivered in chunks that are aligned with learning objectives.
4. Learning experiences are relevant, meaningful, and translate to real-world applications.
5. Content is personalized and delivered just in time when needed.
6. Content is designed to be responsive, scalable, and portable.

7. A modular approach to the development of content.
8. Formative and summative assessments are integral to the success of the learner.
9. Learner dashboards that provide constant updates on performance, progress, and participation.
10. Feedback and coaching included within the learning pathway.
11. Facilitate deliberate practice to help achieve performance goals.
12. Promote continuous improvement and learning until performance benchmarks are achieved.
13. Artificial intelligence and learner analytics offer insights into achievement of competencies (knowledge, skills, and attitudes).

The CTAP learning pathway as shown in Fig. 1 addresses the needs of residents in different levels of training. The program will be launched in the United States in 2021 as a pilot and will be scaled across the globe (Fig. 2). The first iteration of the program will be focusing on residents as the target audience and all instruction and assessments will be aligned with the Accreditation Council for Graduate Medical Education milestones, specifically the EPAs. The EPAs will define the assessments and the instructional content along with skills that need to be acquired. The program is focused on anatomical regions, accomplishment of the Accreditation Council for Graduate Medical Education milestones, and comprises 5 modules (hip, ankle, distal radius, forearm shaft, and tibial shaft). Learners participate in personalized activities, assessments, practice and coaching sessions, and the final assessment, based on their baseline knowledge and skills they

enter the program with. The adaptive learning platform aligns content delivered to the learner’s specific needs and levels of expertise. Strong fundamentals and evidence-based educational principles inform the design and delivery of the program. Adult learning principles,¹² backward planning, and instructional design frameworks¹³ that support constructivism¹⁴ and deliberate practice lead to meaningful, personalized, learning interactions. In combination with assessments and evaluations at different levels, they enable the learners to complete all requirements needed to train and be assessed for competence and proficiency. Performance and learning dashboards will be made available through the online learning platform to provide easy access to assessment scores to both learners and program directors. In addition, the faculty will access these scores to provide feedback to the learners.

Learners start the program by completing an assessment to establish a knowledge, competence, and performance baseline and identify the gaps¹⁵ that need to be addressed during the program. Based on the results of the baseline assessments, the learners are provided with opportunities to address the gaps. The learners then go through several learning packages (Fig. 3) to access content (knowledge and skills) in various formats and different learning levels delivered through an adaptive learning platform. The online curriculum will be a combination of several instructional elements and offers self-study modules and instructional videos with progress monitored by an adaptive learning platform. A portion of the skills training can be accomplished remotely using virtual and augmented reality simulators but will be enhanced and improved with face-to-face events and higher fidelity simulations.

Proposed Pathway for Residents

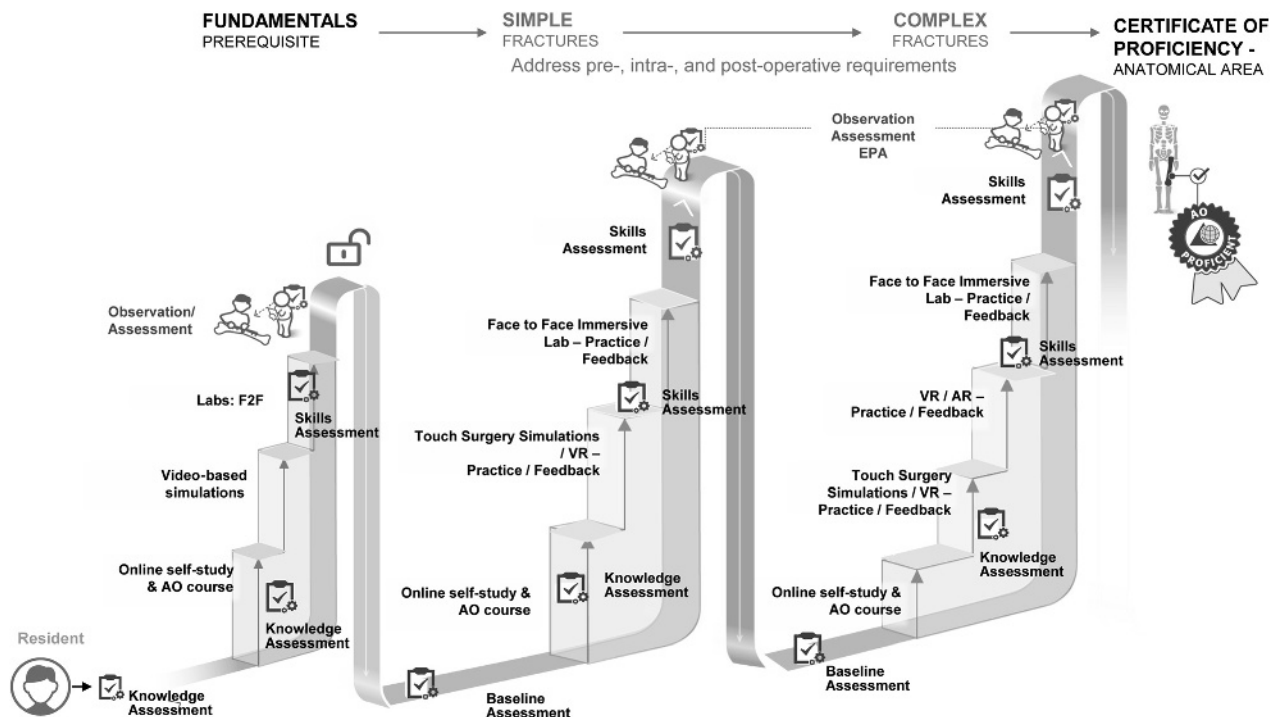


FIGURE 1. CTAP: Proposed pathway for residents.

CTAP is scalable in three dimensions

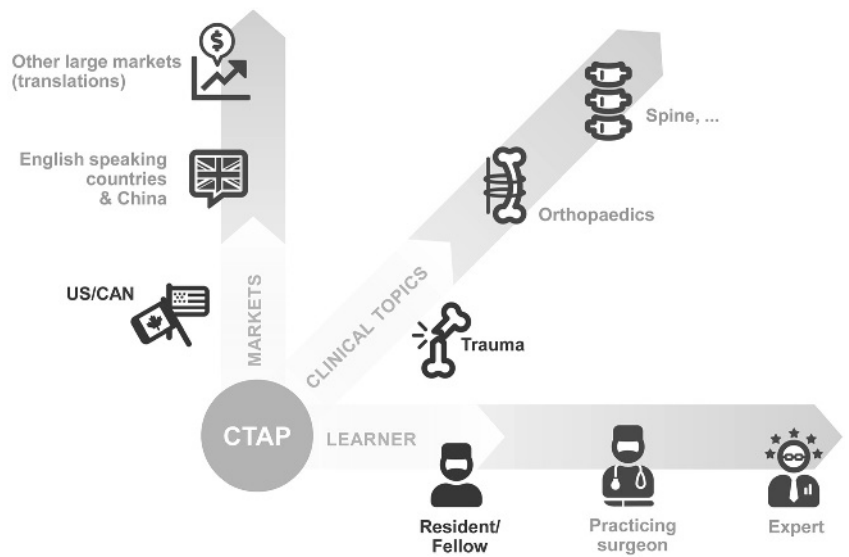


FIGURE 2. Proposed approach to scaling CTAP.

All program content is designed and developed in a peer-reviewed process by subject matter experts and in collaboration with those proficient in eLearning, simulation training, and assessment. To define simulation content for skills training, a diligent peer-reviewed task-analysis approach was applied.¹⁶ Learning and training activities in the CTAP are provided at different levels of complexity. Immediate automated feedback in combination with individual coaching and adaptive learning functionality allows for personalized competency-based progression through the

CTAP content. To ensure that the delivery of content in CTAP aligns with the needs and preferences of today’s young adult learners, residents have been involved in the development of the different types of assets used in the CTAP at an early stage.

The program is also being developed in collaboration with CAE health care based in Montreal, Canada. CAE is the leader in simulation training in aviation and has several years of proven success, the expertise, and engineering capabilities needed to support the CTAP. On completion of the

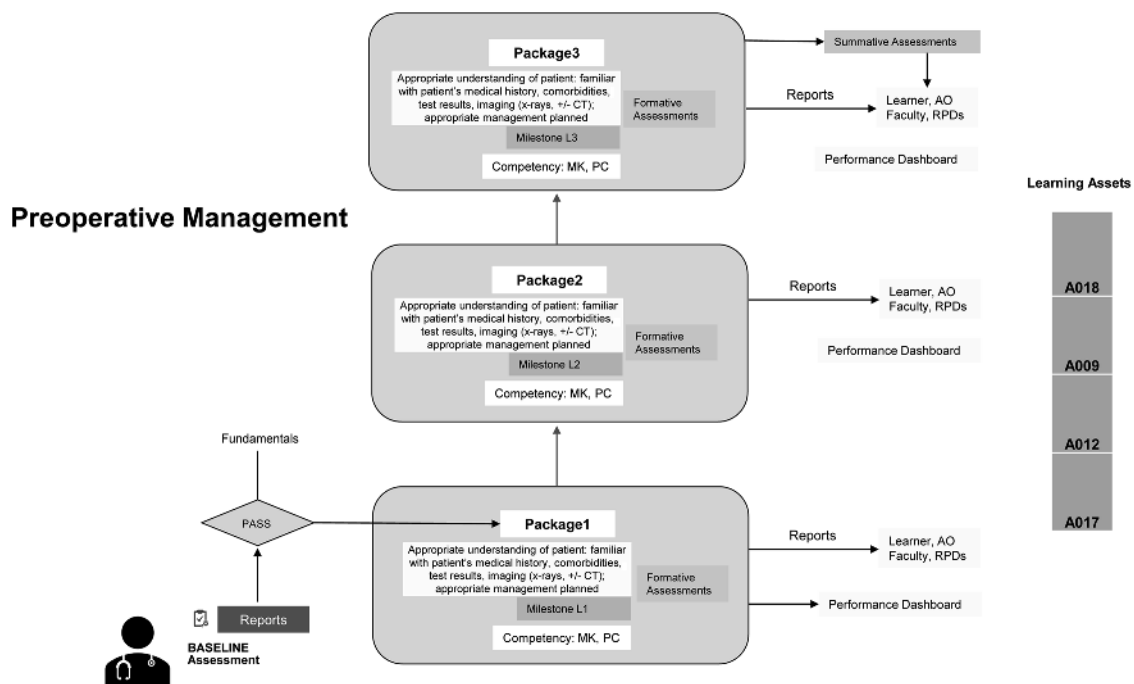


FIGURE 3. CTAP learner pathway.

Validation, evidence, and continuous evaluation in CTAP

Research plan: Why, How, and When does competence develop? Factors contributing to learning?

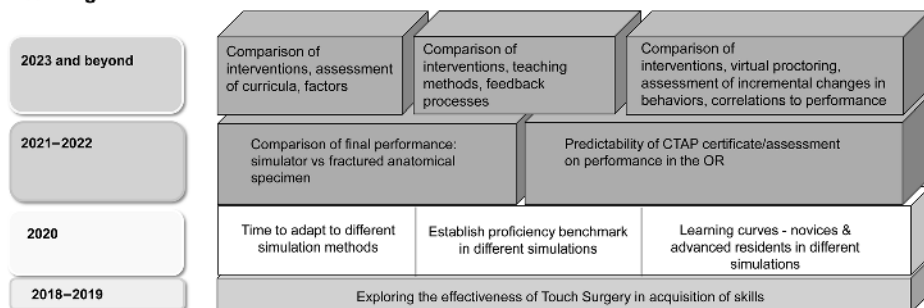


FIGURE 4. CTAP research plan.

instruction delivered online, the learners with the use of a simulator train, practice, and achieve proficiency of the defined procedures. Their performance will be further validated through feedback and assessment of metrics related to the procedures. The AO plans several studies to assess the validity and reliability of the simulator as a platform for training and assessment. Once validated, proficiency related to the surgical procedures defined for the different CTAP modules can be assessed by the simulator.

Implementation

Seven workstreams have been established to develop and build the various components of the program, each with a workstream lead, clearly defined deliverables, and a dedicated team of collaborators and contributors. The 7 workstreams are as follows:

1. Instructional design, content development, and production.
2. Simulation design/metrics development.
3. Assessments, validations, and data analytics.
4. Research.
5. Faculty development.
6. eLearning/IT infrastructure.
7. Marketing and Promotion.

To account for the links and interdependencies between the workstreams, regular meetings take place to ensure alignment and overall progress of the program during the development phase. Key stakeholders are involved at various stages of the development. The first CTAP module will be piloted with several residency programs, carefully evaluated and findings will be implemented in the further development of the platform and the learning, teaching, and coaching activities.

Team Structure

There are 2 main CTAP governance bodies, the CTAP Steering Committee and the CTAP Taskforce, both led by surgeons. By providing cross-functional leadership and direction, the CTAP Steering Committee ensures the delivery of the project and the achievement of project outcomes. The CTAP Taskforce consists of 9 surgeons, an educationalist, and the CTAP project manager. The CTAP Taskforce is responsible for defining the learning pathways in the CTAP, including educational plans, learning, training, coaching and assessment activities, evaluation, and continuous

improvement. They closely collaborate with the teams of authors who develop the content and learning assets for the CTAP modules and with the other workstream teams. The project manager is responsible for the overall project management and the coordination across all workstreams. The launch of the first module is planned for April 2021. Additional content and modules will be added gradually and is planned to have the full program with 5 modules available in the next couple of years. A plan for the roll-out of CTAP to additional English-speaking countries will be developed in due time.

Validation Studies

A series of research studies are planned to measure the success of the training program and the contribution and efficiency of the program components. The proposed multi-year study plan presents an opportunity to explore surgical skills acquisition, contribute to evidence in the learning sciences, and position the AO as a leader in this emerging field. Research to identify proficiency metrics from data gathered from the simulators will be conducted in collaboration with the Neurosurgical Simulation and Artificial Intelligence Learning Center at McGill University. Subsequent studies are planned to deepen our understanding of how people learn and what the critical issues are in the assessment of orthopaedic surgical expertise (Fig. 4).

As envisioned the program will not only improve the efficiency, breadth, and depth of learning but also the inclusion of skills education will fill an important gap in current surgical training. By creating metrics and validated assessments for performance we hope to achieve a more scientific understanding of surgical skills and how to optimally teach them. It is our hope and goal to create a learning environment that will lead to a lifetime of engagement that will constantly offer new opportunities for constant improvement.

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Multicenter Video Recordings of Minimal Invasive Cephalomedullary Nailing of Pertrochanteric Femur Fractures for Metrics Validation Studies: Lessons Learned

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Summary: Validated performance metrics are the fundamental building block of a successful and effective proficiency-based progression training program. We recently demonstrated face and content validity of the metrics for internal fixation of an OTA/AO 31-A2 pertrochanteric fracture with a short cephalomedullary nail. We then conducted an international multicenter study to determine the construct validity of the metrics. The study required recording of real orthopaedic trauma procedures performed by novice and experienced surgeons in a live operating room setting using 3 separate cameras. In this report, we present and critically discuss the main challenges in implementing the study protocol. We also report our solutions to overcome the challenges to guide future metrics validation studies.

Key Words: proficiency-based progression, construct validity, protocol implementation, video recording, ethics approval

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INTRODUCTION

Surgical training is experiencing a paradigm shift from an apprenticeship model to a proficiency-based progression (PBP) approach. PBP training requires trainees to achieve a predefined proficiency benchmark in skill performance before progressing to more complex techniques.¹ Trainees engage in deliberate practice against a set of clearly defined metrics. Metrics are elemental performance characteristics that unambiguously capture important aspects of procedure

performance (ie, procedure steps) and delineate deviations from optimal performance (ie, errors).² They are usually developed through breaking down the key sequence and actions imperative for the procedure and operationally defining the units of performance that constitute the skill.³ Metrics are used as criteria for objective evaluation of performance and form the foundation of the proficiency benchmark. Randomized controlled trials have shown that PBP-trained surgical residents had better skill performance and made fewer objectively assessed procedure errors than traditionally trained surgical residents.^{4–8}

Our group recently published the first metrics for internal fixation of an OTA/AO 31-A2 unstable pertrochanteric fracture with a short cephalomedullary nail.⁹ This surgery was chosen as the reference procedure because it is a common fracture with growing procedure volume and has well accepted procedural steps. The metrics provide unambiguous operational definitions of 15 phases with 75 steps, 88 errors, and 28 sentinel errors. A group of 32 surgeons from 18 countries verified face and content validity of the metrics.⁹ The next step was to determine the construct validity of the metrics. Results from this study are of high value because they will show if the metrics can distinguish the performance of an experienced surgeon from that of a novice surgeon. If so, the metrics can be deployed for PBP training purposes. The results may also be used to establish a proficiency benchmark.

This construct validity study requires video recordings of real orthopaedic trauma procedures performed by novice and experienced surgeons on patients in a live operating room (OR) setting. In this case study, we present the main challenges that we encountered while implementing the study protocol and our solutions. Our goal was to share this information to help guide the establishment of best practices for future metrics validation studies.

Overview of the Study Protocol

This international multicenter observational study is currently ongoing at 3 centers in Europe, and one each in Israel, the United States, and South Korea. Eligible patients are with an isolated closed OTA/AO 31-A2 pertrochanteric fracture requiring close reduction and cephalomedullary nailing with a single cephalic element. Exclusion criteria for patients are body mass index >40 kg/m², use of local nerve

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block for anesthesia, and reoperation. Eligible surgeons are surgeons who perform the surgery on the patients. A novice surgeon is defined as an orthopaedic resident/trainee who has performed the procedure less than 5 times before the recording. An experienced surgeon is who performs the procedure on a regular basis and who meets current standards of care. Fifty-six videos of the surgical procedure performed by 14 novice and 14 experienced surgeons are being obtained. A maximum of 2 procedures are recorded with each surgeon. Based on the results from Angelo et al,⁵ where the mean (SD) total number of errors (including sentinel errors) was 2.95 (1.85) for experienced surgeons and 5.68 (3.51) for novice surgeons, a sample size of 26 videos per group was calculated at a significance level of 5% and a power of 95%.

To include all steps, the video recording starts when the patient arrives in the OR and ends after clinical evaluation of reduction and outcome measurement is performed in the OR. A video capturing system consisting of 3 separate cameras is set up in the OR before the procedure. Camera 1 is mounted in a way to capture the overall setup and movements in the OR. Camera 2 is attached to the main light to capture the surgical field. Camera 3 is attached to the image intensifier facing the monitor to capture its screen output. After obtaining informed consent from the patient and all members of the OR team, the cameras are started remotely by an appointed person to avoid interruption to the procedure.

Once the recording is completed, the 3 separate video files are saved locally on hard disk storage devices and the hard disks are then sent to the Education Institute, AO Foundation (Davos, Switzerland), for further processing. The outputs from the 3 simultaneous recordings are then synchronized and compiled into one composite view to be used for assessment using the metrics. To ensure blinded assessments, video files are de-identified by removing all metadata such as names of patients/hospitals/surgeons or patients' birthdays.

Two independent assessors, who are blinded to the category of the surgeons, assess the performance using the metrics. Steps, errors, sentinel errors, and attending takeovers are assessed as either observed or not observed.⁹ The assessors were not involved in the development of the metrics or any parts of the metrics validation study other than assessing the videos. They were trained on the evaluation of performance using the metrics. During the training session, the assessors independently scored 5 sample videos collected for other purposes. Training was provided until they consistently achieved an interrater reliability of 0.8 or above. Collected data are entered into an electronic data capture system (RedCap, version 6.5.2). The primary analysis is to compare the performance of novice surgeons with that of experienced surgeons regarding steps completed and errors made.

Challenges and Solutions

Site Selection, Training, and Monitoring

Table 1 summarizes the main challenges that we encountered in implementing the protocol and our solutions. An eligible study site had to meet several criteria, particularly the feasibility of recruiting the required number of patients

and surgeons and the availability of infrastructure and personnel to support the video recording. Because each site must contribute recordings from at least 2 novice surgeons, the site must have a dedicated residency program to allow recordings from trainees. Legal requirements for contracts varied greatly from site to site. Contracting took several months, expertise, and good communication, which required, in the end, more resources than initially planned.

We designed a detailed feasibility checklist for selecting sites. It included caseload, surgeons, video support, and availability of study coordinators. We selected only sites that met all criteria. Training on the study protocol was provided for the study site staff. Particularly important was to clarify the terminology used in different sites, such as fracture classification other than the OTA/AO classification and what constituted a short cephalomedullary nail. As it took time to collect all videos, residency rotations and staff changes must be considered and addressed when they arose. New residents and staff had to be reformed about the study, and consent to participate must be obtained from them. Retraining was particularly important when there was a change of the study coordinator.

Obtaining Ethics Approval

A few institute review boards (IRBs)/ethics committees (ECs) had difficulty categorizing the study, which dictates standards or guidelines to follow. Other than clinical research, some IRBs/ECs categorized the study as "quality assurance" or "educational" studies, which have different guidelines for application. Clear policies and guidance for a study involving recording of patients and medical staff were not available at all sites. This required several rounds of consulting and communication, and in some cases, reapplication to ensure all ethical principles and applicable laws were met. To tackle these issues, we used nontechnical language in our application to ensure an effective communication with IRBs/ECs. This helped them grasp the study scope and procedures, properly categorize the study, and provide us with clear guidance. Measures to protect privacy and preserve confidentiality of all study participants must be provided in the application.

Obtaining Informed Consent

In this study, study participants were the patients, the novice/experienced surgeons, and all the OR team members who might appear in the videos, such as the anesthetist, chief/assistant surgeon, theater nurse(s), and circulating nurse(s). The challenge was to obtain informed consent from all these participants before each recording. Patients who sustain this type of fracture are often older adults who may have impaired cognition or acute pain, which can hamper communication. We also encountered difficulty obtaining consent from a few patients when they were told that a surgeon in training would perform the procedure. Furthermore, the procedure is usually performed within 24 hours of the injury. Considering the time needed for clinical decision and preparation, this left a narrow time window for the informed consent process. Ensuring that a study coordinator was available was the key to meet these challenges. We provided training for the coordinators on how to identify potential patients, how to communicate with them

TABLE 1. Main Challenges and Solutions

Study Stages	Main Challenges	Solutions
Site selection, training, and monitoring	<p>Finding study sites that met all criteria, particularly:</p> <ul style="list-style-type: none"> The feasibility of recruiting eligible patients and surgeons. A dedicated residency program to enable recordings from trainees. The availability of infrastructure and personnel to support the video recording. <p>Legal requirements for contracts varied greatly and contracting took months, expertise, and good communication.</p> <p>Different terminologies used by different study sites.</p> <p>Residency rotations and staff changes.</p>	<p>A detailed feasibility checklist for selecting sites.</p> <p>Selected only sites that met all criteria.</p> <p>Training on the study protocol for the study site staff.</p> <p>Reinform and reobtain consent from new residents and staff, particularly when there was a change of the study coordinator.</p>
Obtaining ethics approval	<p>A few Institute Review Boards (IRBs)/Ethics Committees (ECs) had difficulty categorizing the study.</p> <p>A lack of clear policies and guidance for a study involving video recording of patients and medical staff.</p> <p>The process could take several rounds of communication with IRBs/ECs and in some cases, reapplication.</p>	<p>Use nontechnical language for application.</p> <p>Provide measures to protect privacy and preserve confidentiality of all study participants in the application.</p>
Obtaining informed consent	<p>Obtaining informed consent from patients, surgeons, and all the OR team members before each recording.</p> <p>Hampered communication due to patients' clinical condition.</p> <p>Patients were unwilling to participate when they were told that a novice surgeon would perform the procedure.</p> <p>The procedure was usually unscheduled and performed outside of normal working hours, resulting in a narrow time window for the informed consent process.</p>	<p>Ensure that a study coordinator was available.</p> <p>Provide training for the coordinators on how to identify potential patients and communicate with them in an effective and reassuring way.</p>
Videos recording, processing, and transferring	<p>No standardized ways to position the cameras due to the variations in the local setup and size of the ORs.</p> <p>The cameras must be properly anchored to prevent them from moving or falling into the sterile field during the operation.</p> <p>The cameras had to be installed and removed for each recorded procedure as they could not remain in the OR.</p> <p>Cameras were not ready to record before the procedure or were moved during the operation, resulting in loss of views.</p> <p>Sometimes it was not possible to record the first and last phases due to logistical, workflow, or consenting issues.</p> <p>Recording of the 3 cameras were not simultaneous due to insufficient battery life or a lack of a coordinator to start and monitor the recording.</p> <p>Batteries had to be changed to ensure that cameras could record over several hours without turning off.</p> <p>Recording of a complete procedure generated a considerable amount of data and large files.</p> <p>One IRB/EC requested deleting sound before transfer, which made synchronization difficult. Missing parts or views of the recording was another obstacle for synchronization.</p>	<p>Perform a test video recording at each site with a simulated case or dummy before recording real procedures.</p> <p>Checked the quality of the recordings and provided feedbacks and troubleshooting to the sites.</p> <p>Only continue with sites that had the infrastructure and equipment to support the recordings.</p> <p>A dedicated study coordinator at each site to schedule, coordinate, and monitor the recordings.</p> <p>A step-by-step protocol to set up all cameras and perform the recording.</p> <p>Extensive training to the coordinator on how to manage and transfer the video files.</p> <p>Continuous communication with the sites through the coordinator to share the best strategies.</p> <p>Provide the sites with the necessary equipment, adequate batteries, and computing systems.</p>
Quality of the video files	<p>The quality of the video files was affected when all phases or steps could not be consistently captured.</p> <p>Noncomplete procedures from novice surgeons where the attending/consultant surgeon took over and performed a part of or the rest of the procedure.</p> <p>Quality and completeness of the videos could only be checked during the assessment. Additional recordings had to be collected if videos were excluded from the assessment.</p>	<p>Providing training to the assessors on detailed definitions of observable events and how to apply them in the assessment.</p> <p>Eligible videos must capture the core procedure starting from patient positioning to closure of incision.</p> <p>Only phases/steps/errors that were observable could be included in the assessment.</p> <p>70% of the procedure must be completed independently by the novice surgeon.</p>

in an effective and reassuring way, and how to prepare them that a surgeon in training would perform the procedure with the oversight of an attending/consultant surgeon. The coordinators could also build a rapport with the surgeons and OR staff to ensure an efficient informed consent process.

Recording, Processing, and Transferring Videos

We encountered various challenges with the video recording. First, there was no standardized ways to position the cameras due to the variations in the local setup and size of the ORs. It required thorough planning before the procedure. Second, to avoid the risk of contamination or interruption to the surgeons, the cameras must be securely anchored to prevent them from moving or falling into the sterile field during the operation. Third, the cameras had to be installed and removed for each recorded procedure as they could not remain in the OR. This was further complicated by the fact that this procedure was often unscheduled and performed out of normal working hours. Fourth, in some sites, cameras were not ready to record before the procedure or were moved during the operation, resulting in loss of views. Sometimes it was not possible to record the first and last phases due to logistical, workflow, or consenting issues. Finally, a few recordings were not started or continued with all cameras simultaneously due to insufficient battery life or a lack of a coordinator to start and monitor the recording. Batteries had to be changed to ensure that cameras could record over several hours without turning off.

Recording of a complete procedure generated a considerable amount of data and large files. Synchronizing the 3 views was facilitated using audio from the videos; however, one IRB/EC requested deleting sound before transfer, which made synchronization difficult. Missing parts or views of the recording were another obstacle for synchronization.

These obstacles were reflected in the quality of some of the early recordings, particularly, issues such as missing parts and incomplete views. Several actions were taken. First, a test video recording was performed at each site with a simulated case or dummy before recording real procedures. We then checked the quality of the recordings and provided feedback to the sites. This ensured that problems and issues could be tackled at an early stage. Second, we only continued with sites that had the infrastructure and equipment to support the recordings. Third, each site should have a dedicated study coordinator who was responsible of scheduling, coordinating, and monitoring the recordings. The coordinator was given a step-by-step protocol prepared by the ASSERT Centre, College of Medicine and Health, University College Cork, Ireland, to set up all cameras and perform the recording while meeting all OR health and safety regulations (Fig. 1). The coordinator was also responsible for storing, naming, and transferring the files. Extensive training was provided to the coordinator so that he/she had the technical expertise to perform these tasks. The coordinator was also the key person for our continuous communication with the sites, through which we identified their specific needs and obstacles, provide them with instructions and solutions, and share the best strategies. Finally, we provided the sites with the necessary equipment, adequate batteries, and computing systems that could store,

manage, process, and transfer all files in an efficient and secure manner.

Quality of the Video Files

A qualified video must capture the core procedure starting from patient positioning to closure of incision. To avoid subjective and implicit inferences, during the training session, the assessors were trained on the detailed definitions of observable events and on how to apply them in the assessment. Only phases, steps, and errors consistently captured and proven to be observable could be included in the assessment. The assessors documented the phases or steps that could not be clearly seen in the videos due to missing parts, inappropriate brightness, blurring, movement of the cameras during the surgery, and artifacts. Videos of novice surgeons were excluded if an attending/consultant surgeon took over and performed the rest of the procedure. Because completeness of the procedure could only be determined by the assessors during the assessment, additional recordings had to be collected until the required number of recordings was achieved.

DISCUSSION

We encountered many challenges and obstacles while implementing this international multicenter study. These challenges must be monitored and accounted for analytically over the course of the study. Success requires thorough planning, attention to details regarding infrastructural and technical requirements, clear and user-friendly checklists and protocols, and continuous communication with the study sites to early identify issues and obstacles and to provide them with feedback and solutions.

These challenges are almost certainly related to the fact that we recorded real orthopaedic trauma procedures performed on patients in a live OR setting using 3 cameras. This is in contrast to previous metrics validation studies, in which simulated procedures⁸ or procedures on cadaveric specimens¹⁰ were recorded, or only one view was obtained.⁷ The 3 views from our video capturing system provided a comprehensive view of the procedures to better capture the performance of the surgeons; however, it also created significant challenges to obtain quality videos. Because real procedures were recorded in a live OR setting, study participants involved not only patients but also surgeons and the OR team members. A few IRBs/ECs had difficulty grasping the scope of the study and directing us to policies and guidance for obtaining ethics approval. Furthermore, it was challenging to obtain informed consent from all participants before each recording within a narrow time window. In our experience, selecting study sites must consider not only the caseload but also the feasibility of recruiting novice and experienced surgeons, the willingness and collaboration of the OR staff, and the availability of infrastructure to support the recording. Time and effort for communication with the IRB/EC must be properly planned. Moreover, the key solution to many of these challenges is to ensure that a dedicated study coordinator is available at each study site to obtain informed consent,

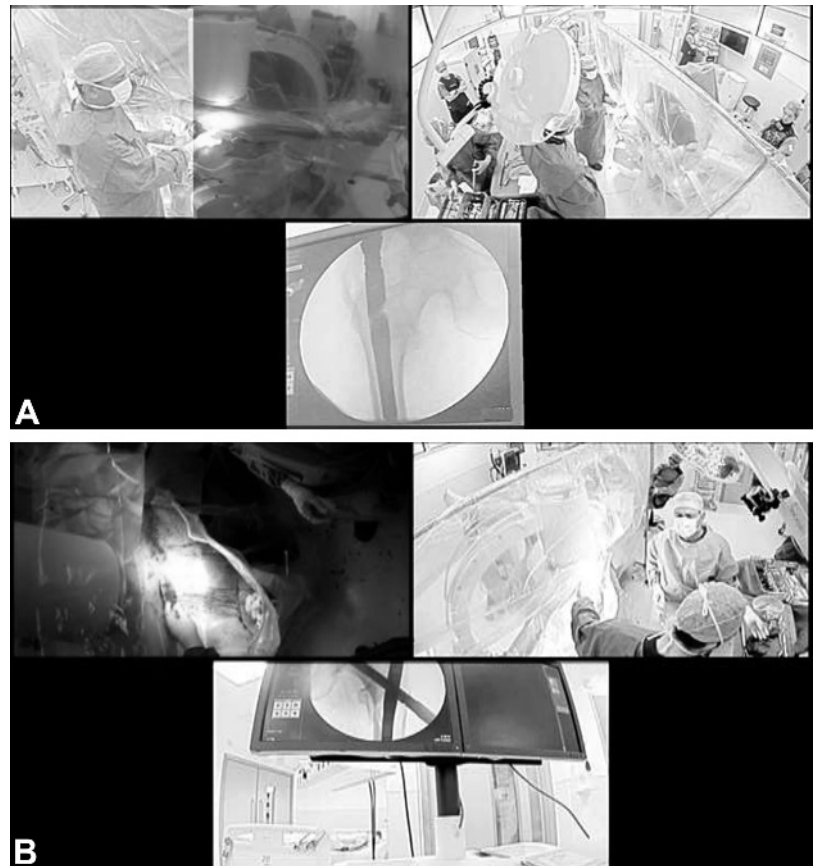


FIGURE 1. An optimal (A) and a low-quality (B) composite view by synchronizing the views from the 3 cameras. Top left: surgical field; top right: the operating room; bottom: output from the image intensifier. An optimal view should clearly capture the surgical field and the surgeon's movements, the entire operating room and staff's movements, and the screen output of the image intensifier. Problems with the low-quality view are (1) the surgical field too bright and too close; (2) operating room only partly visible; and (3) camera moving during the procedure. Proper positioning of the cameras would solve these problems.

schedule and monitor the recordings, and to manage the video files. Extensive training must be provided to the coordinators to ensure that they are competent in performing their tasks.

Validated metrics are the fundamental building blocks of a PBP training program. They serve as a detailed and comprehensive procedure template that engineers and computer scientists can use to build simulations that accurately capture the essence of the procedure performance.² Error metrics can be “simulated” so that trainees experience the potential operating risks without harming patients.³ Metrics inform the operational definition of a proficiency benchmark that trainees must demonstrate before training progression. Trainers can use the metrics to provide trainees with constructive, objective, transparent, and fair performance feedback. This type of feedback underpins a “deliberate” rather than a “repeated” practice approach to training.¹¹ Several blinded randomized controlled trials have demonstrated that PBP training produced 40%–70% improvement in the performance of procedure steps and >40% reduction in objectively assessed intraoperative errors compared with traditional training or simulation training without the proficiency benchmark.^{4–8} One study has shown that improved performance skills by PBP training translated into better patient outcomes.⁷ This construct validity study lays the foundation for the IMMPACT (Improved Morbidity and Mortality for surgical

fixation with intramedullary nailing of unstable pertrochanteric fractures resulting from Procedure charACTerization and proficiency-based progression simulation Training) study initiated by the Education Institute, AO Foundation. The IMMPACT study is a large multicenter study, which aims to determine if a PBP simulation training program for orthopaedic surgeons to learn to perform standard cephalomedullary nailing of unstable pertrochanteric fractures results in better intraoperative performance and better patient outcomes compared with traditional training or the same simulation training without the proficiency benchmark. The goals of the IMMPACT study are in line with the mission of AO Foundation, which is to promote excellence in patient care and outcomes in trauma and musculoskeletal disorders.

Our case study highlights the importance of thorough planning, attention to details, effective communication, and continuous feedback with study sites to meet the challenges in implementing an international multicenter construct validity study of metrics that involves video recording of real orthopaedic trauma procedures performed on patients in a live OR setting. Our solutions to these specific challenges are context specific but may be useful to help conduct similar studies and to establish best practices for similar projects in the future, particularly for studies that focus on performance assessment using recordings of real surgical procedures performed on patients.

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Effect of Cognitive Task Simulation in Transfer of Performance Skills in an AO Practical Skills Laboratory

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Objectives: To assess the effectiveness of a simulation platform (Touch Surgery) on the learning and transfer of procedural skills as measured by number of steps completed, sequence of the steps, number of errors, and time to task completion, in a controlled environment.

Methods: A total of 120 residents registered in an AO Basic Principles course were invited to participate in the research protocol. Fifty-two participants responded to a preassessment questionnaire and were assigned randomly to control and treatment groups. Forty residents participated in the study. The simulation exercise for this study involved intertrochanteric fracture reduction and sliding hip screw implantation. Using a standardized procedural-based assessment checklist, AO trauma faculty observed and rated the procedural skills of participants as they performed the practical exercise. A two-tailed *t* test was used to compare the 2 groups.

Results: The treatment group completed the exercise in significantly ($P < 0.05$) less time ($P = 0.027$) and made less errors ($P = 0.027$) than control.

Conclusions: The value of practicing the procedure in Touch Surgery demonstrated additional opportunity to learn and refine surgical skills. Residents' ability to remember and perform the surgical steps was enhanced by Touch Surgery.

Key Words: Touch Surgery, simulation, intertrochanteric fracture
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INTRODUCTION

Orthopaedic trauma is a leading contributor to the global burden of noncommunicable disease.¹ Orthopaedic

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surgery is traditionally learned through repeated practice on patients and proctorship.² Because of concerns regarding patient safety³ related to the traditional number of work hours during residency, there has been a reduction in training hours in North America and Europe^{4,5} that has led to a change in surgical training. Simulation in surgery has become important to the training process, providing a way for trainees to practice operative tasks in a protected environment without putting patients at risk.⁶ When such practice is accomplished just before an operation or combined with patient-specific cases, it can be referred to as “surgical rehearsal.” The concept of rehearsal is relatively new in surgery. Surgical rehearsal for a procedure before performing it can decrease both the operating time and errors.⁶

In most cases, orthopaedic simulation consists of practicing surgical exposures and procedures on cadaveric specimens or saw bones. Face-to-face live training, activities conducted in university simulation centers, and the operating room are potential opportunities for training. However, challenges in access to dry and wet laboratories, shortage of cadavers, and the high expense of teaching facilities and equipment often create situations where training is sub-optimal. Multimedia software and virtual reality (VR) simulators can help overcome such limitations, but expense remains a significant barrier to widespread adoption. One argument against virtual simulations versus high fidelity simulators is that mechanical VR systems account for psychomotor and technical skills and, hence, address force, dexterity, and other factors important for trauma care. They, however, do not allow for nontechnical skills such as cognitive decision-making. Decision-making contributes to demonstration of clinical and nontechnical competency.^{7,8} Because of the decrease in surgical volumes during residency, simulation in orthopaedic training is on the rise. Simulation allows for sustained practice without harming a patient and provides the necessary feedback on cognitive and decision-making skills when designed well with a purpose.⁹ Thus, an effectively designed simulation using cognitive task analysis (CTA) can address the lack of practice and support the objective assessment of performance skills in surgery.

The Touch Surgery application (Kinosis Limited, London, United Kingdom) is a unique cognitive task simulation and rehearsal platform. It focuses exclusively on the cognitive decision-making proponents of surgical procedures and offers a step-by-step manual to complete orthopaedic operations. Development of simulator-based training models normally starts with a structured analysis of the

complex procedures, using CTA, a process that involves review and analysis of experts' performance of the task. While performing the task, the experts share their knowledge, their thought processes, and the optimal way to perform the steps of the tasks.¹⁰ These models also can include appropriate objective assessments and provide feedback on performance. Touch Surgery combines this framework with VR to simulate procedures that have defined objective metrics to measure performance. The simulation modules consist of a learn mode, which teaches users the procedure, and a test mode, which assesses users' procedural knowledge. The use of the Touch Surgery simulations for practicing procedural skills has shown to affect performance in practice.¹¹ The Touch Surgery application is an interactive and immersive VR multimedia software available on mobile and smart devices.

One of the most common fractures an orthopaedic surgeon will manage is a pertrochanteric femur fracture. One method of fixing a simple pertrochanteric femur fracture uses a sliding hip screw (DHS) which is a complex task for novice residents. For complex procedures that have significant impact on patient outcomes, consistent training with continuous opportunities for feedback and practice is necessary. Studies that can prove the validity of simulations in enabling skills acquisition and performance are thus important. In addition, the process of CTA and expert discussions on steps in the process are very valuable for educators and simulation designers who need to work together in the development of the simulation.

The primary aim of the study was to compare resident performance (measured by percentage number of steps completed, the sequence of the steps, number of errors, and time to task completion) related to the DHS procedure in a simple pertrochanteric fracture bone model, between control and treatment groups. The control group was exposed to the standard AO teaching methods (online DHS procedural video + the face-to-face practical skills exercise) The treatment group was exposed to standard AO teaching methods plus the Touch Surgery DHS module delivered through the application.

We hypothesized that practice using virtual simulations enables transfer of procedural skills and that significant differences in performance occur between learners who practice the skill using simulation and those that do not. If the practice proved effective, the desire was to include Touch Surgery as a tool to augment the learning and acquisition of skills.

METHODS

Pilot Study

The study protocol and methods were approved by the Institutional Review Board (IRB) at Cork University in Ireland. A pilot study designed and developed using the same approach and processes of the current study was conducted December 2017, in Davos, Switzerland, the headquarters of the AO (Fig. 1). The pilot study included the development of a procedure checklist related to cranio-maxillofacial surgery and involved fixation of a mandibular

fracture using lag screws. The treatment and control group definitions and the process for face and content validation of the performance checklist were also adopted in the current study. The pilot study indicated significant differences in error rates between the control and treatment groups as seen in Fig. 1.

Participants

Participants included residents who registered for the 2018 Basic Principles of Fracture Management courses offered by AO North America (AO NA). The courses are face-to-face live events, offered throughout the country, and are designed by surgeon faculty who are members of AO NA. This group offered a relatively homogenous participant pool since North American residency training programs are standardized and based on Accreditation Council for Graduate Medical Education competencies and associated milestones that are adopted across the country.

Inclusion and Exclusion Criteria

All 120 residents invited to participate in the study were in year 1 or 2 of their residency training and received a pre-event questionnaire based on expressed interest in simulation and Touch Surgery. Fifty-two responded to the initial survey, and 40 participated in the study. Table 1 provides an overview of the participants, including their experience levels. Residents without previous exposure (not at all familiar) to the Touch Surgery application and those with limited exposure to DHS procedures (very rarely) were included in the study. Residents who were familiar with the Touch Surgery application (somewhat familiar and familiar) and had exposure to the DHS procedure (somewhat frequently and frequently) were excluded from the study.

Prestudy Questionnaire

It was anticipated that there would be variations in knowledge and skill levels based on training sites and potential exposure to the Touch Surgery application. To control for variations in experience levels and previous exposure to Touch Surgery platform and the modules, a prestudy questionnaire (see **Appendix A, Supplemental Digital Content 1**, <http://links.lww.com/JOT/B299>) that assessed the frequency of performing the procedure in their practice settings and a participant's level of exposure to Touch Surgery was distributed to the participants.

Random Assignment

After application of inclusion and exclusion criteria, 40 participants were placed into the control or the treatment group through random computer-generated assignment. Each group was assigned 20 participants.

Control and Treatment Groups

Both groups were sent a follow-up email providing access to the instructional materials necessary to prepare for the session. The control group participants were asked to review the DHS procedure video that was available online to all participants. The treatment group participants were asked to review the DHS procedure video and access the Touch

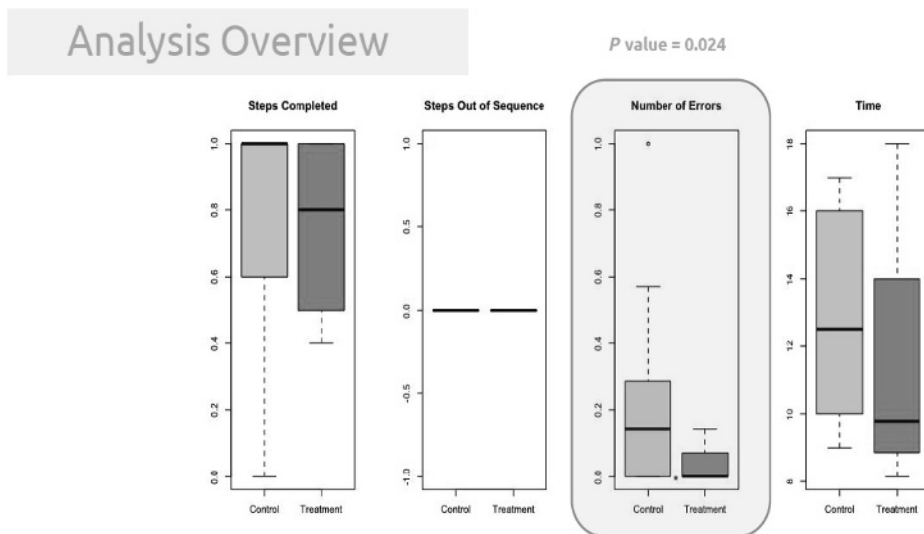


FIGURE 1. Results of the pilot study held in 2017.

Surgery DHS module through the application. Once the treatment group participants accepted the invitation to access the module, they could download the application, create an account, and gain access to the Touch Surgery DHS module online.

The participants could access the online Touch Surgery module in the learn mode as many times as necessary until they were able to score a 100% in the test mode twice consecutively. Participants were required to complete these activities 2 days before their participation on the skills laboratory exercise. Their access and use of the application were tracked and recorded on the analytical platform. In addition, their performance in the learn and test mode was captured. The study protocol is shown in Fig. 2.

Study Environment

AO NA offers several Basics and Advanced Principles of Fracture Management courses annually. Courses are based on a global standardized curriculum and are offered throughout the year in all specialty areas of trauma, spine, cranio-maxillofacial, and veterinary. The AO Basic Principles courses offer an optimal standardized setting for conducting the research study since there is minimal variation in the skill level of participants because most are in postgraduate year 1–2. These participants present a homogenous group trained using a standard curriculum by their academic institutions.

Using the assistance of the logistics team, 12 stations were set up in a separate area of the meeting space used for the course. This helped ensure that the study did not interfere with the rest of the course proceedings and the participants could focus on the task rather than on other sessions within the course. Four sessions of 30 minutes each were organized to accommodate the 40 participants.

Procedure

Each of the stations were set up with a simple 2-part intertrochanteric fracture (AO 31 A1) synthetic bone model and the standard equipment needed for the DHS procedure.¹² The study team reviewed each of the stations to ensure

consistency in the arrangement and equipment being used. The AO DHS instructional video that participants could access online was also made available. Faculty who were recruited to serve as observers were assigned to each of the sessions. Observers to participant ratio was 1:1. The faculty were blinded to which group (treatment or control) the participants were assigned.

On arrival, the participants and the observers were asked to select a station. One of the surgeon faculty who helped design the study and the research tools provided an overview of the process and introduced the purpose of the session and the role of the observers. The participants were provided an opportunity to ask any questions related to the process or their role and the procedure. A total of 30 minutes were allocated for each session. Once the participants were ready, they viewed the AO DHS module instructional video and subsequently performed the procedure. The time taken to complete the procedure was noted. The study schematic is shown in Fig. 2.

Role of Surgeon Experts

The surgeon experts were integral to the design and development of the study. They served as coprincipal investigators (Co-PI), codeveloped the assessment tools, and served as observers and facilitators of the study sessions. The surgeons who participated in the study have been involved in teaching AO courses for more than 15 years. They also served on several committees and panels involved in content and curriculum development. Thus, the surgeons were very familiar with the content delivered through the AOTrauma Basic and Advanced Principles of Fracture Management courses. Each of the surgeon observers were also faculty assigned to different teaching sessions at the selected Basic Principles course. They arrived the day before the start of the course and participated in a training session that was led by the expert faculty who served as the lead Co-PI. The performance assessment checklist was reviewed, and all the items on it were discussed individually; the definitions of errors and critical errors were shared. The goals of the session

TABLE 1. Categorization of Participants Based on Survey Responses (52 Responded and 40 Participated)

Category	Beginners	Adv Beginner	Intermediate	Proficient
Level of expertise with DHS	37	6	8	1
	Very rarely	Rarely	Somewhat freq	Very freq
Frequency of DHS use	34	12	5	1
	N/A	Rarely	Frequently	V frequently
Performance of DHS on patients	5	43	4	0
	No	Yes	No response	
Use of TS	46	6		
	Not familiar	Somewhat familiar	Familiar	Very familiar
Familiarity with TS DHS module	51	1	0	0

were shared, and the use of the tool and its application in assessing performance was discussed in detail. The faculty observers were given the opportunity to ask questions. The outcome of the training session was to ensure that the observers were familiar with the tool and had a clear understanding of the steps defined along with the errors. Twelve faculty members were recruited, trained, and performed the observations and assessments of participants in all the 4 sessions.

Assessment Checklist and Performance Metrics

According to Gallagher and O’Sullivan,¹³ the development of metrics involves task analysis which is the breakdown of a procedure into its component steps and for each step, defining the most optimal and suboptimal performance.

Defining optimal performance and relevant errors that can be made during suboptimal performance requires consensus from a team of experts. A team of experts and those proficient with the procedures worked together on the checklist to ensure its validation. The development of the checklist for this study followed all the steps described by Gallagher and O’Sullivan.¹³

Face and Content Validity

The Touch Surgery medical team and the AO Foundation video team worked together with 3 surgeon experts to develop the instructional video of the selected procedure. Video recording of the procedure performed by the 3 expert surgeons served as the basis for a step sheet that was developed by the Touch Surgery medical team. This step sheet was then reviewed by a panel of 6 surgeon faculty who

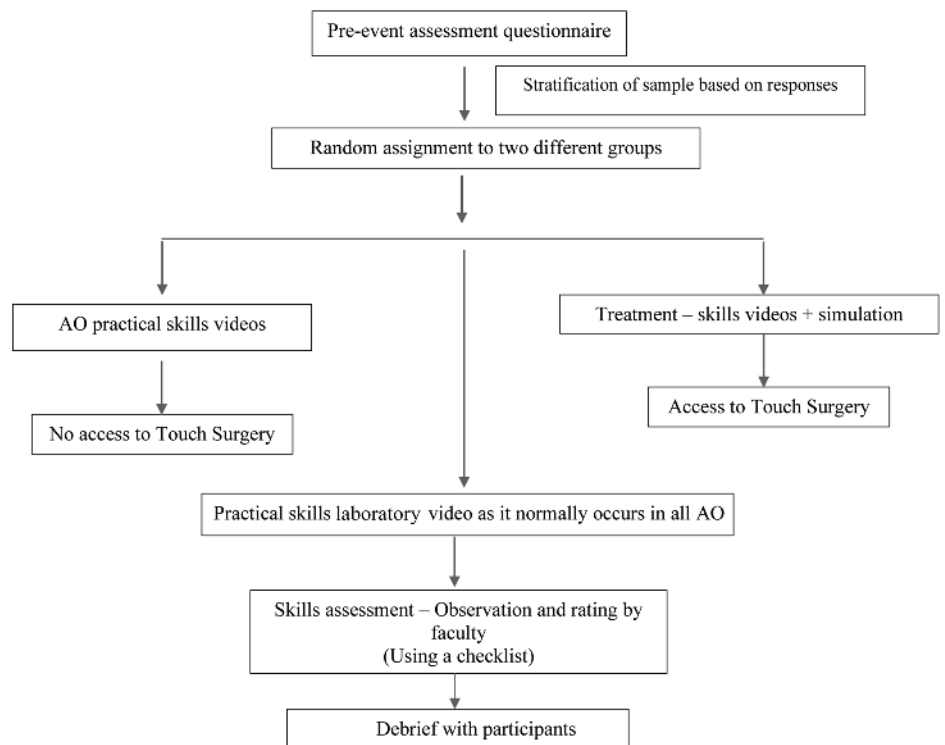


FIGURE 2. Study schematic.

were invited to participate in the research study as Co-PIs. The step sheet (see **Appendix B, Supplemental Digital Content 1**, <http://links.lww.com/JOT/B299>) was then translated by the video team to a story board to be used as the basis for video production. The story board was further reviewed by the experts, and any input/revisions to the checklist were addressed. Thus, the AO NA DHS video that was used in the study was developed based on the standard procedures adopted by the expert surgeons. The DHS video module is the standard media presentation of the procedure that is used in all AO NA principles courses. In addition, a surgeon proficient in the procedure from North America was requested to record a video of the procedure. The panel of the 6 faculty experts who reviewed the initial draft checklist reviewed the video and assessed the accuracy, sequence of steps, and the potential errors. The surgeons could complete the procedure without any errors in 11 minutes and 55 seconds. The group of 6 faculty experts who viewed the video ensured that the checklist steps were aligned with the procedure that the expert surgeon performed. Consensus on the errors defined in each of the steps was achieved. The checklist was then finalized by a consensus panel of 4 expert surgeons who were not involved in the development of the checklist or the review of the videos. The lead Co-PI, an orthopaedic trauma surgeon, led the review and presented each of the steps in the process. Each of the experts shared their comments related to the different steps, the sequence of the steps, the definition of errors, and the sentinel errors. These processes helped assess the checklist for face and content validity. The metrics for performance developed included time taken to complete the procedure, number of steps in the procedure completed, number of steps missed, number of errors, and number of sentinel errors.

Skills Lab—Study Procedure

The study was a randomized 2-arm assessor blinded study. Once the participants arrived for the study sessions, they were asked to sign in. Faculty assigned to each of the stations observed performance based on the checklist provided. Faculty were requested not to help the participants, since they needed to work through the procedure independently. Repetition of steps to accomplish accuracy was noted on the checklist, and faculty provided additional comments if they felt it necessary. Because of logistical challenges and the costs involved, each participant performance was not recorded. Instead, faculty observed participant behaviors (1:1)

using the checklists. After the study sessions, 2 surgeon experts who were a part of the checklist review team reviewed the completed checklists for completeness. Checklists with incomplete data were not used in the analysis. The experts also went through comments made by the observers to ensure any data that could be gathered from the comments were included in the analysis.

Statistical Analysis

Sample size calculations for a power of 80% at $\alpha = 0.05$, 38 total participants were required allowing for 19 to be randomly assigned in each group. For both the treatment and control groups, number of steps in the procedure performed, number of steps completed out of sequence, number of errors, number of sentinel errors, and time taken to complete the exercise were calculated. Because of missing data in the treatment group, only 19 of the total 20 participants' scores for the number of steps performed out of sequence was considered. All other dependent variables included 20 participants in the analysis for both control and treatment groups.

Descriptive statistics to describe and summarize the data were analyzed to study the 2 groups. Mean, median, mode, and range were reviewed and reported. To analyze the differences between the 2 groups, a 2-tailed independent-samples *t* test was conducted.

RESULTS

To describe the basic features of the data, descriptive analysis was conducted and differences were revealed, between groups, for time, number of errors, and steps out of sequence. Descriptive statistics are presented for the control and treatment groups in Tables 2 and 3, respectively. The results of these statistical summaries suggested a between-group difference and, specifically, that the treatment group may have performed better than the control group. To determine whether there was a significant difference between the mean values of the 2 groups (Table 4), independent-samples *t* tests were used for hypothesis testing and are reported in Table 5.

The results of these analyses suggest that residents in the treatment group had fewer errors ($P = 0.027$) and took less time to time taken to complete the exercise ($P = 0.014$). Although not statistically significant ($P < 0.05$), there were marginal differences in sentinel errors and completion of all

TABLE 2. Frequency Distribution—Control Group

	Steps Completed	Steps Out of Sequence	No. of Errors	# of Sentinel Errors	Time in minutes
N					
Valid	20	20	20	20	20
Missing	0	0	0	0	0
Mean	18.15	4.30	4.50	2.70	25.63
Median	17.50	3.00	4.00	3.00	24.22
Mode	22	0	3	4	14.23
Range	11	21	9	8	27.77

TABLE 3. Frequency Distribution—Treatment Group

	Steps Completed	Steps Out of Sequence	No. of Errors	# of Sentinel Errors	Time in minutes
N					
Valid	20	19	20	20	20
Missing	0	0	1	0	0
Mean	20.05	3.00	2.70	1.60	20.84
Median	20.50	2.00	3.00	1.00	19.81
Mode	23	0	3	1	18.00
Range	10	11	7	5	16.00

steps, with the treatment group seeming to perform better (Table 6).

Correlation analysis was then used to measure the strength of the relationship between variables and the potential associations between them. Analysis revealed a moderately positive relationship between time taken to complete the exercise and number of errors ($r = 0.51, P < 0.05$) and a moderately negative relationship between number of steps out of sequence and number of steps completed ($r = -0.66, P < 0.05$). Collectively, these results indicate that when the participants practiced using the Touch Surgery application, there was a difference in their ability to perform the exercise based on the dependent variables analyzed, thus supporting cognitive “surgical rehearsals” and their value in enabling skills performance.

Postsession surveys and conversations (verbal debrief) with participants provided insights into the value that participants perceived of the Touch Surgery platform and the opportunity to practice and receive feedback. The treatment group was much more motivated to start the procedure and spend time and effort to receive feedback and practice again until they were satisfied that they knew the steps. Observations also showed that the treatment group participants quickly self-corrected and hence were more “consciously incompetent,” a factor that promoted learning.

Implications

Touch Surgery is an interactive mobile surgical simulator that guides users step by step through every part of an operation. Simulation in orthopaedic training is becoming increasingly popular and has been widely used in formal curricula. However, these resources are expensive and not easily accessible to every trainee. Other means of disseminating surgical education through VR multimedia can act as useful adjunct to traditional methods of teaching. Studies have shown that Touch Surgery, a cognitive task simulation and rehearsal application, has helped novices demonstrate cognitive competencies to ensure patient safety before operating.¹⁴ Based on the results obtained in the current study, the application can serve as an effective adjunct to traditional learning methods and has the potential for curricular implementation.

The demands of a comprehensive curricula in orthopaedic surgery residency with the current time restrictions create challenges in producing competent orthopaedic surgeons. Lack of enough hours dedicated to practice during residency creates significant gaps in skills and competence of

resident trainees who go through their residency curriculum. Simulations provide opportunities for practice in a safe environment before surgeons perform a procedure on patients. Simulations can also provide real-time formative feedback based on metrics that can enable the deliberate practice¹⁵ necessary for obtaining proficiency. When simulations are thoughtfully integrated into a curriculum, they provide opportunities for continuous assessment and feedback, thereby promoting learning and more rapid mastery of a surgical procedures.

Studies that inform the use and effectiveness of simulation further validate the need for such tools to ensure surgical efficiency, successful patient outcomes, and ultimately patient safety. Recognizing criteria that make simulations successful at providing a meaningful experience to learners will also inform their design and delivery.

Limitations

The study was conducted in a controlled environment within an AO NA Basic Principles of Fracture Management course limiting generalizability. For the results to be generalized, the study should be conducted with a group of participants who are not familiar with AO courses and in environments outside course settings. Although the performance tool was reliable, and face and content validity were assessed, predictive validity (out of scope for this study) could help determine the effectiveness of the TS platform and

TABLE 4. Group Statistics

	Group	N	Mean	SD	Std Mean Error
Steps completed (23)	0	20	18.5	3.602	0.80
	1	20	20.05	2.781	0.62
Out of sequence (23)	0	20	4.30	5.12	1.15
	1	20	3.00	3.055	0.70
# of errors (19)	0	20	4.50	2.646	0.59
	1	20	2.70	1.658	0.37
# of sentinel Errors (16)	0	20	2.70	2.029	0.45
	1	20	1.60	1.353	0.30
Time in minutes	0	20	25.6310	7.74579	1.73
	1	20	20.8419	5.15304	1.15

TABLE 5. Independent-Samples Test Results

	df	Sig*	Mean Diff	Std Error diff	95% CI	
					Lower	Upper
Steps completed						
Equal variances assumed	38	0.07	-1.90	1.01	-3.96	0.16
Equal variances not assumed	35.71	0.07	-1.90	1.01	-3.96	0.16
Steps out of sequence						
Equal variances assumed	37	0.34	1.30	1.36	-1.47	4.07
Equal variances not assumed	31.12	0.34	1.30	1.35	-1.45	4.05
# of errors						
Equal variances assumed	38	0.01	1.80	0.70	0.39	3.21
Equal variances not assumed	31.92	0.01	1.80	0.70	0.38	3.22
# of sentinel errors						
Equal variances assumed	38	0.05	1.10	0.54	-0.00	2.20
Equal variances not assumed	33.11	0.05	1.10	0.54	-0.01	2.21
Time in minutes						
Equal variances assumed	38	0.03	4.79	2.08	0.58	9.00
Equal variances not assumed	33.06	0.03	4.79	2.08	0.56	9.02

*2-tailed significant.

practice in the operating room and hence in the real world. Both treatment groups were exposed to the standard videos and learning materials that a standard AO Basic Principles course offers. The treatment group was then further exposed to Touch Surgery. However, the amount of time each participant spent reviewing the study materials is unknown and was not controlled for. Thus, the effects observed could be simply due to increased education time and not practice using the Touch Surgery application.

CONCLUSION

The study was performed to assess the effectiveness of Touch Surgery in contributing to skills learning, before including it as a learning/practice intervention in the AO Basic Principles course. The study results have shown that the use of Touch Surgery can augment learning and help residents practice the skills and the application was effective in the transfer of what was learned in performing the skill in a controlled environment. Addition of the platform to support practice when there are less

TABLE 6. Treatment Group—Pearson Product–Moment Correlations

	# of Errors	Time in Min	Steps Completed	Out of Sequence	Sentinel Errors
# of errors					
Pearson corr	—				
N	20				
Time in min					
Pearson corr	0.51*				
Sig (2-tailed)	0.02				
N	20	20			
Steps completed					
Pearson corr	-0.28	-0.37			
Sig (2-tailed)	0.29	0.11			
N	20	20	20		
Out of sequence					
Pearson corr	0.03	0.38	-0.66†		
Sig (2-tailed)	0.91	0.10	0.00		
N	19	19	19	19	
Sentinel errors					
Pearson corr	0.06	0.25	0.41	-0.02	
Sig (2-tailed)	0.80	0.28	0.07	0.91	
N	20	20	20	19	20

*Correlation significant at the 0.05 level.

†Correlation significant at the 0.01 level.

opportunities to do so in residency programs could support acquisition of skills. Sophisticated mobile devices today can offer easy access to the simulations anytime, anywhere, and at point of care. Touch Surgery developed as a mobile application thus could serve as an anytime, anywhere reference resource, a practice tool before trainees participate in the actual surgical procedure.

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A Biologically Friendly Wire Tensioning Technique and How a Worldwide Surgeon Education Network Can Affect Patient Care

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Summary: The use of cerclage wiring for fracture fixation is well described, and when done in a biologically friendly manner, it can be an effective method to aid fracture reduction and fixation. There are multiple techniques for both wire insertion and wire tensioning. Wire tensioning can be performed using proprietary tensioners or by manual tension with sternal clamps. However, using a standard large wire drill collet can be effective and efficient and can be used for both 1.25- and 1.6-mm wires. Although this method of tensioning has not been described in the literature, it is used in several countries and institutions. This method has been propagated through the relationships fostered by the AO Surgeon Community. The mentorship, and friendships, developed through AO help spread ideas and stimulate innovation with one goal in mind—improving patient care. The aim of this article was to both formally describe the use of a large wire drill collet for cerclage wire tensioning and to demonstrate the value of the AO community for education and surgeon mentorship.

Key Words: cerclage, large wire drill collet, wiring tensioning

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INTRODUCTION

Using cerclage cables or wires as an adjunct for fracture fixation is well described in the literature and is commonly used in periprosthetic fractures. However, its use was discouraged due to concerns regarding soft tissue and periosteal stripping leading to bone necrosis and nonunion. Anatomic studies have demonstrated limited disruption to the bone blood supply occurs when careful soft tissue handling is practiced.¹

Recently, a resurgence in the use of cerclage wiring for the treatment of subtrochanteric femur fractures and femoral shaft fractures with long oblique segments has increased,

incorporating percutaneous techniques allowing for minimal disruption of soft tissue, improved anatomic reduction of fractures, and improved fracture stability.^{2–6} In oblique and spiral fractures, the wires act centripetally on the bone to reduce the fracture and compress the fragments. When using an intramedullary nail, the hoop stresses generated with nail insertion are counteracted by the wire. When used in the setting of a subtrochanteric fracture, the wire aids to counteract the typical deforming force of flexion and abduction. This facilitates obtaining a starting site for nail insertion and fracture reduction.^{3,7} If plate fixation is used, the wires are lower profile when compared with cables and allow the plate to rest on top of the wire.

Advances in technology have allowed for improved methods of percutaneous wire placement, further limiting soft tissue disruption. Percutaneous wire passers have recently been studied and have been shown to decrease soft tissue disruption.^{4,6} Wires have several advantages over cables. They are typically less expensive, readily available in most hospitals, and are lower profile. Biomechanically, wires may be inferior to plates and cables, but one biomechanical study noted that one double looped wire was equivalent to a single cable.⁸ However, this may be of little clinical consequence as they are typically used for temporary fracture fixation during plate or nail insertion. The biomechanical properties should be negligible in these situations, as the plate or nail assumes the majority of the load.

Technique articles have described different methods for percutaneous wire fixation,^{4,6} including different wire tensioning methods. A biomechanical study comparing hand and power tensioning demonstrated that power is effective and advantageous over hand tensioning.⁹ This article will serve 2 unique purposes: describe the use of a large wire drill collet to efficiently tension cerclage wires under power, and how a worldwide surgeon education network facilitated the spread of this technique and impacts patient care around the world.

Technique

Although multiple methods and instruments can be used to perform cerclage wire passing, for this article, the Depuy Synthes (West Chester, PA) Percutaneous Cerclage Wire Passing Set was used. The overall goal was to place the wires in a biologically friendly manner to facilitate fracture reduction or stabilize the fracture after reduction is obtained. Although this technique can be applied using open or larger surgical approaches, the instruments can also be placed through

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relatively small surgical incisions, typically around 2 cm in length. Soft tissue dissection down to the level of bone can be performed per surgeon preference. For femur fractures, the authors' preference is via a subvastus approach as opposed to a trans-muscular approach although both may be used when performing percutaneous instrumentation. Once the iliotibial band is incised, blunt dissection is used to separate the vastus lateralis from the iliotibial band. The vastus lateralis is then retracted anteriorly and the muscle is elevated anteriorly from the intermuscular septum. Careful dissection is performed to identify and ligate any perforating vessels, and blunt retractors may be placed over the anterior aspect of the femur. The trochar is passed through the linea aspera to minimize errant insertion of the cerclage passer. Each of the 2 passing instruments are placed around the far side of the bone (Fig. 1) and a 1.25- or 1.6-mm cerclage wire is then passed through the soft tissue passers (Fig. 2). The passers are removed, leaving the 2 exposed ends of the wire. Typically, the wires are manually twisted via industry-specific instrumentation. Tension is held during twisting to ensure the wires twist around each other and not one wire twisting around another. However, the utilization of power is a useful method as it saves time and allows for reliable application of tension and a more uniform twisting of the wire. Previous methods have described using a quick chuck to secure both wires; however, this can be tedious.

We have found that both ends of the 1.25- and 1.6-mm wires can fit into a large wire collet (Fig. 3). The 1.25-mm wire uses the small setting and the 1.6-mm wire uses the large setting. One wire is typically left slightly longer than the other to facilitate easy insertion into the collet. The wires are placed into the collet and secured using the hand grip (Fig. 4). Tension is then pulled on the wire and the power is slowly applied (see



FIGURE 1. The cerclage wire passing device is passed around the bone, ensuring that it remains in contact with bone at all times to prevent entrapment of soft tissue and neurovascular structures.



FIGURE 2. Once the cerclage wire passing device is connected, the wire can be passed. It is sometimes helpful to use a sternal needle driver to help push the wire through the passer.

Video, Supplemental Digital Content 1, <http://links.lww.com/JOT/B305>). As long as tension is applied during power application, the wires will twist around each other (Fig. 5), and once they have formed into one unit, the collet can be advanced down close to the skin to allow for a more concentrated level of wire tensioning (Fig. 6, see **Video, Supplemental Digital Content 2**, <http://links.lww.com/JOT/B306>). The wire can be taken directly down to bone under power without the need to advance the collet; however, care should be taken in patients with poor bone quality (see **Video, Supplemental Digital Content 3**, <http://links.lww.com/JOT/B307>). As the wire luster becomes dull, the collet is removed and the final tensioning may be completed with either power (risk of wire breaking) or sternal needle drivers (Fig. 7). The wire is then cut, bent, and impacted onto the bone (Fig. 8). The wire should be bent perpendicular to the wire loop, or forward parallel to the wire loop, and in the direction of the twist of the wire.¹⁰ The process is completed as many times as needed. Finally, this technique can be done percutaneously, minimally invasive, open; the point is that it should be done in a biologically friendly manner (see **Video, Supplemental Digital Contents 4 and 5**, <http://links.lww.com/JOT/B308> and <http://links.lww.com/JOT/B309>). By placing these wires in a biologically friendly manner, they can assist with oblique or spiral fracture reduction that are most commonly seen in the subtrochanteric region of the femur and periprosthetic femur fractures. They can also add fracture stability to the overall construct.

How the AO Affects Surgeon Education and Patient Care

The second purpose of this article was to highlight how the AO (Arbeitsgemeinschaft für Osteosynthesefragen), a worldwide surgeon education network, improves patient care throughout the world through surgeon education and mentorship. When the authors began to use this technique,



FIGURE 3. Both wires can be inserted into the large wire collet and secured by grasping the handle. It can be helpful to keep one wire end longer than the other to facilitate insertion of the wires into the large wire collet.

they also started teaching others how to do it. They felt the ease and reproducibility of wire tensioning was something that other surgeons would find useful. Although this technique is frequently used by the authors, and they have passed this technique on to others, it was not developed at their institution. As they began discussing authoring a technique article, they wanted to reach out to those who taught them. This act of reaching out led to an appreciation of the mentorship that AO provides its members, which was felt to potentially be the more important message. The junior author (Kyle Schweser) was taught this technique by the senior author (Brett Crist) who practices at the University of Missouri. He was taught the technique at an AO meeting

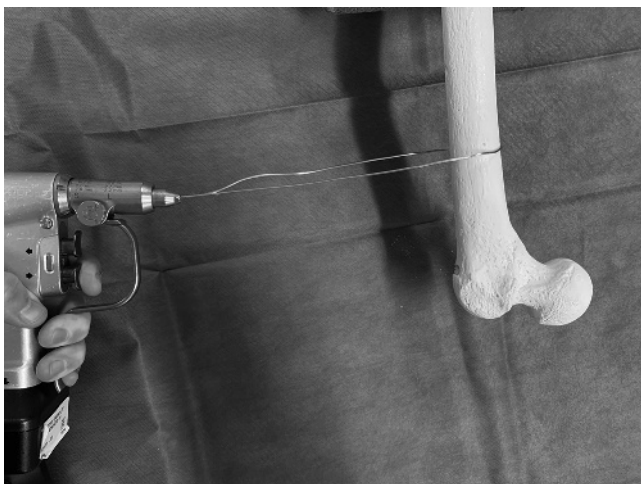


FIGURE 4. The cerclage wire passing assembly is removed before insertion of the wires into the large wire collet. Tension is then applied to the wires, and power is slowly applied to twist the wires around each other. Tension must be maintained, and pulled in line with the wires, to ensure proper twisting of the wires.

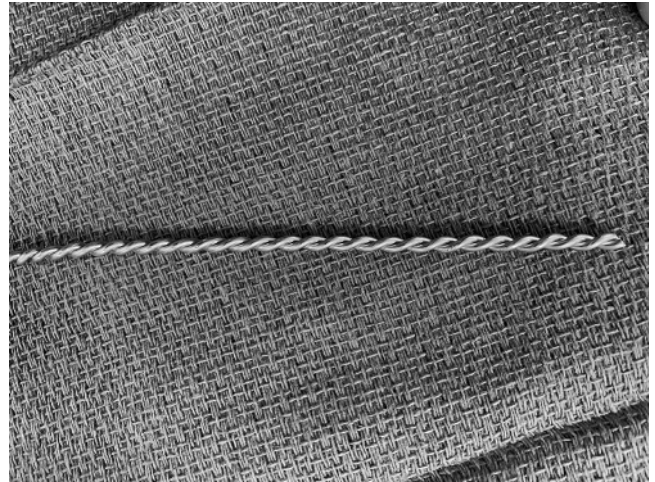


FIGURE 5. When properly performed, the wires will twist around each other in the desired fashion. One wire should not twist around the other, they should twist in tandem.

by Michael Sirkin, who practices in New Jersey, who was taught the method by his partner, Mark Reilly. This technique was taught to Mark Reilly by Karl Stoffel, who passed on the technique from Christoph Sommer, both of whom practice in Switzerland. Christoph, however, learned the technique from Dankward Hoentzsch of Germany.

The standardization of medical education has continued to evolve since the publication of the Flexner Report in the early 1900s. The second half of the 19th century saw the movement toward a more standardized, objective, competency-based educational system for both medical schools and resident physicians. Although this standardization allowed for a more ubiquitous training of high-quality applicants, it may have lost some of the personalization of medical education. The mentor/mentee model is an important aspect of medical education that can sometimes be lost in the objectives and milestones physicians are asked to achieve. A study of residents found that 96% rated mentorship as an important aspect of their training, but only 44% were satisfied with their mentoring environment.¹¹ This sentiment is not just reserved for resident physicians. Mentorship for young faculty in academic medicine was associated with higher satisfaction and academic self-efficacy scores, and programs in which a mentorship program was developed saw greater rates of retention and advancement of faculty, especially those early in their career.^{12,13}

The AO has continued to lead in the field of objective, competency-based education, with the development of courses, lectures, and other educational tools for residents and practicing physicians. However, one of the most important aspects of the AO may be its preservation of the mentor/mentee relationships, which is well represented in the above educational narrative. A simple technique of wire tensioning made its way from Germany to Missouri, not through online articles, or online technique videos, but through the AO community and the mentorship it helps to



FIGURE 6. After tensioning the wire, the handle of the large wire collet can be released, and the drill advanced closer to the bone to allow for further, more controlled twisting of the wires.

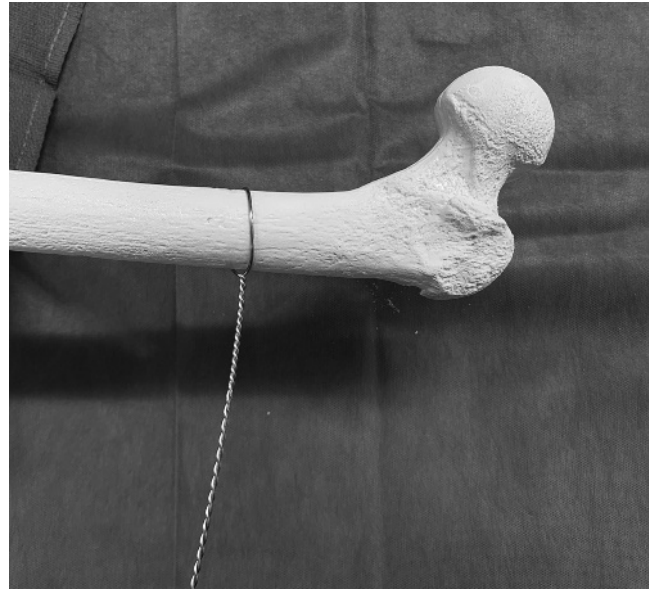


FIGURE 7. The wires can be further tightened with power, or with the use of a sternal needle driver, but the wire should be taught at the end of the procedure using a sternal needle drive, it is easier to cut the wires closer to bone to ensure that application of tension can be performed in line with the wires.

foster. It was mentors passing on techniques, who in turn, passed them on to others. It is a demonstration of how AO fosters education, not only resident and fellow education but also the ongoing education of its members through the courses and the relationships it helps promote. The connections that the AO provides help perpetuate ideas, promote thought-provoking exercises, educate, and lead to research with the overarching goal of improving patient care worldwide. Mentorship extends beyond just the mentor/pupil relationship, as shown with the above technique. It extends to those whom the pupil mentors, who then go on to mentor others.¹⁴⁻¹⁷ They extend to the colleagues who work, socialize, and educate with the pupil, who then pass it on to those that they mentor. AO allows the transfer of an idea as simple as tensioning a cerclage wire with a wire collet to extend beyond not just a hospital, but across countries and continents, and further nurtures and expands the mentorship model of education.

CONCLUSIONS

Cerclage wiring is a simple technique that, when done properly, can facilitate fracture reduction and fixation in a

biologically friendly manner. Using a standard drill pin collet can improve the efficient manner that this procedure can be performed. Through mentorship and networking, the AO facilitates surgeon education and fosters improved patient care worldwide.



FIGURE 8. After the wires are tightened to the desired amount (typically when the luster of the wire dulls), the wires are cut, twisted, and impacted on to the bone.

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