See one—practice—do one—practice—teach one—practice: The importance of practicing outside of the operating room in surgical training

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Central Message

The virtue of practice is a logical and ethical necessity in surgical training and can be accomplished via numerous simulation modalities of varying complexity.

See Editorial Commentary page 678.

Video clip is available online.

“See one, do one, teach one” summarizes the traditional teaching model in medicine whereby trainees are expected to rapidly transition from observers to actors to teachers. However, as we enter an era of increasing pressures impacting residency training,¹ practice outside of the operating theater can, and should, play an increasingly significant role in bridging the conceptual and technical gaps between seeing, doing, and teaching something for the first time.

The importance of practice has long been recognized across various high-performance disciplines. It is widely considered a veritable form of art and science essential, even mandatory, to success. A recent *New York Times* article entitled, “J.J. Redick, the N.B.A.’s Most Meticulous Player” detailed the arduous and persistent practice habits that have made Redick one of the most productive and indispensable veterans in the league.² After each workout, he completes the same shooting drills: 35 jump shots from predetermined locations along the 3-point line, 28 3-pointers “off the dribble,” 4 “catch-and-shoot” 3-pointers from each wing, and 10 free throws. Before each game, he performs the same stretches, dribbling routines, and shots he anticipates attempting in the game. For Redick, these drills prepare him for the game both physically and mentally, enabling him to perform at his best despite the complex and unpredictable nature of the game.

Parallels between elite athletes and practitioners of other technically demanding, high-stakes fields such as cardiothoracic surgery have been drawn.¹ Here we focus on the

virtue of practice from the perspective of 2 young trainees and aspirations to master cardiothoracic surgery in today’s training atmosphere. The subject is timely as the training paradigm shifts toward integrated pathways, where medical students match directly into this technically demanding field. We present an overview of the theory and multidisciplinary examples of practice and how it is currently regarded in modern surgical training. We then discuss the tangible benefits of practice in surgical training, especially practicing on one’s own time outside of the operating room (OR), and propose ways the current culture can integrate the virtue of practice toward a more clinically and ethically favorable direction (Video 1).

SURGICAL TRAINING: THEN AND NOW

The Halsted model for surgical education was established in the late 19th century, marking the first systematic, graduated approach toward helping trainees attain expertise and autonomy. Combined with subsequent efforts by various national organizations to outline core competencies, these measures became the foundation of the surgical educational system as we know it.³ Although this method has been largely successful in ensuring high-quality training over the past century, trainees in the modern era face increasingly stringent learning conditions.^{4,5} On the one hand, they are required to master an ever-expanding repertoire of skills, a task compounded by the rapid integration of newer and more complex technologies. Information is more abundant

VIDEO 1. The authors discuss the motivation behind and the main topics covered in the article. Video available at: [https://www.jtcvs.org/article/S0022-5223\(18\)32471-1/fulltext](https://www.jtcvs.org/article/S0022-5223(18)32471-1/fulltext).

and more accessible than ever, rendering mastery across a variety of topics ever-elusive. On the other, there are fewer hours and opportunities for learning and trainee autonomy, driven by pressures at the system level toward restricting work hours, meeting quality assurance targets, reducing errors, and optimizing operating room efficiency.^{1,5,6}

Balancing these multiple demands has been no easy task. Greater work hours have been associated with decreased well-being and safety for both patients and staff, a dangerous proposition in a profession already plagued by alarming rates of depression, burnout, and suicide.^{7,8} Yet, contraction of duty hours has not yet demonstrated significant improvement in patient safety and resident learning.⁹ As many as 27.5% of recently surveyed general surgery residents expressed concerns over lacking confidence in independently performing procedures.¹⁰ Some reports even suggest restricted work hours increase complication rates in high-acuity fields, such as cardiothoracic surgery.¹¹ To render surgical excellence even more

difficult to achieve, what little time trainees have for learning is further compromised by unprecedented levels of distractions from portable electronic devices and other alerts, obstructing attention, focus, and clarity of thought.¹²

This conundrum whereby trainees must learn more during less time represents the fundamental challenge in contemporary surgical education. How do we maximize efficiency in learning, even as the crucible of training exerts its multiple pressures? In addition to ensuring a high volume of patient encounters and procedures, how do we ensure each experience is extensive and immersive^{13,14}? Various solutions have been proposed, ranging from curricular changes to the use of simulation training. Yet, although these measures touch on the need to innovate training methods, few studies have explicitly addressed the topic of practice as a virtue and an incontrovertible element of performance in surgery.

THE GROWING EMPHASIS ON PRACTICE IN ACHIEVING EXCELLENCE

“The concept of talent hinders a clear understanding of excellence...it satisfies our casual curiosity while requiring neither empirical analysis nor a critical questioning...”

—Chambliss et al, “The Mundanity of Excellence”

Although earliest accounts of exceptional individuals attribute their success to divine influence, as science progressed, people began to seek other, more tangible and reproducible explanations behind excellence. Instead of looking for extrinsic factors (eg, divine), scientists and performers began to espouse a different narrative for these top performers, one that relies on an interplay between innate and developed qualities. The former acknowledges the value of genetic variation, talent, and evolution. The latter recognizes the value of hard work, practice, and perseverance.

Although talent and practice have always been inextricably interwoven as ingredients necessary for success, a substantial body of evidence has since emerged delineating the different degrees of influence these 2 attributes have. Miles and Miles¹⁵ first noted a lack of correlation between higher IQ and success among 300 eminent historical figures they analyzed. Since then, countless studies have reaffirmed that the virtue of practice, not innate talent, may be a more important driver of mastery in the long term.¹⁶⁻¹⁸ It is not sheer duration of training history that leads to success necessarily; studies suggest that achieving true mastery requires “deliberate practice,” a concept developed by Ericsson and colleagues^{19,20} describing “a regimen of effortful activities designed to optimize improvement” with specific goals, intrinsic focus, self-reflection, and

appropriate feedback. Of note, the important distinction is “practice” may include independent work, whereas “deliberate practice” involves that which is paired with appropriate feedback.²¹ The degree to which it is deliberate may determine the degree to which practicing is effective.²²

In recent studies conducted by Duckworth and colleagues,²³ various metrics were used in trying to predict success among participants across various domains, ranging from elementary school classrooms to West Point Academy. Perhaps not surprisingly, above any measure of talent, grittiness—a positive psychology trait defined as a combination of passionate and sustained motivation toward a long-term goal—was among the most important predictors.^{23,24} Importantly, Duckworth notes grittiness can either be innate or acquired. Trainees, therefore, not only possess some grit at baseline but also have remarkable potential to further expand this trait and apply it to their work with appropriate guidance. Together, these findings suggest success can be engineered, a lesson directly translatable to the field of surgery.

Benefits of Practicing for Surgical Trainees

The benefits of practice in augmenting performance are self-evident and have been thoroughly documented across various fields. Yet in a domain as multidimensional as surgical training, there are several, less-obvious benefits of practicing that may escape our notice at first yet are equally paramount to trainees' success.

First, deliberate practice can increase the efficiency of surgical education. It can concentrate one's attention and use of time on perfecting specific skills. In Brazil, a popular game called “futsal,” a modified version of soccer that is played on a hard surface about half the size of a basketball court with a heavier ball and smaller goal, has had a tremendous impact on training by creating a faster game tempo. This allows each to player touch the ball 6 times more often than in a traditional game of soccer, enriching practice time to perfect their handling skills.¹⁸

The lessons from futsal can be translated into surgical training and have already been successfully incorporated into the Thoracic Surgery Directors Association Boot Camp models.²⁵⁻²⁷ Trainees can specifically focus on improving their coronary anastomosis technique, for instance, by participating in massed deliberate practice with high-repetition and constant-feedback. Reserving component practice, such as anastomoses, for only when conducting the entire operation from skin-to-skin would inherently limit learning efficiency. In that same amount of time, conducting drills would enable one to repeat the task many times over, each iteration improving on the previous with improved muscle memory formation.

Furthermore, it can help internalize and form muscle memories around basic, mechanical tasks involved in the operation, in turn creating more mental space to take away

more nuanced and sophisticated learning points from each operation. Each case under the guidance of an attending surgeon can only offer as much learning as a trainee is prepared to extract. Preparation for a case outside of the OR optimizes one's learning curve inside the OR. In addition to allowing trainees to learn more effectively, display of competence and preparedness are also the keys to unlocking greater levels of responsibilities and autonomy. In a large, multi-institutional study, which analyzed factors influencing the degree of autonomy afforded by attending surgeons to residents, the number one predictor was the quality of the resident's operative performance in that case.²⁸

Lastly, and less tangibly, the benefits of practicing extend to the creative realm. By increasing sheer exposure or time grappling with a subject, practicing can lead to experimentation and unforeseeable paradigm changes.²⁹ In June of 1944, stationed in France during World War II, Dwight Harken became one of the pioneers of cardiothoracic surgery by successfully removing shrapnel from the hearts of wounded soldiers, operating on injuries that had been deemed unsalvageable by many before him. What made him successful? Before the war, Dr Harken had spent countless hours in his Harvard laboratory, creating an animal model for valvular vegetations. He had learned how to spear a dog's mitral valve with a dirty safety pin, and more importantly, to remove it without killing the animal. What enabled Dr Harken to save the lives of those soldiers was not a momentary brilliance or luck. It was innumerable hours of practice that prepared him with insight and dexterity for when future life-saving opportunities arose.³⁰

Currently Available Evidence-Based Options for Practicing in Surgery

Various tools are currently available in the armamentarium of surgical education. Simulation is a natural instrument for practice, both independent and deliberate, outside of the operating room. Its most basic schema uses the categories of “simple bench model,” “virtual reality simulator,” and “human performance simulator.” A simple bench model provides a simple, inexpensive model for component practice but lacks the complete surgical experience. A virtual reality simulator model provides computer-based simulation, usually of minimally invasive procedures, with little downtime between simulation sessions and immediate module feedback. A human performance simulator model attempts to simulate the entire surgical experience through a combination of physical and electronic interfaces and may offer the most clinical variation, although it is expensive and laborious to set up.

Additional categorizations include “low fidelity” and “high fidelity.” A high-fidelity simulator may be defined as incorporating hemodynamics or other task-specific feedback, whereas low-fidelity simulators generally do not provide dynamic feedback (eg, simple bench tissue model),

although there is no consensus on this. There are dozens of simulators currently on the market across each of these categories that allow for simulation of cardiovascular procedures, general thoracic, and endovascular procedures. Trehan and colleagues³¹ provide a wonderful summary of these tools with references to manufacturers for those interested in obtaining them. Additional models using fresh human or animal cadavers, living animals, and 3-dimensional printing also have been proposed.

Use and usefulness of these simulators have been studied in the field of cardiothoracic surgery. A recent systematic review identified 16 simulation-based studies in which technical skill acquisition was objectively measured.³² The majority of skill training focused on coronary artery anastomosis (45%), cannulation (15%), aortorrhaphy (10%), mitral valve (10%), and robotics (10%). The majority of studies used "low-fidelity" synthetic or tissue-based models. Live animals were used in one study. Subjects ranged from junior- to senior-level trainees in cardiothoracic training. In almost every instance, the benefit of simulation to acquisition of skill was significant, as evidenced by high effect sizes (2.2; standard deviation 1.6). The benefit was greatest among junior residents (2.8; standard deviation 2.2).

The "Bootcamp" model across various procedural aspects, including coronary artery anastomosis, hilar dissection, and managing cardiopulmonary bypass, has been trialed at the national level.²⁵⁻²⁷ Skills assessed included "respect for tissue," "instrument handling," "quality of vessel isolation," "needle angles," "needle transfer," "suture management," etc. When rated by expert surgeons, resident performance with the technical aspects of each of these tasks improved significantly after only 4 hours of simulation. In the case of hilar dissection, residents improved significantly with only a single repetition of the task. When assessed, residents rated the usefulness of the simulation extremely positively.

More comprehensively, a multi-institutional effort by Feins and colleagues³³ studied the impact of a longitudinal simulation-based curriculum among cardiothoracic surgery trainees, focusing on principles of component task training and deliberate practice. A 29-week program organized into 6 modules, each involving multiple sessions of graduated complexity, resulted in clear improvements in performance and was well-received among trainees and faculties alike.³⁴ These studies, which culminated into a proposed curriculum with the Thoracic Surgery Directors Association, may serve as the blueprint for an imminent transformation in the education of future Cardiothoracic Surgeons.

Establishing the Importance of Practicing in Surgical Education

As trainees, we see firsthand the importance of practicing and simulation. Thus, we aspire to further incorporate the

virtue of practice, both independent and deliberate, into our training experiences as an indispensable, core component. Currently, an emphasis on extraoperative practicing is not universally shared or endorsed among trainees and educators. What we currently face is not a problem of cost, evidence, or technology but rather an absence of culture. After all, even low-cost, low-fidelity simulators are proven to be highly effective for trainees.³² Indeed, the majority of surgical programs have made investments to ensure the availability of equipment and time for simulation training.

The final barrier to implementation is psychological and behavioral. No matter how available or sophisticated simulation technology becomes, it must be used to derive benefit. To this end, we propose 3 simple ideas that can help further integrate the virtue of practice into our field:

1. Embrace it as a core part of training philosophy and culture. It is vital to recognize and embrace the value of practice, as no meaningful change in education can happen until we overcome this psychological bottleneck. In the aforementioned study by Fann and colleagues, residents reported the coronary anastomosis they learned at Bootcamp continued to provide a basis for training at 6-month follow-up; however, only slightly more than half continued to practice outside of the operating room.²⁵ Distributed and deliberate practice requiring persistent and gritty investment of time and energy is far more effective than any isolated Bootcamp session or massed practice. Unless we cement a habit of practice, attrition of skill is inevitable.

Changing culture requires commitment from educators as much as from trainees. Effective feedback and assessment provided by faculty are just as instrumental to skill acquisition as trainees' motivation to practice. Beginning in 2010, The Joint Council on Thoracic Surgery Education has held annual training sessions to help faculty provide high-quality assessment and feedback to residents. Attendance at these sessions includes faculty from nearly every cardiothoracic surgery training program and has grown each year.^{35,36}

We must come to regard practice as a stand-alone ethical imperative. As surgeons, our operative readiness has direct consequences for our patients' well-being. The privilege we hold in being able to operate on another person's body should inspire our commitment to hone our skills to the highest extent. As trainees, before simply pursuing more cases, or time operating, or autonomy, perhaps we ought to first ask ourselves, are we doing the most we can do on our own to demonstrate our commitment to self-improvement and patient safety? To draw analogies from athletes and musicians, both independent and deliberate practice are distinguished from their time to perform in a match, concert, or competition. Practice comprises the majority of their work, preparing them for the rare opportunities to showcase their skills. The current culture in surgical training seems to be inverted from

these other disciplines, regarding operative experience as the dominant, preferred and even exclusive form of practice. Somewhat ironically, surgery also happens to be the only discipline in which poor performance can lead to harm that extends beyond personal failure to the well-being of other individuals.

There are many aspects of our performance that can be addressed independently if we choose to look for them. Once we instill this notion into the training philosophy, it can serve as a foray into discussions regarding future changes in training policies or curriculum design. How much time practicing should be spent inside versus outside of the OR? Should there be a minimum standard of competencies or a number of simulated skills acquired before ever doing something, possibly for the first time on a patient?

2. Create drills. Once we embrace the value of practice, we must also recognize that not all practice is equal. Perfect practice needs to be targeted and deliberate. It has to be challenging enough to not feel mundane yet manageable enough to not overwhelm. It demands focus, attention, and freedom from distractions.¹² Simply operating more may not be the answer to the challenges that current-day trainees face in becoming better surgeons. Deliberate practice incorporates moments to review, to identify, and to practice areas of weakness in a meticulously organized and systematic manner.

Drills are focused, repeatable tasks designed to address specific aspects of one's performance. The utility of using drills to practice is predicated on the advantages of breaking down complex objectives, such as conducting operations, into concrete learning goals that can be rehearsed, honed, and measured. They can help address specific areas of weakness, which are difficult to isolate and often ignored in the context of high-stake, complex scenarios, much like the results demonstrated by Feins and colleagues³³ in the simulation curriculum study.

Some of the critical factors in creating successful drills have been to incorporate clear instructions and objective feedback across several domains of performance. Progress is gained through repetition and persistence. These elements have been instrumental to success across all domains in surgery, including niche curriculums such as fundamentals of laparoscopic surgery and da Vinci Skills Simulator.³⁷ Although a strong body of literature supports the efficacy of drills, these endeavors are highly resource-intensive. The Simulation Curriculum requires a relatively high-cost setup, a collective window of free time among residents protected from clinical duties, and dedicated faculty available to teach. These constraints may render these initiatives only appropriate or available for residents at specific stages or during critical transitions in their training.

One solution to this issue is to supplement resource-intensive simulation opportunities with a different set of

drills—low-cost, low-fidelity exercises one can practice independently in virtually any setting. Some of the most effective, yet underused, drills can also be the simplest. These drills would aim to reinforce certain fundamental operative techniques commonly used in cardiothoracic surgery, especially at earlier stages of training. Such drills can isolate basic mechanical or cognitive skills and help trainees perfect them. Examples of mechanical skills would include tying knots into a deep cavity or needle driving across a spectrum of angles. Examples of cognitive skills would include rehearsing the ability to space sutures evenly or approximate the appropriate length or bevel of a conduit.

Such componentization means these simple drills bear little resemblance to the more complex tasks required in an actual operation, but in fact, this is what makes the drill so powerful. One component skill may have a role in many of the complex tasks required of a real operation, therefore impacting and improving one's overall performance in an efficient way. The legendary UCLA basketball coach John Wooden attributes his success to a similar philosophy in which he focused meticulously on drills which honed fundamental skills—a so called “socks first” mentality.³⁸ Fundamental preparations and extreme reductionism were the hallmark of his practices. Players would drill basic skills such as “balancing” and “stopping and turning.” The basketball would be conspicuously absent in others drills such as “imaginary shooting” and “imaginary rebounding.” Even after introducing a basketball, his drills would remain rudimentary, such as “dribbling one-handed (left and then right)” and “jump shot and pivot.”

3. Create systems around coaching and measurement of trainee progress. Fitts and Posner³⁹ postulated their foundational model for 3 stages of motor skill acquisition: cognitive, integrative, and autonomous. The first stage involves wrapping one's mind around the mechanics of the task. The second brings together the separate elements into one entity, requiring a great deal of concentration and consciousness. The final step, the autonomous stage, results in a well-rehearsed and smooth performance even in the absence of intense focus. In order for trainees to progress along these stages, expert guidance and coaching are essential. Yet, currently in cardiothoracic surgery, trainees and attending surgeons lack a shared lexicon for communicating needed-areas for practice and growth, in part because the culture of deliberate practice is in its nascent stages.

By creating expectations around self-practice and well-defined drills, senior surgeons can direct trainees to work on specific skills related to the operation. What if at the end of each operation, the attending surgeon routinely asked the trainee to focus more on practicing x, y, or z before the next operation? Whether it be something as simple as practicing tying knots into a deep cavity or as advanced as gaining proficiency with specific needle angles required in

mitral valve operations, constructive and practical feedback can help trainees identify and overcome areas which they find challenging. Especially at relatively junior stages of training, these pointers can help solidify basic mechanical tasks into the trainees' skillset, rendering it more autonomous. Over time, the cycle of feedback, practice, and acknowledgement of skill acquisition will provide more structure and augment the quality of the teacher–trainee partnership.

Limitations

Some critics suggest practice is only beneficial insofar as it bears fidelity to real-life scenarios. Isolated drills would fail to encapsulate the more complex, dynamic, and nontechnical aspects of the operation such as teamwork, communication, judgment, and leadership.^{40,41} Dearani and colleagues⁴² astutely noted the importance of improvisation in surgery, especially in less-structured or routine operations, which may require creating or reconstructing structures. Although these critiques are valid and the optimal simulation models for rehearsing such dynamic abilities remain to be explored, they should not deter participation among trainees for the following reasons. Replicating complex operations is not the primary or sole purpose of simulation. The benefits of conducting drills are to be able to provide trainees with focused, individually tailored tasks in low-risk, low-pressure circumstances, such that these techniques become second-nature, and can augment the overall efficiency and efficacy of their training experience. As Dearani and colleagues⁴² write, mastery entails handling basic motor functions without explicit attention, allowing greater focus on higher-level parameters.

Another limitation of practicing is it is inherently time-consuming, which is not an easy prescription for any trainee who must constantly struggle to navigate both the professional and personal demands of the role. However, this need not be a deterrent as even a modest daily investment—as little as 15 minutes—can lead to surprisingly significant improvements over time. Furthermore, practicing should theoretically help trainees operate and learn more efficiently, thus creating more free time in the long run. Even when finding time becomes a challenge, a change in culture to practice more outside of the OR is ultimately a reconsideration of its priority: we must try our utmost to make time for what is essential to our development towards excellence.

CONCLUSIONS

The timeless adage, “see one, do one, teach one,” too often falsely implies trainees can undergo these dramatic and rapid transitions as if by tremendous, inexplicable leaps. Instead we contend it ought to read, “see one, practice, do one, practice, teach one, practice,” correctly capturing the constantly essential role that practice plays at each stage. Facing the challenges of the current era of surgical training,

practice should not be considered a point of weakness but rather one of pride and ethical responsibility. Endeavors to incorporate practice routines involving skill acquisition and assessment into the national curriculum may be of interest to the community and should be further explored.

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