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ONLINE ARTICLES

Shoulder arthroscopy: a bridge from the past to the future

Stephen S. Burkhart, MD*

The San Antonio Orthopaedic Group, Burkhart Research Institute for Orthopaedics (BRIO), San Antonio, TX, USA

This article constitutes the text of the Codman Lecture, delivered by the author to the attendees of the International Congress of Shoulder and Elbow Surgeons on September 19, 2019, in Buenos Aires, Argentina.

Keywords: Shoulder arthroscopy; rotator cuff repair; history of shoulder surgery; shoulder instability; Codman Lecture; history of shoulder arthroscopy; legacy

Ladies and gentlemen,

I'll issue this warning at the beginning: some of you in this audience might be taking up too much space. Now, I don't want you to get the wrong idea. This is not an insult. This is not a reference to your size or weight. It is not an observation about your intrinsic value. However, it is a call to selectively embrace the developing edge of technological advancement.

There's an old Texas adage: "If you ain't sittin' on the edge, you're takin' up too much space." People instinctively see the truth in this statement because, after all, life is more exciting on the edge.

We need to have the surgeon's view of technology, a view in which we honor the past but embrace the future. As for future technology, we need to have a selective embrace, one that is tempered by respect for the surgeon's craft.

Clayton Christensen, in his book *The Innovator's Dilemma*,[23] has emphasized that technology can be an agent of change: change that can take the form of either enhancement technology or disruptive technology. Enhancement technology provides incremental improvements gradually over time, whereas disruptive technology produces sudden drastic changes in the way things are done, ultimately resulting in paradigm shift.

The burden of craft is a term that I came across while reading *Why Things Bite Back*, by Edward Tenner.[42] As it relates to surgery, the author specifically defined this burden as the surgeon's obligation to use his craft for the patient's greatest benefit. In other words, this burden of craft creates the obligation for the surgeon to provide state-of-the-art care by exercising the highest degree of surgical craftsmanship.

In looking at our own field of shoulder surgery, it is evident that the burden of craft has evolved over the years. For example, if we examine the evolution of treatment of rotator cuff tears, it is interesting to see how we have transitioned and arrived at today's state of the art.

I think we can all agree that the era of modern shoulder surgery began with Dr. E. Amory Codman, and I believe that this fact is particularly important to emphasize in the Codman Lecture. Codman was a tenacious man. After he wrote his masterpiece *The Shoulder*, he could not find a publisher for the book, so he self-published it at

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*Reprint requests: Stephen S. Burkhart, MD, The San Antonio Orthopaedic Group, Burkhart Research Institute for Orthopaedics (BRIO), 150 E. Sonterra Blvd., Suite 300, San Antonio, TX 78258, USA

E-mail address: V_ruelas@yahoo.com (S.S. Burkhart).

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considerable personal expense.[24] He was a meticulous record keeper, as evidenced by a graph in his book that showed how many rotator cuff repairs he did over the years. Interestingly, Codman did not perform as many rotator cuff repairs as you might think. There were a number of years in which he did not do any cuff repairs, and the highest number he ever performed in a single year was 8. But that was enough to ignite the interest and enthusiasm of followers that carried this type of surgery into the next generation.

One striking example of the next stage of development of rotator cuff surgery was the book by Dr. James Bateman entitled *The Shoulder and Environs*, [2] published in 1955. In that book, Dr. Bateman described his ‘‘maxi-open’’ rotator cuff repair, which used a generous shoulder strap incision, an acromial osteotomy, and a fascial autograft incorporated into the repair. If the patient was lucky enough to survive an operation of that magnitude, he was kept in the hospital for 3 weeks of supine bed rest with the operated shoulder suspended in traction at 90° of abduction. If the patient subsequently survived those 3 weeks of bed rest in traction, he was then placed in an airplane splint with the arm at 90° of abduction for an additional 3 weeks.

Now let’s fast forward to 2019, where arthroscopic rotator cuff repair is now the standard of care. Arthroscopic repair is a very patient-friendly surgical technique: an outpatient minimally invasive technique that patients have come to expect and demand. The transition from maximally invasive open repairs to minimally invasive arthroscopic repairs might seem, in retrospect, to be an obvious and almost preordained progression. But this transition did not occur without conflict.

Conflict is certainly a consequence of paradigm shift, and there was no shortage of conflict during the evolution from open to arthroscopic rotator cuff repair. When a small group of us began doing arthroscopic instability repairs and arthroscopic rotator cuff repairs in the 1980s and 1990s, Dr. Charlie Rockwood was calling the arthroscope ‘‘the instrument of the devil.’’ At that time, Dr. Rockwood was one of the most influential opinion leaders in the world of shoulder surgery, so the headwind created by his disapproval was a difficult one to overcome. Adversity was a factor that we had to face on a daily basis, so we had to develop a philosophical acceptance of adversity.

Facing adversity

> ‘‘When everything seems to be going against you, remember that the airplane takes off against the wind, not with it.’’
>
> Henry Ford

In the early 1980s, we were adapting knee instruments for use in the shoulder, but we were limited to excisional cases such as removal of loose bodies or excision of a bucket handle tear of the superior labrum (type III SLAP lesion). However, useful crossover instrumentation from the knee to the shoulder was quite limited, as the requirements for shoulder surgery were primarily reconstructive (rotator cuff repair, Bankart repair) rather than excisional.

A pivotal moment occurred for me personally in 1984 when I was attending Dr. James Esch’s San Diego Shoulder Course. At that meeting, Dr. Harvard Ellman of Los Angeles showed me how he had recently begun to perform arthroscopic acromioplasty with a motorized burr after creating a virtual space subacromially. As soon as I saw how effectively this virtual space enhanced visualization of the rotator cuff as well as the acromion, I realized that it would only be a matter of time before we would be able to perform arthroscopic rotator cuff repairs.

By 1987, I was doing side-to-side rotator cuff repairs arthroscopically, using homemade ‘‘custom’’ suture passers and knot pushers. These early instruments were made to my specifications by a local aircraft machinist because the large orthopedic instrument companies had no interest in making arthroscopic shoulder instruments. I had previously met with product managers, engineers, and executives from several large orthopedic device companies, and they all told me that they did not think there would ever be a market for shoulder arthroscopy and therefore they were not interested in pursuing my ideas. So I continued to use my locally produced instruments for arthroscopic repairs in progressively more effective ways. And I was doing this across town from Dr. Rockwood in San Antonio, Texas, which at that time was definitely the single most hostile point in the universe for shoulder arthroscopy.

By the early 1990s, there was a small group of arthroscopic shoulder surgeons that were pushing the envelope of what could be done arthroscopically. We all faced similar adversity and opposition locally, nationally, and internationally. We jokingly referred to each other as shoulder pariahs, and we all became good friends as we worked to improve shoulder arthroscopy’s instrumentation and techniques. This early camaraderie led to lifelong friendships with surgeons such as Steve Snyder, Jim Esch, and Lanny Johnson.

At that point in time, we were extremely enthusiastic about shoulder arthroscopy, but we failed to recognize that we were at the beginning of a major paradigm shift in shoulder surgery.

Thomas Kuhn, in his book *The Structure of Scientific Revolutions*,[33] coined the term *paradigm shift*. He observed that those individuals who initiated paradigm shifts were often young and naïve, and that they were typically outside the power structure of their discipline. These observations certainly held true for this small group of shoulder arthroscopists in the early 1990s: we were mostly young and very naïve, and we were certainly outside the power structure of shoulder surgery. Ironically, our status as outsiders protected us to some degree, as there was not much that the powerful insiders could do to hurt us. So we continued to do what we thought was right for our patients.

From disdain to disruption to transformation

> "First they ignore you.
> Then they laugh at you.
> Then they fight you.
> Then you win."
>
> Mahatma Gandhi

By the early 1990s, there was a quest for more sophisticated instruments and implants. Some of the smaller medical device companies recognized what the larger companies had not appreciated several years earlier: that shoulder arthroscopy represented the future of shoulder surgery and that there was indeed a vast market on the horizon that these companies could potentially tap into. These companies began to work with surgeons to dramatically expand the breadth of arthroscopic shoulder procedures. The disruption had begun; the paradigm shift was underway.

Collateral burdens of craft in the development of shoulder arthroscopy

Let's return for a moment to the concept of *the burden of craft*. As I said earlier, this term refers to the surgeon's obligation to provide the best possible care to his patients. However, in addition to that basic obligation, there were additional burdens of craft that had to be assumed by those surgeons participating in the development of shoulder arthroscopy.

To begin with, there was the *burden of craft in paradigm shift*. If surgeons were going to propose a shift to a radically different technology, they were obligated to prove that the new technology was biomechanically as good as or better than the old technology. That meant biomechanical studies and benchwork needed to be done to test the hypothesis that the arthroscopic constructs were as strong as the open repair constructs.

I had an undergraduate degree in mechanical engineering, so I took it upon myself to perform studies on knot security and loop security. I also devised a series of experiments to compare cyclic loading strength of arthroscopic anchor-based rotator cuff repairs to the strength of open cuff repairs through bone tunnels (the gold standard at the time).[8,11] These studies showed that the arthroscopic anchor-based cuff repairs were stronger than the bone tunnel repairs and furthermore demonstrated that the anchors shifted the weak link of the construct from bone to the suture-tendon interface. This latter finding spurred additional studies in an attempt to improve the suture-tendon interface strength with constructs using margin convergence, double row repair, and load-sharing rip-stop repairs.

Another collateral burden was the *burden of craft in arthroscopic identification*. Arthroscopically, we were seeing things that had never been seen before. We were approaching the shoulder from inside out rather than outside in, and for the first time, we were seeing the anatomy of the interior of the shoulder without traumatically altering tissues on the way in. We had to decide what was normal and what was abnormal. We were seeing structures such as the *comma tissue* adjacent to the superolateral corner of the subscapularis tendon.[36] We were initially mystified by the appearance of the *rotator cable/crescent complex*[9] (Fig. 1). What was its function, and how did that relate to its structure? (Fig. 2). Further investigation produced the suspension bridge analogy for the rotator cable (Fig. 3) and confirmed the importance of reinforcing the rotator cable attachments during routine arthroscopic rotator cuff repair.[13,19]

Next, there was the *burden of craft in the dissemination of arthroscopic knowledge*. As arthroscopic surgeons, we were boxed out of mainstream journals, which had no interest in publishing our research. So we had no choice but to start our own journal, *Arthroscopy*, in 1984. I have special appreciation for the dedication and tenacity of Dr. Gary Poehling, the journal's second Editor-in-Chief, for almost single-handedly taking it from a very basic, rudimentary journal to a world-class publication with a high impact factor.

Another important collateral burden assumed by early shoulder arthroscopists was the *burden of craft in developing the language of arthroscopy*. We were seeing anatomic

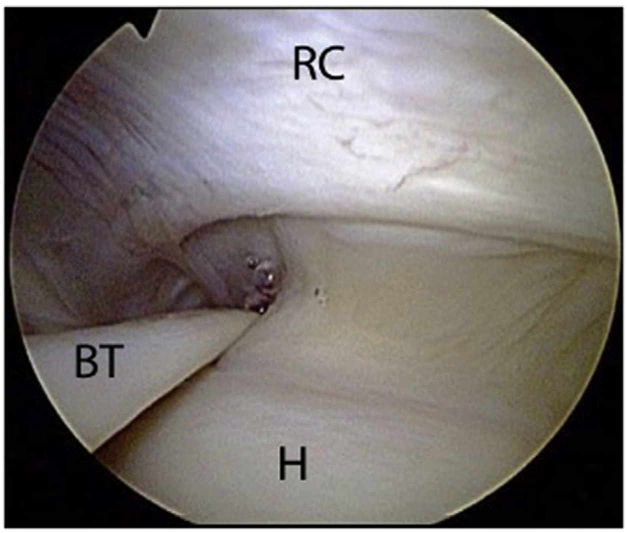

Figure 1 Arthroscopic view of a right shoulder demonstrating a cable-like thickening of the capsule surrounding a thinner crescent of tissue that inserts into the greater tuberosity of the humerus. *BT*, biceps tendon; *H*, humeral head; *RC*, rotator cable. Reproduced with permission from Burkhart et al.[14]

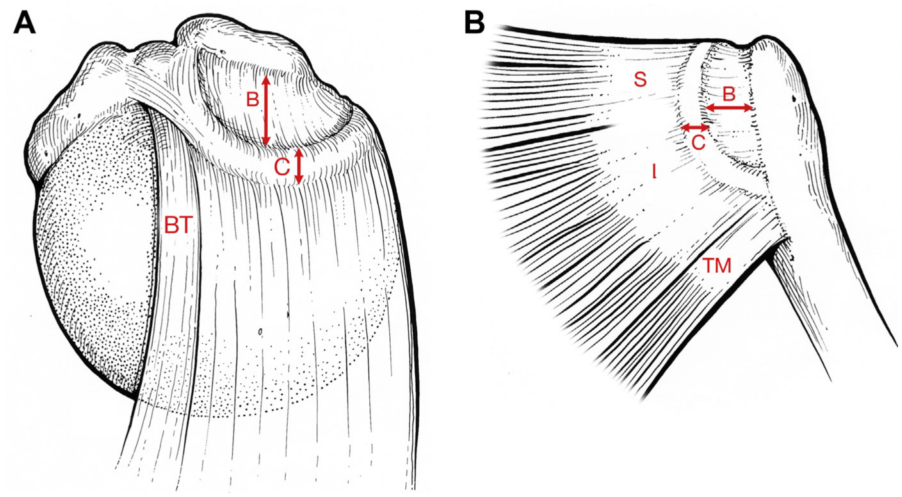

Figure 2 Superior (**A**) and posterior (**B**) projections of the rotator cable and crescent. The rotator cable extends from the biceps to the inferior margin of the infraspinatus, spanning the supraspinatus and infraspinatus insertions. *C*, width of rotator cable; *B*, mediolateral dimension of rotator crescent; *BT*, biceps tendon; *I*, infraspinatus; *S*, supraspinatus; *TM*, teres minor. Reproduced with permission from Burkhart et al.[12]

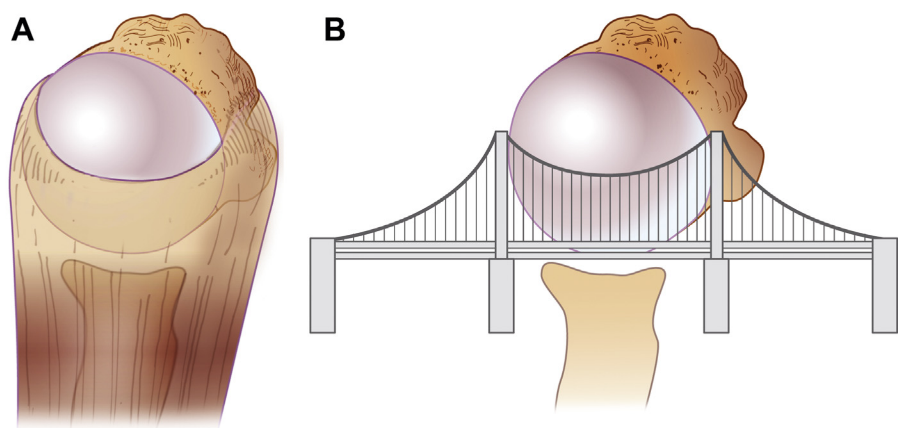

Figure 3 A rotator cuff tear (**A**) can be modeled after a suspension bridge (**B**). The free margin of the cuff tear corresponds to the cable of the suspension bridge, and the anterior and posterior attachments of the tear correspond to the supports at each end of the cable's span. A preserved rotator cable can exert a compressive force sufficient to stabilize the humeral head despite the presence of a large rotator cuff tear. Reproduced with permission from Burkhart et al.[12]

structures that needed names (comma sign,[36] rotator cable/crescent complex[9,13,19]); rotator cuff tear patterns that needed names (partial articular supraspinatus tendon avulsion lesions,[34,41] crescent tears, U-shaped tears, L-shaped tears, reverse-L tears,[18,25,26] occult subscapularis tears);[20,32] repair terminology (deadman angle,[21] margin convergence,[3] load-sharing rip-stop,[7] transosseous equivalent repair,[40] double row repair,[35] loop security[15,17]); and previously unnamed anatomical structural changes that predisposed toward recurrent shoulder instability (inverted-pear glenoid,[6] engaging Hill-Sachs lesion,[6] on-track/off-track Hill-Sachs lesion[28]). A new language of arthroscopy was essential for precise communication of ideas.

There was the *burden of craft in the development of instruments and implants*. All of our early suture passers had to be straight, because they were manufactured in the days before computer-assisted design (CAD) programs. The CAD programs ultimately allowed the design and fabrication of complex shapes, but before that we were limited to straight stainless steel bar stock. This meant that all the early suture passers had to be retrograde passers that required a straight path to the pathology; therefore, a heavy emphasis was placed on determining safe arthroscopy portals that would allow straight access to rotator cuff tears. Later, there were second-generation retrograde suture passers that had simple curves or angles at their working ends.

From my standpoint, retrograde suture passage had a major drawback: it typically took an oblique path through the tendon, and therefore there was a tension mismatch between the upper and lower fibers of the repaired muscletendon unit. I was anxious to eliminate this tension mismatch in our repair constructs by converting to antegrade passage. By the mid-1990s, we had CAD programs that allowed us to create instruments with complex shapes. Our first successful antegrade suture passer was one in which the upper jaw had a hook that would penetrate the tendon and retrieve the suture from a tray in the lower jaw, thereby pulling the suture up through the tendon. Ergonomically, pulling the suture through the tendon with a hook was much more difficult to perform and to teach than pushing the suture up and through the tendon. However, pushing a needle through the tendon from below required the needle to be flexible yet have ''memory,'' so that it could take a curved path through the lower jaw of the antegrade passer and then travel straight up through the tendon and through a racket-shaped upper jaw. Nitinol proved to be the ideal material for needle fabrication. The addition of a spring-loaded trapdoor on the upper jaw allowed for automatic capture of the suture by the upper jaw, obviating the need for a separate grasper to capture the suture. This enhancement dramatically simplified suture passage to a one-handed ergonomic maneuver by the surgeon.

Tying secure arthroscopic knots was, in my opinion, the most difficult skill to teach beginners. I knew that the steep learning curve of arthroscopic knot tying could be a potential roadblock to the widespread adoption of arthroscopic shoulder surgery. Because of that, I developed an early interest in knotless fixation. My personal quest to develop arthroscopic knotless fixation began in the mid-1990s; however, I did not truly understand knotless suture fixation until I made a trip to Hong Kong in 1998 as the guest of the Hong Kong Orthopedic Association. I had been invited to speak on various shoulder arthroscopy topics in order to introduce this emerging technology to the Hong Kong orthopedic community. On my second day in Hong Kong, my host, Dr. James Lam, took me to lunch at a restaurant that was across the street from an older building that was undergoing extensive renovations. Construction crews were busily working from scaffolding that extended many stories up the side of the building. After lunch, Dr. Lam took me across the street for a closer look at the scaffolding, where I learned the secret of the Hong Kong skyscrapers. As I looked at the scaffolding, I saw that it consisted entirely of bamboo sticks that were held together by leather lashings that were wrapped around the sticks and then turned back on themselves. There were no knots used in the lashings. They depended entirely upon cable friction to produce internal interference that was even stronger than knots.[4,22] I realized at that point that a knot is only one of many ways to increase internal interference, and this realization led me to a more in-depth study of cable friction and how it could be used in knotless fixation.

My first knotless rotator cuff repair was done in February 2000. I used a knotless twisted suture that had been passed through the rotator cuff and then wedged into a bone socket with an anterior cruciate ligament interference screw. This technique produced excellent fixation, but I did not like the fact that the anterior cruciate ligament screw required such a large (8-mm-diameter) bone socket. So we developed a ''twist-lock'' fixation system[4] with a 4-mm-diameter anchor that had an eyelet on the tip that would allow twisting of the fixation suture limbs to produce cable friction before wedging the anchor into place in the bone socket.

The problem with this early ''twist-lock'' concept was that the suture would often break as the anchor was being inserted, due to significant abrasion of the suture at the edge of the inlet to the bone socket. Keep in mind that we were developing this technique in the days before high-strength sutures, and the braided sutures available to us at that time would break at relatively low loads. So I became convinced that we needed an atraumatic way to insert the suture to the base of the bone socket and then to gently introduce an anchor alongside the suture, thereby minimizing the risk of abrasive damage to the suture. We achieved this goal with an anchor that had a separate eyelet on the tip of an extended-tip inserter (Fig. 4). The extended-tip inserter allowed for atraumatic introduction of the suture to the base of the bone socket. The fact that

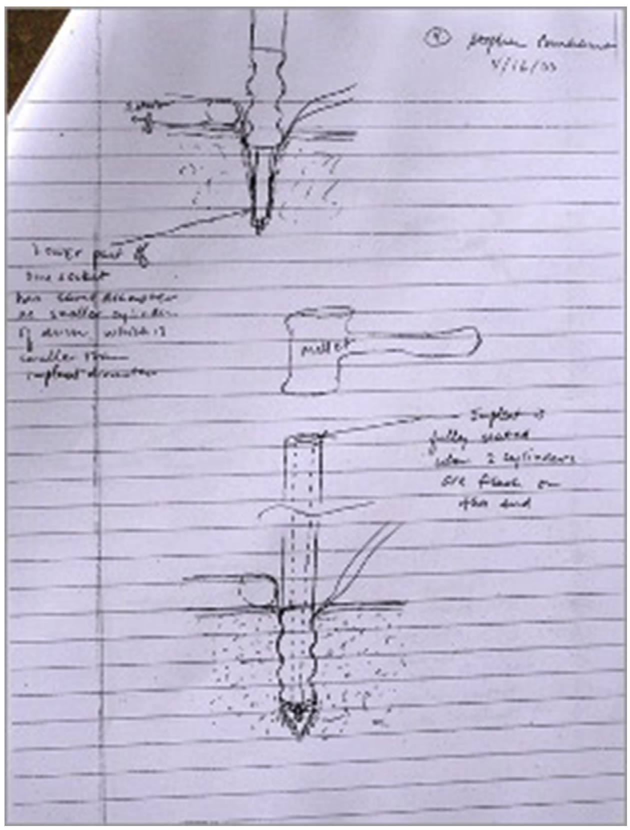

Figure 4 My original concept sketch from April 2000 showing an eyelet at the leading end of an extended-tip anchor inserter. This configuration allowed for atraumatic insertion of a suture at the base of a bone socket before the insertion of a push-in anchor or a screw-in anchor alongside the suture.

the suture passed through the eyelet and then reversed direction immediately after exiting the eyelet created a large amount of cable friction to enhance the static frictional wedging effect of the anchor. This anchor, with a distal eyelet on an extended-tip inserter, rapidly evolved to include both push-in anchors and screw-in anchors that would accommodate high-strength sutures and tapes.

For massive irreparable rotator cuff tears in shoulders without glenohumeral arthritis, I have been performing superior capsular reconstructions (SCRs) for the past 5 years. Mihata et al[37] first showed the feasibility of this concept by using a fascia lata autograft, whereas I have used a 3-mm-thick dermal allograft in my SCR technique.[10,16,27] These SCRs have provided dramatically better functional results than previous treatment modalities in this very difficult category of patients.

The two faces of craft

In my opinion, SCR is an advanced example of the burden of craft. This is a high-degree-of-difficulty procedure that is technically very demanding. Properly done, this procedure yields outstanding results, but it is not an easy procedure to perform. Even so, I firmly believe that surgeons who elect to treat patients with massive irreparable cuff tears should either take the time and effort to master the SCR technique, or else be willing to refer such patients to other surgeons who have demonstrated capabilities with SCR. Surgeons must be willing to assume the burden of craft that is required for the proper treatment of their patients.

In order to have a meaningful discussion on the burden of craft, it is essential to first define the word *craft*. Strictly speaking, *craft* is a skill that relies on and maximizes manual competence. As such, there are 2 distinctly different components to craft:

1. expertise and
2. problem-solving.

This duality of expression is responsible for the 2 faces of craft: depth and breadth.

The first face of craft is depth of expertise. Depth optimizes execution, thereby optimizing results in a specific patient or in a specific field. The need for depth is best met by *super-specialists* such as dedicated shoulder surgeons.

The second face of craft is breadth (or range) of experience for problem-solving. Breadth is achieved by individuals with experience in multiple fields. Breadth of experience optimizes the possibility of combining knowledge from different domains to obtain a creative solution. Breadth maximizes the ability to solve problems, thereby providing the potential to advance the level of the entire craft.

Simply put, depth (expertise) optimizes the chance for achieving an excellent result in an individual patient, whereas breadth (range) optimizes the chance for advancing the discipline and potentially achieving a paradigm shift.

Malcolm Gladwell discussed *depth of experience* in his book *Outliers*.[31] In this book, he postulated the "10,000-hour rule," which suggested that the attainment of an elite status in a craft (particularly music, art, or sports) requires at least 10,000 hours of practice and participation.

Obviously, surgeons cannot possibly spend 10,000 hours practicing rotator cuff repairs, then another 10,000 hours performing instability repairs, as well as the requisite time required to achieve elite status in all the other operative procedures in the field of shoulder surgery. Fortunately, there are some shortcuts. Dr. Chris Ahmad, a surgeon from New York City whom many of you know, has written a book entitled *Skill: 40 Principles That Surgeons, Athletes, and Other Elite Performers Use to Achieve Mastery*.[1] This book describes targeted drills and practice that the surgeon can use to achieve excellence in a compressed timeframe. And please note that the surgeon's goal is excellence, not perfection. Vince Lombardi, the iconic American football coach, had a compelling observation about perfection vs. excellence: "Perfection is not attainable. But if we chase perfection, we can catch excellence." As surgeons, our goal should be to "catch excellence."

Let's now turn our attention to breadth as the counterpoint of depth. Breadth is the other face of craft, the one that facilitates problem-solving. Author David Epstein examined this issue in his book *Range: Why Generalists Triumph in a Specialized World*.[30] Epstein asserted that there is a technological trend toward specialization not only in medicine, but also in large companies and academic institutions, where there has been elevation of narrowness to an ideal. Research is conducted at these institutions by groups of individuals with expertise in a single domain, a condition called *vertical thinking*. Vertical thinking can lead to technological enhancements, but not to paradigm shifts.

Dr. Arturo Casadevall, Chairman of Immunology at the John Hopkins School of Public Health, has a *theory of parallel trenches*, in which he points out the danger of narrow expertise. As quoted in David Epstein's book *Range*, Dr. Casadevall explains that, with narrow expertise, we keep digging deeper in our own trench in search of a solution, never realizing that the answer may lie in the trench next to ours. This theory highlights the need for broad experience within individuals and groups. Such broad experience facilitates *lateral thinking*, which can provide unique insights that lead to paradigm shifts.

Dr. Casadevall has studied trends in medical research in the 21st century, and he has found that there have been very few interdisciplinary grant proposals in this century, indicating an emphasis on depth rather than breadth. As a result, he observes, over the past 35 years, that biomedical research funding has risen exponentially, whereas discovery has slowed significantly.[30]

The case for breadth as the basis for creativity

There is a clear case to be made for breadth. Modern life requires breadth, with the ability to make connections across far-flung domains and ideas. Multitasking has become a way of life.

On close examination, breadth appears to be the basis of creativity. It favors *lateral thinking* over *vertical thinking*. What some authors have called ''thinking outside the box'' is simply lateral thinking: applying a solution from one domain to a problem in another domain. Perhaps the most striking example of lateral thinking was the series of thought experiments that led to Einstein's Theory of Special Relativity in 1905.

If bridging between domains is so important, why isn't it more common? Uzzi et al[43] published an article on this topic in *Science* in 2013 that reached some surprising conclusions. They found that scientific work that bridges between disparate domains is:

1. less likely to be funded,
2. less likely to be accepted into high-impact journals, and
3. more likely to be ignored upon publication.
   These are 3 powerful reasons not to conduct research between domains. However, their fourth conclusion highlighted the main incentive in favor of participation in domain-bridging research:
4. It is more likely in the long term to have a high impact on human knowledge.
   Simply stated, breadth-enhanced research is more likely to make a difference, even to the point of disruption and paradigm shift.

The end point: depth vs. breadth in technological advancement

We must ask ourselves, ''What is the end-point of depth and of breadth as tools in technological advancement?''

Depth, with its concentration on extensive but narrow expertise, is likely to lead to incremental improvements, or enhancement technology. There is certainly a strong case to be made for this type of technological advancement, with steady progress over time.

In contrast, the end point of breadth-based research, with a broad base of experience and the ability to connect unrelated domains, is the unpredictable but very real potential for disruptive technological advancement resulting in paradigm shift. So it is essential that we recognize the importance of breadth and never abandon it.

Perhaps the most eloquent case for breadth was articulated by Robert Heinlein, the noted science fiction author:

> ''A human being should be able to change a diaper, plan an invasion, butcher a hog, conn a ship, design a building, write a sonnet, balance accounts, build a wall, set a bone, comfort the dying, take orders, give orders, cooperate, act alone, solve equations, analyze a new problem, pitch manure, program a computer, cook a tasty meal, fight efficiently, die gallantly. Specialization is for insects.''

David Epstein noted a recent Nobel Prize phenomenon.[30] He stated that, almost annually, a Nobel Prize recipient explains that their breakthrough could not have occurred today. So we might ask ourselves if shoulder arthroscopy could have developed in the 21st century from scratch, particularly since we now have such strong headwinds as evidence-based medicine, Level I studies, and progressively restrictive FDA policies. My belief is that yes, shoulder arthroscopy could have developed in today's world. But such a paradigm shift would require a dedicated group of surgeons, scientists, and engineers willing to take on all the burdens of the new craft.

The future

> ''The future ain't what it used to be.''
>
> Yogi Berra, U.S. Hall of Fame baseball player

What about the future of shoulder arthroscopy? In my opinion, the future has already begun with dramatic arthroscopic joint preservation techniques such as SCR. The potential for biologic enhancements such as platelet rich plasma, stem cells, and allografts has barely been tapped.

On the near horizon lies a very exciting technology that uses senolytic agents. Senescent cells are old cells that cease to divide but are difficult for the body to eliminate. Senescent cells release harmful proinflammatory cytokines, chemokines, and proteases that retard healing. A research team led by Dr. Johnny Huard at the Steadman Philippon Research Institute in Vail, Colorado, has discovered that decreasing the number of senescent cells can enhance healing (Huard J. Personal communication, July 27, 2019). Furthermore, they have identified orally administered FDA-approved medications (eg, Losartan, Fisetin) that act as senolytic agents to eliminate senescent cells, and they have postulated that senolytic agents could be an adjunct to surgical repairs to enhance healing. Dr. Huard and his research team have tested this hypothesis in an animal model by treating articular cartilage defects with a combination of surgical microfracture plus orally administered senolytic medication. Amazingly, they found that this method of augmenting surgical treatment with senolytic agents achieved healing of the cartilage defects with hyaline cartilage rather than fibrocartilage: an outcome that had not previously been observed after other treatment modalities.

Farther on the horizon, 3D bioprinting holds great promise as a source of biologic tissues for surgical reconstructions. At Tel Aviv University in Israel last year, scientists 3D printed a small human heart by manipulating human adipose-derived stem cells.[39] Even though the scientists were unable to get the myocardial cells to beat synchronously, this was still an incredible breakthrough.

In the realm of orthopedic surgery, researchers are now producing 3D printed human ligament and tendon tissue. Bowles and Ede, from the University of Utah, reported in 2018 that they had 3D printed human ligament and tendon tissue from adipose-derived stem cells.[29] Equally impressive, from the Wake Forest Institute for Regenerative Medicine, Murphy and Atala have reported that 3D bioprinted skin and cartilage are very close to the functionality needed for human transplantation.[38] They have even 3D bioprinted a human ear.

Legacy

I would like to spend a few moments discussing legacy. Dr. Codman was acutely aware of legacy, and he addressed this topic in the Preface of his book *The Shoulder*[24]:

> "Through much of my life I have suffered somewhat from a sense of isolation, because I have always been thinking, or saying, one thing or another, with which doctors did not agree…My regrets are for wasting so much time on the opinions of a previous generation and not realizing that it was the approval of my pupils, rather than of my masters, that was desirable."
>
> E. A. Codman

Clearly, Codman had a strong desire to influence the next generation of surgeons and to leave a legacy that would live on beyond his own career. On the basis of that passage in his Preface, I think it is fair to ask if Codman was a cowboy. Like the cowboy, he always tried to do what was right, even if it wasn't easy or popular. And we know that there were lots of people who didn't like Codman; he was definitely not popular.

The American cowboy lived by his credo: "There's the easy way and there's the Cowboy Way." This meant that the cowboy would try his best to always do the right thing. Even in today's world, I believe there is a *Cowboy Factor* in surgery and science that demands that the surgeon/scientist do the right thing for his patients.

My heroes have always been cowboys. When I was a young boy, my number one hero was Roy Rogers, the King of the Cowboys on the silver screen. One of my prized possessions is an autographed picture of Roy Rogers with his horse Trigger that simply states:

To Steve—
Happy Trails,
Roy Rogers and Trigger

Because of my admiration and respect for the cowboy and his values, I decided to honor the cowboy by incorporating the term and the value system into the titles and into the fabric of my 3 books on shoulder arthroscopy[5,12,14] (Fig. 5).

Many people have asked me if there is going to be a fourth Cowboy Book. Well, let me tell you a story to clarify where I stand on that topic.

In 2017, my ex-fellows gave me a pair of custom-made handcrafted boots. On each of the 4 side panels of the boots, the bootmaker had crafted leather graphic representations of the logos on the cover of each of the 3 Cowboy books. Because there were 4 panels on the boots, there was 1 extra panel, so the fellows had the bootmaker add a new logo that they told me should be on the cover of the fourth Cowboy book (Fig. 6).

Now, for those of you that have written a book, you know that it is an arduous, demanding, and sometimes onerous task. In fact, David Epstein captured the essence of book writing when he said, "Writing a book is like

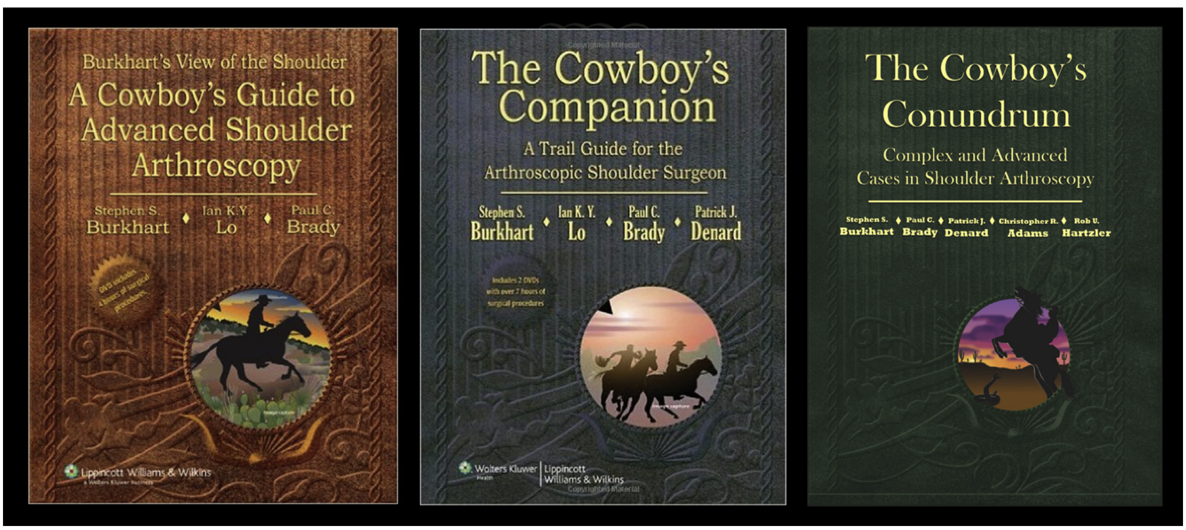

Figure 5 Dr. Burkhart's 3 textbooks describing the principles of *The Cowboy Way of Shoulder Arthroscopy.*

Figure 6 Potential logo for a fourth *Cowboy Book*.

wrestling a gorilla. You don't quit when you're tired; you quit when the gorilla is tired."[30]

So I told my fellows, "I'm not going to be writing that book. You guys can write it and I'll approve of the project. But I won't be writing it. I won't be wrestling any more gorillas."

It is fair to ask, what do I consider my legacy? Well, I would like to think that my legacy would be, to a large extent, my role in the paradigm shift from open shoulder surgery to arthroscopic shoulder surgery. But also, I cherish the legacy of having trained so many shoulder surgeons worldwide to do shoulder arthroscopy. I have trained more than 30 extremely talented fellows, and I have hosted more than 3000 visiting surgeons in my operating room over the past 25 years. I have had the opportunity to teach the teachers, many of whom are in the audience today. My life has been enriched by knowing you, and I thank you for your friendship.

Legacy is particularly important to me at this point in my career, as I have announced my retirement from active surgical practice as of October 31, 2019.

As I conclude this Codman Lecture, I would like you to ask yourselves again, "Was Codman a cowboy?" If your answer is *yes*, I feel certain that Dr. Codman would have been honored by that compliment.

But I would also like you to ask yourselves, "Is Steve Burkhart a cowboy?" If your answer is *yes*, then that would be the greatest legacy that I could ask for, and the greatest honor that I could ever receive.

So…Adios, Amigos!

Happy Trails!

Disclaimer

Stephen S. Burkhart is a consultant for and receives inventor's royalties from Arthrex (Naples, FL). He also receives book royalties from Wolters Kluwer (Philadelphia, PA).

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