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ON SURGICAL FAILURES: Onward to objective evaluation of our less proud moments

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In recent years a spate of popular writing has focused on the merits of failure. (1)(2)(3)(4)(5)(6) In various forms, failure is approached from the perspectives of parents (let your children fail!), leaders (allow your employees to fail!), and self-help (let yourself fail and learn from it!). One of my favorite coffee brands states plainly on its container that “things that matter in life” include “never being afraid to fail.” Failure is chic, failure is trending! Twenty years ago, my university commencement speaker orated the experiential virtues of failure as being essential to our growth as individuals and as a society. ‘So, get out there and fail!’ he concluded with gusto. He was not a physician—he taught history.

I am unsure what it means to fail as a professor of history, and I do not endeavor to minimize the travails of other professions. However, failure in the care of patients is—at best—to not make good on a promise to heal; at worst it is to do harm—potentially mortal—to another human. Any operation, regardless of its technical requirements, places a patient at risk of life-threatening infection, among other harms. A surgical failure, whether occurring acutely in the operating room or delayed, is to expose a patient to these perils without achieving the desired benefits that justified the intervention. Bearing this in mind it is unsurprising that we surgeons are reluctant to engage the admission—or even the contemplation—of failure with the exuberant rapture described by contemporary self-help print and motivational speakers. Ironically though, it is the very gravity of our missteps that makes their recognition and study so absolutely imperative, for within them are signposts to better care. To discredit, discount, or disregard any adverse surgical outcome is to eliminate the only remaining benefit to be gleaned from the procedure that yielded the undesired result. In order for us to improve, it is crucial that we study our outcomes—good and bad.

To fully appreciate the merits of studying failure we need only to reference our smartphones or laptop computers, comparing them to their predecessors. Today’s most advanced smartphones have computing power $>10^4$ of the most powerful early supercomputers despite being even greater orders of magnitude smaller, lighter, and cheaper. Compare these advances—borne of the labors of our engineering colleagues—to the anemic progress in our chosen field of musculoskeletal oncology and the difference is startling. Our surgical

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methods for tumor resection and reconstruction are relatively unchanged over the past 30 years, with similarly slow progress in non-surgical treatments. It would be foolish to conclude that surgeons should approach the creation and testing of new techniques in the same get-out-there-and-fail manner as designers of microprocessors and other engineering marvels; to do so would be both illegal and immoral. But there are lessons to be learned.

The principal difference is cultural. In contrast to surgeons, engineers view failure as an inevitable and key part of the lifecycle of any mechanical device or software application. Failure, in the eyes of engineers, is not a question of if, but when. Recognizing failure as imminent lessens its stigma and thereby improves the ability to acknowledge, study objectively, and improve upon it. This philosophy—formally named the *Engineering Design Process*—raises the status of failure analysis beyond a tedious detour in the innovation process to a unique and separate occupation with its own specialized practitioners, peer-reviewed journals, and texts.

Embrace of these mores has led engineers to—at various times—celebrate or venerate their failures. Jubilant revelry for failed devices is particularly evident on YouTube where engineering students frequently post videos of eye-catching failures of early test—'beta'—designs. These anticipated, laboratory-based 'fails' provide a controlled, low-stress learning environment free of human harms. In contrast, spectacular public engineering failures, such as the Tacoma Narrows Bridge, the Hindenburg, and the Challenger Space Shuttle live on in engineering lore, standing as grim warnings to others who would undertake similar feats.

Colossal surgical failures—particularly those in the operating room—and accounts of their genesis, on the other hand, are generally smaller, private, and more subjective affairs. Most intraoperative failures are witnessed by only a small few and discussed at local morbidity and mortality (M&M) conferences but rarely communicated further due to concerns over liability. Institutional culture may even discourage open discussion of failures either actively —through recriminations—or passively—through wanton ignorance or tacit acceptance. How does surgery arrive at a place where its less proud feats are better catalogued and receive academic scrutiny that may reduce repetition? As a mentor once told me, a good surgeon learns from his (or her) mistakes; a great surgeon learns from the mistakes of others.

Better ex vivo *training*

To perform a surgery is to create a team-based work of art in a small amount of time, with finite tools, uncertain assistance, on a singular canvas. When an undesired dissection move is undertaken in his operating room, a colleague of mine is known for telling residents 'I cannot undo what you have just done." While he speaks the truth, early training experiences should not hold such morbid physical and psychological consequences for the trainee and patient. No other profession save surgery has such limited training mechanisms and such dire consequences for trainee missteps. The problem is lack of surgical simulation. Airplane cockpits can be recreated with high fidelity to yield realistic flight simulators. Alternatively, the human body's varied tissues, each with a unique appearance and turgor are difficult to replicate. New virtual reality, haptic-enabled technologies stand to improve upon this critical need, but lack of market interest has not stimulated appropriate development. Perhaps it is

time for we providers, who are both the instruments of surgical training and the guardians of our patients' safety, to stand firmly and require that our medical schools and industry partners develop these didactic tools that will surely lead to trainees with more uniform and higher caliber abilities and, simultaneously, lower patient morbidity.

Overhaul academe's reward system

The classic 'publish or perish' academic reward system is culpable in large part for clinical medicine's slow progress compared to other fields. Compared to lab-based science and engineering, where iterative experimentation may be performed without limit, our research medium—patients—is precious and scarce. Emphasis on publication worked when there were a handful of tertiary academic medical centers sprinkled around the globe. The expansion of medical schools in recent decades—25 just in the last 10 years in the U.S.—has led to an explosion of academic faculty, all wrangling to meet expectations, leading to innumerable 'throw away' journals replete with underpowered and largely unhelpful manuscripts that serve only to drown out and detract scientifically from more sound works. This is not who we should be. Medical schools, all of which claim to serve the greater good, should redefine faculty expectations to align with society's needs and emphasize the value of collaborative science and multicenter study participation over feckless case series. Similarly, first and last authorship idolatry should be attenuated.

Objective, hypothesis-driven recording of patient outcomes

Since the publication of the first ISOLS limb salvage classification article in 2011,(7) I have received numerous emails from surgeons asking if, usually for reporting purposes, a particular event in a patient's postoperative course constitutes a failure. These descriptions usually include an event that led to reduced function treated without surgery, or a repeat operation with retention of all or most of the original implant. The goal of these inquiries is to determine at what point does the severity of an adverse event tip the scales to become a failed operation. In my opinion, this form of retrospective outcome designation is biased and unhelpful. It is impossible to objectively determine in hindsight whether one event is a failure, and another is not. Instead, we need to first collectively and prospectively agree on the overarching goals of the operations we perform and what endpoints are noteworthy.

One key flaw in the 2011 article was the titular reference to failures of "tumor endoprostheses." This phrasing shifted emphasis solely to the implant, lessening the important roles of the tumor resection and soft tissues in facilitating cure and function. This implant-centric myopia was evident at the 2013 ISOLS meeting in Bologna when a prominent surgeon sitting near me remarked, during a discussion about disease recurrence, 'local recurrence is not a failure, the endoprosthesis is intact!' I disagree completely. An intact endoprosthesis is present in most instances of recognized surgical failure: joint instability, soft-tissue rupture, wound dehiscence, aseptic loosening, infection, and local recurrence. A title focused on 'limb salvage failures' would have been apropos and was therefore enacted in the revised classification manuscript published in 2014.(8) Given the seemingly innumerable mechanisms by which a limb salvage surgery can go awry, how are we to accurately, precisely, and definitively distinguish our successes from our failures?

The Oxford Dictionary of Mechanical Engineering defines failure as: "*The result when a body, component, or structure is incapable of performing the task for which it was designed*." Instead of delineating failure by what it is, this simple, elegant, and prospective definition considers failure based upon what it is not—success. Engineers define their goals from the outset, in a hypothesis-driven manner, and consider failure to be any condition where these objectives are not met fully. When this definition is applied to musculoskeletal oncology, subjective and nuanced debates over definitions and etiologies of failure melt away. Every event that prevents realization of the initial surgical goals is a failure; events that do not interfere with these goals are not. Consider the debate surrounding bushing wear. Roughly one-half of orthopaedic oncologists I have engaged consider worn bushings limb salvage failures; the other half vehemently argue they are not. Alternatively, no engineer would consider a worn, defunct polyethylene bushing a success, regardless of its duration of service. The bushing, a key component of the limb salvage surgery, was created for a single purpose, and when it can no longer fulfill that role the bushing—and therefore the limb salvage of which it is an integral part—has failed. The bushing should be retrieved, replaced, and studied. Simple. For application to limb salvage, I recommend adding to Oxford's definition the words '*without external intervention*.' This slight amendment would decrease reporting avoidance for looming failures kept at bay by artificial means—circumstances such as chronic antibiotic suppression and external bracing. This prospective, goal-based definition of success and failure should be our goal. But doing so is not without challenges.

Defining limb salvage success presents its own obstacles due to the diversity of our patient population, their diseases, and the various goals that result from admixing the two. Similarly, surgeons and patients may have disparate goals so their perceptions of success and failure may be incongruous. Ultimately, we must choose an uncomplicated definition of success that accounts for the most basic limb salvage goals—disease cure and function—and begets an open and inclusive definition of failure. In 2002, Nagarajan and colleagues described a successful limb salvage as "… a satisfactorily wide excision" with "the reconstructed extremity… at least as functional as an ablative procedure and prosthesis." To date, this is the least cluttered definition of limb salvage success that I have encountered, and I believe it is a good starting point. If we hold Nagarajan's words as our preliminary definition of limb salvage success, I would return to Oxford—with minor adjustment—to arrive at a new definition of failure: '*The result when a limb salvage operation does not deliver its intended results of local disease control and a functional extremity without external intervention*.' Simple.

Words and messaging matter, and I understand the reluctance of some surgeons to describe an outcome as a failure. I inform all of my patients who receive an articulating implant that its service duration is finite, and if cycled to its limit it will someday fail and require revision; to date no one has balked, they get it. For your own practice, however, call them what you want. In the end, it does not matter what we name these events—complications, adverse events, failures—but study them we must. All outcomes—positive or negative—are worthy of recording and analysis regardless of whether it is deemed a failure. Unfortunately, the threat of litigation probably fuels reporting abstention more than any other element and this, in time, will hopefully be better addressed. While it should have no bearing on inclusion or exclusion from reporting, it is probably worth modifying our nomenclature to

distinguish *certain* (or *imminent*), wear-related failures, such as a worn polyethylene bushing, from *uncertain* (or *non-imminent*) failures, such as deep infection, joint instability, and aseptic loosening. Recognizing the inexorable nature of wear-related failures removes from the surgeon some of the stain of liability and, reciprocally, should broaden reporting.

In summary, we must be inclusive when studying patient outcomes. Ultimately, I believe that our collective professional aim as musculoskeletal oncology surgeons should be *local tumor control and a painless extremity with abilities equal to the original in its pre-disease state,* and we should study with vigor all results that fall short of this lofty mark. Not one of us will achieve this goal on her or his own and therefore we must band together—through multi-institutional, prospective efforts—and record our outcomes broadly, honestly, and openly.

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