Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Education

The Past, Present, and Future of Orthopedic Education: Lessons Learned From the COVID-19 Pandemic

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ABSTRACT

The COVID-19 global pandemic has upended nearly every medical discipline, dramatically impacted patient care and has had far-reaching effects on surgeon education. In many areas of the country, elective orthopedic surgery has completely stopped to ensure that resources are available for the critically ill and to minimize the spread of disease. COVID-19 is forcing many around the world to re-evaluate existing processes and organizations and adapt to carry out business, of which medicine and education are not immune. Most national and international orthopedic conferences, training programs, and workshops have been postponed or canceled, and we are now critically evaluating the delivery of education to our colleagues as well as residents and fellows. This article describes the evolution of orthopedic education and significant paradigm shifts necessary to continue to teach ourselves and the future leaders of our noble profession.

Pre-COVID-19 Orthopedic Education

At the turn of the 20th century, surgical training in the United States underwent a significant evolution from the apprenticeship model to a more structured system in large part because of the influence of William S. Halsted, MD, FACS [1]. Halsted made major contributions after his two years in Europe and fathered the Halstedian training model giving his landmark lecture at Yale in 1904 (Table 1) [2,3]. The subsequent transformation of orthopedic resident and fellow education in the United States in the 20th century was profound. In January 1933, the American Orthopaedic Association recommended the specific composition of a board for orthopedic certification consisting of representatives of the American Orthopaedic Association, the American Academy of Orthopaedic Surgeons (AAOS), and the Section of Orthopaedic Surgery of the American Medical Association [4]. This became the American Board of Orthopaedic Surgery (ABOS) and soon thereafter the ABOS formed an Examinations Committee, an Eligibility Committee, and a Residency Training Committee. The ABOS was responsible for the evaluation of hospitals and medical schools that were educating young surgeons to become orthopedic surgeons [5].

After World War II, the Committee on Graduate Training in Surgery was the basis for the establishment of the Residence Review Committee in Surgery in 1950 [6] for the purposes of standardizing surgeon training, and the formation of the Accreditation

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Table 1
Halsted Principles of Surgical Training.

- The resident must have intense and repetitive opportunities to take care of surgical patients under the supervision of a skilled surgical teacher.
- The resident must acquire an understanding of the scientific basis of surgical disease.
- The resident must acquire skills in patient management and technical operations of increasing complexity with graded enhanced responsibility and independence.

Council for Graduate Medical Education (ACGME) in 1982 [6,7]. Since its establishment, the ACGME introduced several landmark changes in orthopedic surgical education. In 1999, the ACGME defined 6 core competencies in which residents must achieve competency during their training (Table 2) [8]. The accreditation model used by the ACGME shifted from process measures to evaluation of outcomes [8,9].

Resident, fellow, and surgeon education before the advent of computer-based learning and the digital age relied on print and face-to-face interaction for continuing medical education. This was the traditional education model that we accepted as the gold standard in the past before COVID. Learning new surgical techniques required participation in surgical cases, direct observation, travel to academic meetings, and cadaveric training. Any live surgical training post-fellowship was done by visiting surgeon programs and traveling fellowships. Maintaining up-to-date orthopedic knowledge via peer-reviewed literature was done via subscription to journals arriving via postal mail (Table 3). Digital and web-based learning platforms were not available through this period and ABOS/MOC examinations required travel to take hard copy tests. However, with the advent of the internet and the ability to share content electronically, resident education in all medical specialties has been going through a gradual transition over the past decade.

Just before the COVID-19 pandemic, orthopedic residents and fellows were primarily using digital content for their education in the form of electronic textbooks, journal articles, online presentations, and surgical videos on a variety of websites (Table 3). Web-based learning platforms have rapidly gained popularity for resident education, and in a recent national survey of American orthopedic residents, a web-based training resource was found to be the most commonly used educational resource, used by 99.5% of respondents [10]. Video-based surgical education, which has been shown to be effective [11], has grown dramatically in popularity with the advent of on-demand surgical video websites, which now host tens of thousands of surgical videos and have very large numbers of surgeon users.

Consistent with these educational trends, in 2019, the ABOS decided to offer a new option for board-certified orthopedic surgeons to keep up with their maintenance of certification in the form of the Web-Based Longitudinal Assessment (WLA) in which surgeons can now electronically review several chosen key articles and answer questions in an online examination. In the inaugural year of the WLA, 55% of eligible diplomats decided to use this format and over 95% said they were either moderately or very likely to continue with the WLA the following year [12]. Finally, even before the COVID-19 pandemic, the necessity of gathering for discussion in the way of a formal journal club meeting was being challenged with evidence supporting the use of smartphone messaging applications to lead electronic journal clubs and teach critical appraisal skills to residents [13]. The era of web-based learning, testing, and even group discussion was emerging before COVID-19 and will likely be solidified as we modify how we continue to educate ourselves as practicing orthopedic surgeons and our surgeon trainees in the midst of this challenging pandemic.

Table 2
Core Competencies for Resident Education as Listed by the Accreditation Council for Graduate Medical Education (ACGME).

Six Core Competencies
1. Medical knowledge
2. Patient care
3. Interpersonal and communication skills
4. Professionalism
5. Practice-based learning and improvement
6. Systems-based practice

Fellow and Residency Education During the COVID-19 Pandemic

The Residency Experience

The COVID-19 pandemic has forced health care systems throughout the United States to redirect available resources. Consequently, residency programs, particularly in surgical subspecialties, have responded with an abrupt shift in resident responsibilities and available teaching methods. With most residency programs completely suspending normal clinical rotation schedules and overhauling residents into alternating coverage teams [14], concerns exist regarding trainees obtaining adequate time for proper orthopedic education. Fortunately, the ABOS has swiftly and appropriately responded in these unprecedented times by increasing the "time away" from residency training activities from 4 to 6 weeks per academic year to provide flexibility, which can further be averaged over the five years of orthopedic instruction [15]. In orthopedics, many issues need to be addressed such as the milestones system, and of paramount importance will be how training institutions will adapt to provide their trainees' adequate exposure to meaningful surgical opportunities or surrogates to meet ACGME minimum case requirements necessary to graduate and sit for board examinations [16].

The ACGME addressed the COVID-19 pandemic by recognizing that each program will function in one of three stages during the pandemic [17]. As the pandemic affects each region differently, programs will fluctuate within each stage. Stage 1 is business as usual and thus no effect on requirements. Stage 2 will be implemented as clinical demands increase and some residents may be shifted to patient care duties associated with the pandemic. The effects on education will be acknowledged during this stage 2, by suspending accreditation and clinical learning environment review site visits. Supervision of residents via telemedicine is allowed but self-study activities are suspended. Virtual lectures and journal clubs are permitted. ACGME fellows will be allowed to function as attendings for up to 20% of the time, and although work hours are not affected in stage II, requirements for graduation are left to the discretion of the program director. Stage 3 is deemed Pandemic Emergency Status. Declaration of emergency status begins a 30-day period during which all educational activities are suspended. Residents are, thus, wholly available to participate in the clinical duties required by their program or hospital to prioritize patient care.

With most residencies moving to rotating schedules to protect the resident workforce and balancing the various stages of the pandemic crisis, there is an opportunity to fill that time for the off-duty resident with educational content. Because of social distancing policies, many programs have quickly implemented a virtual curriculum to discuss various orthopedic subjects in a more intimate, relaxed manner than typical weekly didactic conferences. In addition to online meetings, supplemental educational content incorporating computer-based journal clubs and modules from

Table 3
Three Types of Educational Approaches for Surgeon Education Before COVID-19.

Institutional Group Education	Travel for Group Education	Web-Based Education
• Core curriculum lectures—didactic	• International meetings (AAOS)	• E-learning modules
• Grand rounds	• National meetings (AAHKS)	• Electronic textbooks
• Visiting professor	• Regional meetings	• Web-based video platforms
• Peer review (morbidity and mortality)	• Local meetings	• Podcasts
• Journal club	• Academic journals	• Online blogs
• Research project presentations	• Maintenance of certification	• Webinars
• Textbooks	• AAOS Orthopaedic Learning Center	• E-literature searches
• Cadaveric training		

AAOS, American Academy of Orthopaedic Surgeons.

online surgical video databases, such as the Orthopaedic Video Theater (OVT) and Orthopaedic Video Theater plus (OVT plus) through the AAOS, can enhance the digital educational experience. Similar online offerings are also being offered through various subspecialty societies and industry.

Because of the overall decreased number of elective orthopedic surgeries being performed, there is an impetus to provide alternative technical tools for residents. Surgical simulations have been deployed in certain programs and are well studied for select procedures, namely arthroscopy [18,19]. Technologies surrounding simulation are currently being advanced and validated for arthroplasty-related surgical training to expand on the baseline required arthroplasty modules that are presently only mandated for the PGY-1 year by the ABOS [20]. There are additional options for increasing access to cadaver and bone-substitute simulations (Sawbones, Vashon, WA) as well.

The Fellowship Experience

After the recommendation by the American College of Surgeons that elective surgery is halted for the foreseeable future on March 13th, surgeons responsible for arthroplasty fellowships across the nation immediately saw a need for alternative methods to educate fellows [21]. Without the ability to perform hands-on surgical training and implementation of social distancing measures with several “shelter in place” orders enacted limiting the ability to meet in group settings, educators’ focus shifted to didactics and virtual case presentations. This change happened organically and quickly at the program level with regularly scheduled presentations conducted virtually as well as supplemental didactics. Soon, regional and national collaborations occurred among adult reconstruction fellowship programs to enhance educational opportunities.

The American Association of Hip and Knee Surgeons (AAHKS) Board of Directors met on March 18th, 2020, and by this time, many programs had already begun virtual didactic sessions for fellows. During this board meeting, Dr. William Hamilton, MD of The Anderson Orthopaedic Clinic in Alexandria VA, suggested to the board that AAHKS play a role in amplifying virtual lectures already happening to make them available to every arthroplasty fellow nationwide. “It was certainly not a novel idea,” explains Dr. Hamilton, “as many fellowships in the New York City area were already doing regional meetings, while other large fellowships had transitioned to virtual conferences as well.” AAHKS leadership agreed to put forth resources to meet the educational needs of fellows by establishing the Fellows Online COVID-19 AAHKS Learning (FOCAL) initiative.

The FOCAL program was designed, in part, with information gleaned from a recent survey sent by AAHKS to fellow members. Logistical considerations included opting to present lectures at a time amenable to most time-zones, understanding that clinical responsibilities were limited so early start times were not needed and that the lectures be recorded for streaming on demand. FOCAL content aimed to supplement fellowship curricula with topics on primary and revision arthroplasty including infection, periprosthetic fracture, the hip-spine relationship, and other high-yield topics for those soon going into practice.

Through gracious volunteering of time and expertise by more than 20 programs, 16 conferences were scheduled and organized by the AAHKS staff through March and April. Each lecture was a one-hour live video-based conference, including didactics, interactive learning, and questions from participants. On average, 120 participants logged into each lecture, most of which were fellows and senior residents. Feedback from participants was resoundingly positive. Highlights include the interesting regional differences in managing common complications, interactions with other fellows in an educational setting, and multiple presenters per conference so audience submitted questions could be answered in real-time while the presentation continued.

The participating fellows and presenters agreed that, although FOCAL was a productive way to supplement learning during the COVID-19 cancellation of elective surgery, virtual lectures do not replace the daily mentorship and technical skills learned in the clinic and operating room while caring for patients [22]. It is clear that collaborative, web-based lectures can add value to arthroplasty fellowship curricula in the future. Further efforts toward cultivating the FOCAL program, as well as the study of educational outcomes, are needed.

Post-COVID-19: What the Future May Hold

There is no doubt that the post-COVID-19 world will be different. Around the world across all businesses, COVID-19 is forcing us to reevaluate how existing organizations and systems carry out business, to which medicine and education are not immune. It has been said by Dalai Lama, “It is natural that we face obstacles in pursuit of our goals. But if we remain passive, making no effort to solve the problems we meet, conflicts will arise and hindrances will grow. Transforming these obstacles into opportunities is a challenge to our human ingenuity” [23]. The manner in which we pass on the orthopedic knowledge of today now faces new obstacles that must be overcome. Proximity and efficiency in relaying this information have been challenged.

Large national and regional orthopedic meetings, once a staple of educational solidarity in the past, may feel pressure to move to more virtual platforms. Annual AAOS and AAHKS meetings may become separate dedicated weeks or days in which surgeons spend time viewing advanced prerecorded lectures with integrated live surgeries and live question and answer sessions via chat rooms. Many of these developing platforms have interactive features such as chat and messaging where listeners can actively interact with the presenters, no different than traditional question and answer periods [24]. Currently, we have difficulties placing all scientific

presentations in the available lecture space at annual meetings. Now with a virtual 3D environment, this challenge might go away and lower our costs. Listening to two different papers given 5 minutes apart in different locations in the convention center, once physically impossible, is now potentially as easy as a click of the mouse.

Massive industry-sponsored technology halls could now be toured virtually with interactive face-to-face discussions experienced with industry representatives via virtual booths and endless possibilities for product demonstrations. Web-based meetings [24] have become increasingly common, as in-person meetings can be very time-intensive and costly. Virtual meeting platforms have revolutionized the way we can conduct business while decreasing time away from your home institution [25]. There exist tremendous financial savings including decreased travel, hotel rooms, convention hall space, meals, planning and setup. Newer platforms are now being investigated that incorporate artificial intelligence to facilitate pre- and post-meeting tasks and may also help facilitate live meetings [26]. These platforms allow participants to share documents, photos, and videos to enhance learning. Of course the question begs, at what cost. Medicine is a field dependent on human interactions. As a profession, we must critically evaluate whether virtual meetings are the best way to learn and whether or not these methods of learning are a detriment to surgical training? Human networking is a key component of these meetings and would certainly suffer in a virtual world if not implemented with this in mind.

Networking within the orthopedic community has already found ways to expand through the stresses of the pandemic in ways that will likely continue to foster interconnectivity, particularly in regard to education. Fellowship programs now sharing journal club responsibilities allowing for more articles to be discussed within the same period may become a staple of literature review going forward. These new dynamics allow for both increased networking among the fellows and residents at the various shared sites and the attendings responsible for providing the education. This could lead to increased and or strengthened research collaboration as well. Shared lectures and conferences among fellowship and residency programs also advance these programs out of the previously siloed educational structure to one more broadly based with national faculty. In many ways, this may serve to level and elevate the playing field for orthopedic education. Fellows and residents, regardless of which program they may train within, will now potentially gain exposure to thought leaders across the nation and not just from their home institution.

The COVID-19 pandemic has served as an effective catalyst to expand educational opportunities—particularly with respect to knowledge sharing through web-based technology. Although digital education platforms are not new, the dramatic slow-down of clinical operations has afforded many surgeons the time to engage them to connect with other colleagues and educators. Most of these efforts have effectively served noble purposes for refining understanding. But, orthopedic surgery remains a skills-oriented profession requiring expanded knowledge acquisition to be effectively complemented with technical skill development. The latter process requires repetition of movement in an environment that replicates similar conditions experienced during both primary and revision total joint arthroplasty. The coming years will likely see a maturation of several virtual learning technologies that will enhance the preparation of younger surgeons entering practice and the maturation of more experienced surgeons refining specific surgical techniques.

Surgical simulators and virtual reality (VR) platforms have been developed for total hip and total knee arthroplasty surgery [27–30]. VR creates immersive, realistic, three-dimensional environments that involve visual feedback from body movement [31]. Although primarily an entertainment tool at present, it is slowly making its way into training and education as well as surgical skills. VR can either provide augmented or mixed reality [32] and has the potential to increase participant enthusiasm in the educational activity. These platforms provide the opportunity for basic skill development and demonstrate substantial promise for the education of medical students and surgical residents. However, at present, most surgical simulators lack the definition and tactile feedback that are necessary for advanced skill development. Although these technologies may help learners to acquire the basic motions for surgical performance, they lack the tactile feedback necessary to reproduce safe and effective surgery and have not been confirmed in the application of advanced techniques used in revision arthroplasty surgery. The post-COVID-19 environment will likely stimulate an emphasis for virtual technology development that, over time, will eventually provide both the visual and tactile feedback necessary to recreate joint replacement surgical reality. Initial applications will likely occur in the areas of primary joint replacement surgery. Effective partnerships between skilled surgeons, educators, and software developers will be necessary to ensure that future platforms address surgeon needs for both basic primary joint replacement and advanced reconstruction techniques.

Cadaveric training has been used during the acquisition of new techniques for many surgeons for many years. This provides a safe environment for surgeons to learn and to apply novel techniques for their practice. Surgical procedures carry risks and have been associated with measurable learning curves. Until VR platforms have matured to a point where they replicate both visual and tactile experience, cadaveric training will remain a valuable tool for surgeons refining arthroplasty surgery techniques before their first patient engagements. Because cadaveric training can be accomplished on either an individual basis or in small groups, these remain an attractive kinesthetic laboratory.

Visiting surgeon experiences have also been used for both novice and experienced surgeons to refine their surgical expertise. A major detractor for utilization of this experience has centered on travel-related opportunity costs. Contemporary digital platforms allow for these experiences to be brought closer to home. These can allow surgeons to have the “visiting” experience with a much smaller time footprint away from their patients, practice, and family. Surgeons can acquire the surgical observation experience at a much lower opportunity cost. When coordinated with other surgical skill development tools, video surgeon visiting experiences may help to complete a remote/isolated surgeon training experience.

Surgeons desire and benefit from interpersonal connection and mentoring. Digital platforms and virtual experiences can provide some of the basic pathways to becoming a better surgeon. Ultimately, these technologies will still need to be complemented by face-to-face interaction and fostering relationships, even if it occurs with more limited direct contact in the months and years that follow the current pandemic response. Virtual and digital platforms are here to stay and will require a learning curve inherent with all new technology. As noted by a fellow surgeon, Dr. Atul Gawande, “Better is possible. It does not take genius. It takes diligence. It takes moral clarity. It takes ingenuity. And above all, it takes a willingness to try” [33]. Let us make sure that however we move forward, we do so with safety in mind for all of us and also keep the traditions and mission of our society alive.

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