The Mathematics of Failure: Observations from Galileo to the Institute of Medicine—Presidential Address CNS 2006

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It is with great pleasure that I welcome all of our members, domestic and international, to Chicago for the 56th Annual Meeting of the Congress of Neurological Surgeons. It has been an honor to represent and serve all of you. I want to thank my parents, brother, and sister who are with me today for providing me with guidance and unconditional love. I would also like to thank my extraordinary wife Sandy and my children Rachel, Paul, and Zach for their never-ending support and constant humor, who this year, I saw less, but loved more. In addition, I bid a heartfelt thank you to all my neurosurgery colleagues and residents, past and present, who have carried me on their shoulders. You have taught me more than I could ever teach you.

Lastly, I want to acknowledge my friends and partners at the CNS. You have been an invaluable part of my life and education. It has been a great ride. But, I am constantly reminded that the Congress exists because of the tireless work of hundreds of volunteers from the membership ranks. . . the folks sitting out in the audience (nearly 900 volunteers strong this year), combined with a very Spartan, professional headquarters staff. That story has been thankfully told for each of the past 56 years.

THE MATHEMATICS OF FAILURE: OBSERVATIONS FROM GALILEO TO THE INSTITUTE OF MEDICINE

Failure and mathematics. . . . (*Fig. 7.1*). Can you think of any other two concepts that could be juxtaposed so perfectly at 9 AM on a Monday morning to alienate an audience of talented neurosurgeons? The message of my talk is quite simple: **Failure in our field is an absolutely essential part of our evolution**. Failure can be viewed more favorably by using a mathematical perspective called *Surgical Parallax*, which I will share with you. It is simply a different view from a different part of the neurosurgery orbit. I am going to discuss how failure 1) has affected our field, 2) our professional lives. and 3) lastly, our public persona, all, in ironically positive ways.

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I happen to be a friend of these concepts, failure and mathematics. I have mastered failure, and I have failed at mathematics. You see, I had a brief affair with the idea of being a mathematics major in college because I enjoyed the logic of it. But, when I tanked my sophomore year proof assignment that the number 2 existed, that was just the beginning of the end. Then, I realized that partial differential equations and string theory were easy courses for my very clever class mates, sort of like geology, or "rocks for jocks," is the joke course for biochemistry majors. By junior year I was done toying with mathematics or visa versa. So, I can reassure you this talk will mostly consist of pertinent math history and ridiculously easy math because at my stage in life I still struggle. In fact, my teenage children no longer let me help them with their math homework. In the wise words of my brutally honest children: "Dad, we actually want to do well in this subject, but thanks for the offer."

By choosing neurological surgery, failure becomes the invisible backdrop in our careers!

That is because we, as a group, continue to aggressively treat severe head trauma, injured spines, cerebrovascular disease, severed nerves, incurable cancers, intractable epilepsy, recalcitrant pain, hydrocephalus, and movement disorder. We have accepted that failure permeates our profession, but hardly give it a thought, on a day-to-day basis. This is a good thing. But, as I reflect today, the neurosurgery growth process historically involves huge risks, a very meandering course, and spectacular failures, which inspire innovation. This is also true at the individual practice level, regardless of your practice type, every single day.

When we hide the complex discovery process, our students and public pay the price with false or unrealistic expectations. Yet, this is precisely the position we often find ourselves in today with our patients, the public. In the past decade or so, we have increasingly gone underground with our bad results, and for good reason. Discretion has been an absolute must in this current medicolegal environment, regardless of our practice. But, maybe that is not a good thing. Surely, none of us got here by failing more than we succeeded. We all know that each of us evolve toward our clinical excellence and equilibrium at different speeds, based

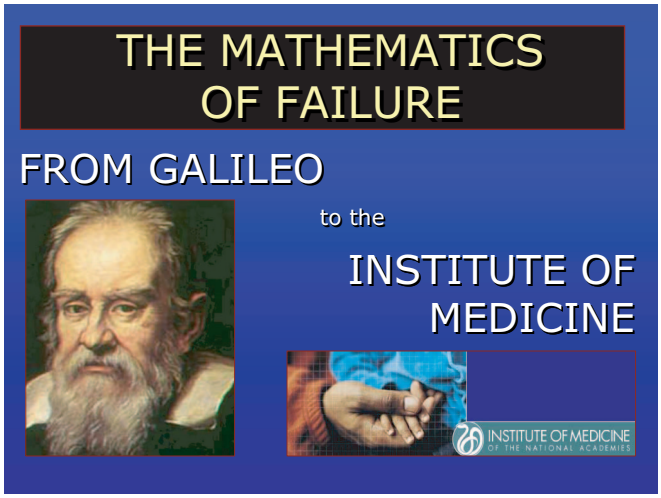

FIGURE 7.1. Mathematics of failure.

on the lessons from our last misadventure. We evolve as individuals, honing our intellectual, technical, and interpersonal aptitude. We all strive to reach a safe equilibrium with our confidence, arrogance, and skill set. I am often reminded of the astute advice of my wise late grandmother, the matriarch of our family. Upon graduation from neurosurgery residency she said to me, "I am very, very proud of you, but may very sick patients go to other neurosurgeons first."

However, from a purely unemotional perspective, a scientific assessment of our failures is precisely what has permitted us to make great advances and radical paradigm shifts in our field. Shifts that seem pedestrian now were once revolutionary and viewed with skepticism. Although it is the job of all of us to question all new scientific findings, think for a moment about the subtle and not so subtle shifts you have witnessed in your lifetime: from maximally invasive to endovascular, endoscopic, stereotactic, and minimally invasive. Why, because maximally invasive surgery has a downside. We have gone from inaccurate tactile and visual confirmation to real-time navigation and intraoperative imaging. Why? Safer and more accurate is better. We have gone from obliteration to neuromodulation. Why? Because neuromodulation preserves neural structures. We have an obligation to educate the public and our students that none of these shifts were purchased, earned, or achieved without complications and human suffering. And none of them were earned without private donations, grants, industry support, and major misdirection in many blind alleys.

This sometimes-desperate situation has forced us into scientific and economic partnerships that we never previously entertained. I believe that industry/academia/community practice relationships must flourish when there is legitimate patient advocacy justification for them. When industry serves only the financial interests of the holder, without direct scientific advancement, no legitimate justification exists for our involvement. We must be honest and forthright to our public that financial and non-financial incentives are what spur innovation. In our capitalist democracy, these incentives are necessary and good. Invention and transferring our inventions from the lab to the bedside is not always a clean and crystal clear process. Conflicts of interest that are inherent in these processes will, and are, being addressed by our hospital, national trade, and academic organizations. The key to our success as a surgical field and as individuals within our field will be no different for the next 10 decades: we must figure out how to continue to bridge a chasm, my colleague, Professor Yongman Kim, calls, the "Valley of Death," where 99% of our ideas and proposed treatments die (personal communication between Professors Yongmin Kim and Richard G. Ellenbogen, 2005).

Here is the process. In this slide, we can see the meandering course of success occurring only after bitter failure (*Fig. 7.2*). I have been to the neurological surgery Valley of Death, and it is not pretty. Take example one of my many personal dalliances with the Valley of Death (*Fig. 7.3*). I sent an article to a well-known (unnamed) neurosciences journal, and this is the review I received: "This represents the single most dangerous surgical approach this editor and his reviewer's has ever seen. It should be mentioned in the literature only to be condemned for the single minded insanity it brings to this field." So, what was my crime? . . . A new technique. I thought it would be a good idea to perform an endoscopic biopsy of pineal region tumors at the same time we perform the endoscopic third ventriculostomy for the associated hydrocephalus. I had performed this on several pineal region tumors safely and effectively, but the editors considered it dangerous. I was quite discouraged after this

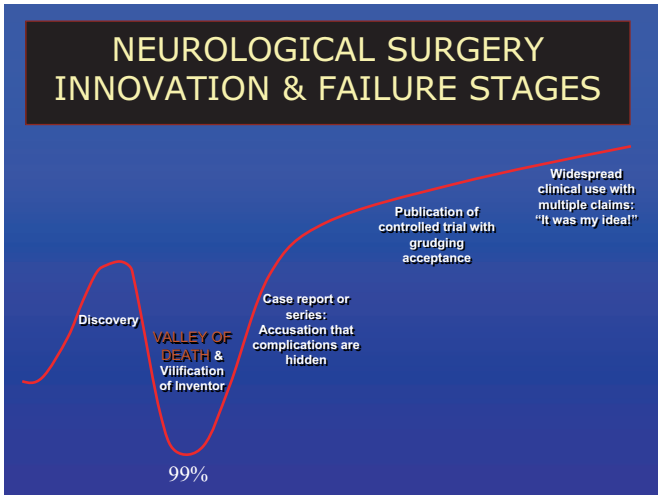

FIGURE 7.2. Neurological surgery innovation and failure stages (based on Professor Yongmin Kim).

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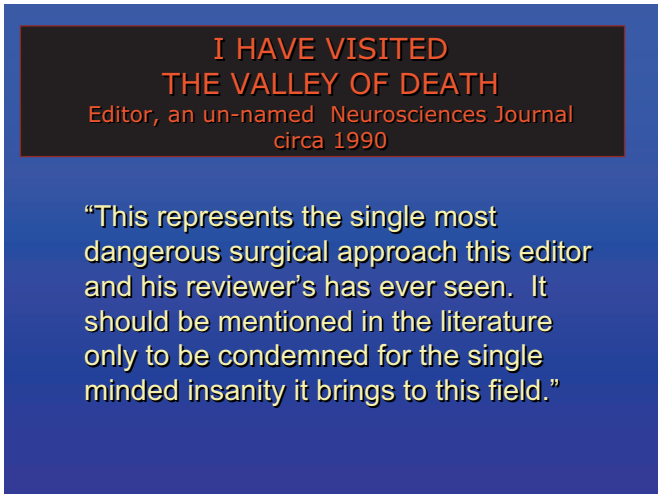

FIGURE 7.3. Surviving the Valley of Death.

particular review and many similar ones, and questioned my own sanity. Was this approach truly dangerous? Was I crazy? Admittedly, these observations may have been true in 1990 when I first started performing this operation instead of the more accepted approaches. And, it was not until 1997 that I actually achieved publication success of what I thought was a relatively minor deviation from the norm.[3] However, now, approximately 10 years later, this technique has now been accepted as one of the more reasonable approaches to pineal region tumors, as shown by larger series.[6] This is merely a simple example of how many of our ideas can die in the Valley of Death, until they are revived by new perspective, by more astute, mainstream colleagues, and by "tincture of time."

Each of us can play a part by contributing unique ideas or patients who consent to a new study to advance our field. So, how do we in our profession, bridge the Valley of Death in the current challenging environment? I studied many conditions and their associated surgical champions in preparation for this talk to uncover an epiphany. There was no epiphany during my research. Not surprisingly, each champion had a different story and approach. However, they shared a thematic variation of *Transcendent Leadership*! They were agile and innovative but vulnerable to financial and personal collapse that goes with laboring under a torment of criticism. Think back nearly 6 decades ago, when 21 men started the Congress of Neurological Surgeons for the simple purpose of education. What a seemingly crazy idea. . . . The Harvey Cushing Society already existed. But, the CNS sought to serve all neurosurgeons, especially those who were returning from service from World War II, who may have not had the standard neurosurgical training of the time, and were not accepted by the mainstream. The goal in 1951 was to create a more flexible and international flavor within this new organization. The CNS membership is now nearly 6000 strong and embraces some of the most original and innovative segments of our field, regardless of age or national origin. Talk about transcendent leadership overcoming "certain" failure. Think back nearly 2 decades ago, when leaders like Nick Hopkins had to sermonize on behalf of endovascular surgery, or Volker Sonntag, who was proselytizing about neurosurgeons routinely performing spine instrumentation. Well, in those two cases, the common theme is also a great sense of humor. But, they possessed the fortitude to take the lonely walk over the Valley of Death. It was the dissident Russian author Bulgakov who reminded us that "Cowardice is the worst of all vices." Admittedly, it is much easier to take an ordinary route through our field, as opposed to embracing an unconventional concept and the criticism that inevitably follows. I try to remember that Bulgakov quote whenever we are asked by a colleague to entertain a new idea that may seem unusual "crazy."

The surgeon of the future as a true triple threat with uninterrupted success as the bridge will simply be a rarity. Get over it. We now work in teams of experts, collaborators in bridging the Valley of Death. This often comes in the form of "translational research." Specifically, the major clinical solutions now come from the collaborative work of a stem cell biologist, a bioengineer, a radiologist, a cardiologist, or a computational scientist working in concert with a neurosurgeon who understands and can define the problem (*Fig. 7.4*). These are just a few examples of how we build bridges over the Valley of Death. So, as we start each Neurological Surgery meeting, I again remind myself to open my mind and welcome the outrageous ideas, seemingly unrelated fields, and untested arenas yet to be discovered. I am convinced that the next "nanotechnology or neuromodulation-like" concept is yet to be discovered by a neurosurgeon who is unlikely to

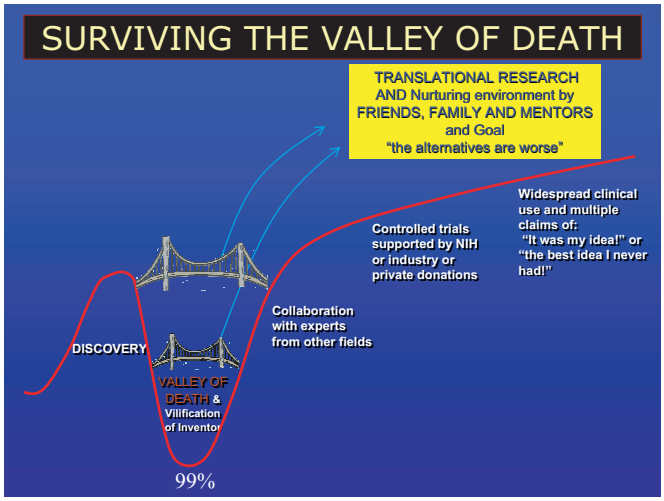

FIGURE 7.4. Valley of Death.

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be warmly received the first time he opens our eyes to his/her world.

Everyone we mentor should understand the myriad lessons that Galileo taught us about mathematics, physics, and failure. Galileo remains as one of the foremost scientific thinkers in my mind, as well as failures in his time (*Fig. 7.5*). This statement is not intended to be provocative. Galileo is a hero now simply because we view him through the beautiful kaleidoscope of time. His history has been revived by the diligent work of historians who have resurrected his immeasurable scientific contributions to mankind. Consider this: Galileo was found guilty by the Inquisition and sentenced to a life of imprisonment by the most powerful political force in the world at the time, the Church, a force that he revered. He would go blind, loose the daughter, a Nun, Suor Maria Celeste, whom he deeply loved most and was devoted to him in the most admirable way. In death, he was denied burial in his family tomb, a final indignity. His first work, *De Motu*, about the theory of motion would never be published in his lifetime. This work, *De Motu*, was deeply flawed. Yet, hidden in Galileo's unpublished works are some of the most important tenets known to science. Galileo was one of the first to use theories that were proven by well-conducted experiments. Galileo's genius lay in the way he approached scientific problems and failed hypotheses. For example, later in his career, he was able to conclusively show, with a telescope he constructed, that the earth revolved around the sun, providing mathematical proof for the Copernican theory of the solar system.

And, what happened once he discovered the truth? Shortly after his publication of *Dialogue Concerning the Two Chief Systems of the World Ptolemaic and Copernican*, the Inquisition banned its sale and ordered Galileo to stand trial in Rome in 1633 (*Fig. 7.6*). I admit that our current struggles

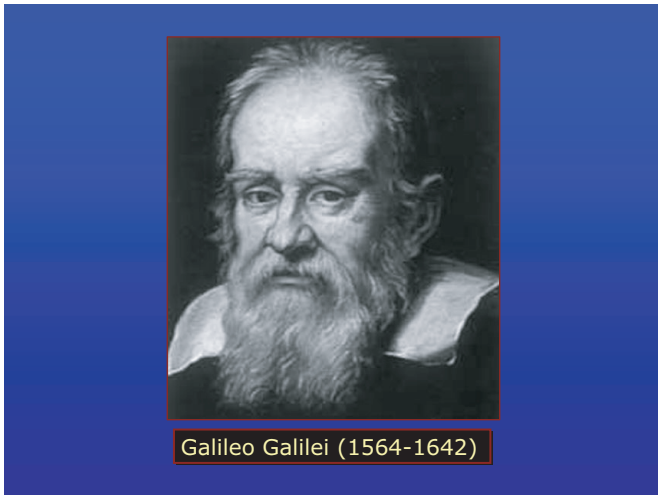

FIGURE 7.5. Galileo Galilei.

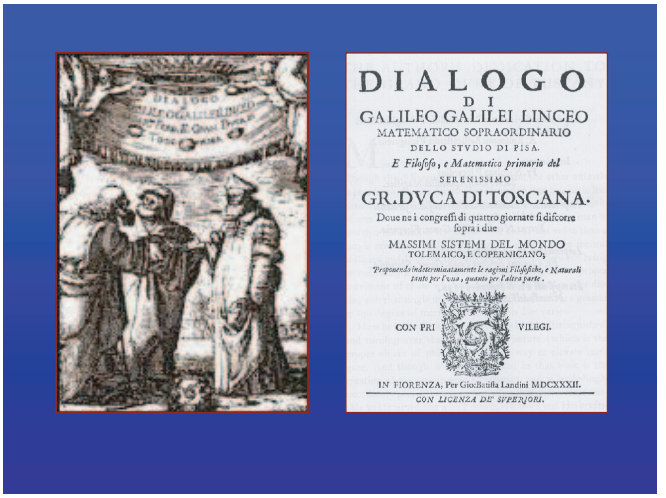

FIGURE 7.6. Lithograph from the classic Galileo work, *Dialogue Concerning the Two Chief Systems.*

with hospital administrators, the legal system, inflexible human subjects committee, and governmental quality assurance committees are significant. And, I respectfully submit that they must be fought at every level, political and personal, by each one of us. But, I dare say. . . our current day problems pall in comparison to the problem in which Galileo found himself embroiled. Whatever our current problems are with getting our ideas across the Valley of Death, I can assure you, his were much bigger (*Fig. 7.7*). Galileo never gave up hope, the invaluable love of his family or his religious and scientific beliefs. He said, "I do not feel obliged to believe that the same God who has endowed us with sense, reason and intellect has

FIGURE 7.7. Galileo before the Holy Office attempting to explain why his experiments with the telescope proving that the earth revolves around the sun is not in conflict with Church doctrine.

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intended for us to forgo their use." On the 31st of October 1992, 350 years after Galileo's death, Pope John Paul II gave an address in which he admitted that errors had been made by the theological advisors on the issue of Galileo centuries ago. It was vindication offered by yet another great and principled man. We are comforted that although we may have to take huge risks with our ideas, all failures can eventually be forgiven; albeit not always by the Pope.

Well, our neurosurgical patients, for better or worse, do not need Galileo size heroes; they need honesty, sound judgment, and good psychomotor skills. I still am absorbing this invaluable lesson from my surgical mentors and would like to share them with you (*Fig. 7.8*). Men like Professors Shillito and Scott were master surgeons and exemplary human beings. They remained the model of dignity and equanimity despite the rudimentary methods they inherited and failures they endured, inherent in our field. Nevertheless, they advanced our field one idea at a time. They were boringly consistent in their honesty, character, and incomparable commitment to their patients. They stubbornly stood on principal regardless of the shifting sands of legal or economic forces. Men such as Professors Loeser, Sekhar, Ojemann, Roberts, and Black were steadfast even in the face of great doubts and torrential critiques as they championed novel ideas in fields ranging from the surgical treatment of pain, cranial base surgery, cognitive neuroscience, and operative imaging, respectively. As a result, they managed to build bridges across the Valley of Death for the rest of us with their innovative spirit (*Fig. 7.9*).

All of these mentors always took total responsibility for their failings and our failings, as if they, our mentors, failed us, not visa versa. I ask myself daily; will we take the same responsibility. To this day, people like that simply have a halo

FIGURE 7.9. Professors Sekhar, Roberts, Black, Ojemann, and Loeser clockwise.

effect on all of us. . . . One of the most important lessons of failure I have learned is this: **We feel harmony wherever men and women of honor are, despite the often disheartening nature of our field. Sometimes it is a brave mentor, other times it is an incorruptible, loving spouse or an honest child who ironically shows you the way.** For me, it has been both mentors and family that have consistently carried me through the Valley of Death (*Fig. 7.10*). I can only respectfully suggest that you seek out unwavering people like this and spend as much time around them as possible. The satisfaction you derive will be as harmonious to your life, as it has been to mine.

Regardless of our practice, our ability to translate success from failure often remains simply a matter of perspective, or what I refer to as *Surgical Parallax*. Let me

FIGURE 7.8. Professors Shillito and Scott and R.G. Ellenbogan and Mrs. Shillito.

FIGURE 7.10. The Ellenbogen family.

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explain the meaning of this particular parallax. Celestial parallax was a mathematic concept that Galileo tried but failed to prove to determine the distance of the stars from earth (*Fig. 7.11*). The German astronomer Johannes Kepler eventually succeeded. Kepler's laws opened the way for the development of celestial mechanics and mathematical physics. Here is a simplistic way of how parallax works. Here is the first of the interactive parts of the meeting. Hold your arm out in front of you with your thumb pointed up and look at me. Now look at your thumb with one eye leaving the other closed, and then the other, going back and forth between the two eyes with one closed. The thumb will appear to jump back and forth on me. This is parallax. If you hold your thumb closer, the jump looks larger and if it is further away, the jump is smaller.

The same thing happens when astronomers look at nearby stars compared to much more distant stars from different ends of the earth's orbit. It turns out that the angle of the jump is halved if the distance to the star is doubled. By knowing the size of the earth's orbit and the amount of jump, scientists can determine how far away a certain star is. Nothing about the star or its physics changes, just how we see it. For me, *Surgical Parallax* is not much different. Parallax can be applied to the way we look at disease, each other, and failure. That is, two neurosurgeons can look at the same problem or solution and see them quite differently (*Fig. 7.12*). Have you always wondered why this happens so often? Well, because 1) we, as surgeons tend to be on different ends of an orbit 2) our point of view often depends on how close we are to the data. . . i.e., *Surgical Parallax*.

Now let us apply this principal to the case of the Institute of Medicine (IOM), an organization that is quite good at categorizing our failures. The Institute works outside

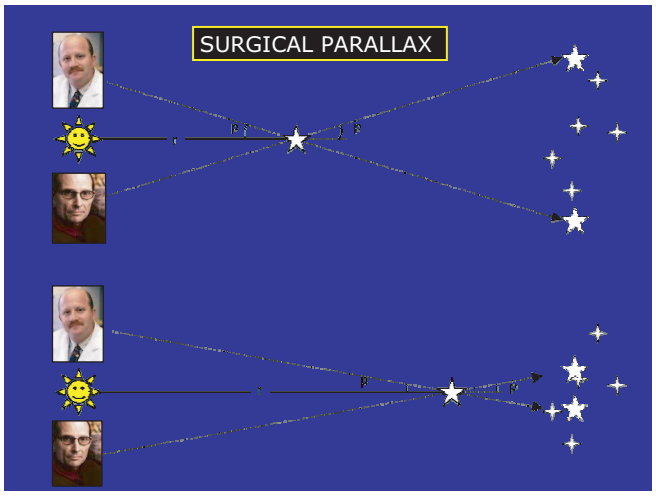

FIGURE 7.12. Example of *Surgical Parallax* as the revered editor of our CNS journal, ***Neurosurgery*** and I routinely disagree in a positive and good-natured way about various CNS issues.

the framework of the government and provides unbiased, evidence-based, and authoritative information. It provides advice for health and science policy to policy makers, physicians, and the public at large. But, from a personal point of view, like you, I feel a bit overwhelmed by their findings during the past 7 years. In November 30, 1999, the now famous report from the IOM, was released called *To Err is Human: Building a Better Health Care System* (*Fig. 7.13*). They found that there were nearly 100,000 preventable deaths per year in our sophisticated medical system.[1] In other words, more people died from medical errors than from breast cancer, HIV, or motor vehicle accidents. The direct health care costs total 9 to 15 billion dollars a year.[4,7] A key theme in this report is that legitimate liability concerns discourage

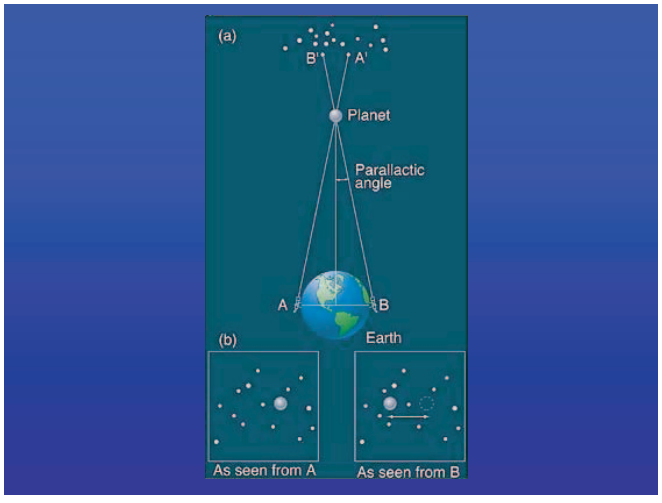

FIGURE 7.11. Diagram demonstrating the mathematical principal of celestial parallax.

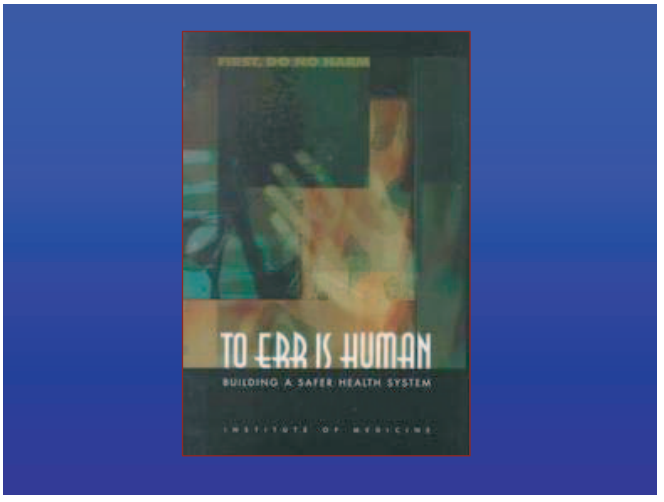

FIGURE 7.13. *To Err is Human.*

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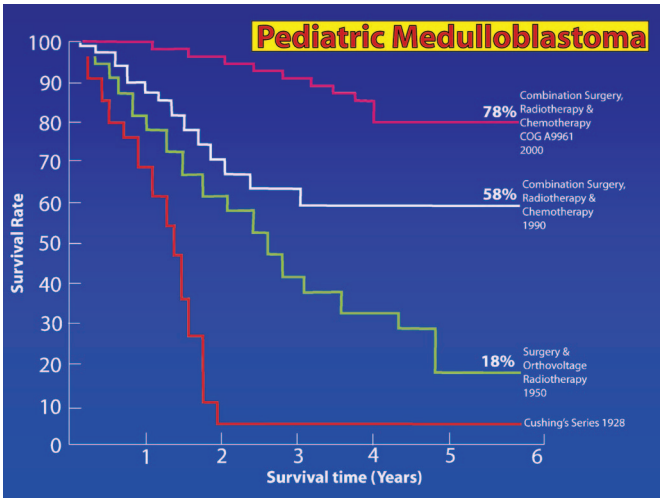

FIGURE 7.14. Kaplan-Meier graph outcomes in pediatric medulloblastoma as scientific advances were realized.

FIGURE 7.16. Building bridges.

reporting of errors, which we could fix in the future. According to their report, we have gone underground, which begs the question, "How can we learn from our failures in today's litigious age?" It is clear that our system has failed us and our patients.[5] To *Err Is Human* is an important study that asserts that the problem is not bad people in health care—it is that good people are working in bad systems that need to be made safer and more efficient. I am convinced that good people, like us, the true patient advocates, the people in this audience who put patient safety issues first, will fix these problems if given the resources. I will go out on a limb and say it certainly will not be the policy wonks and social scientist who deliver the much-needed results. But, for me, the IOM findings

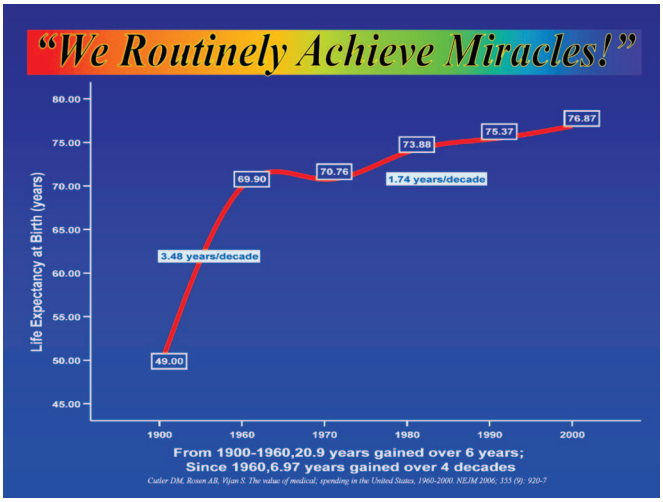

FIGURE 7.15. Life expectancy as we realized advances in medical/surgical care.

represent the mathematical equivalent of *Surgical Parallax*. . . a view that does not consider the complete data set.

Thus, in closing, let me offer you that "other" mathematical perspective, the neurosurgical end of the orbit looking at the same data. It struck me that what is missing in our discussions of failure of ideas and systems is how far we have managed to come despite making millions of decisions each day, some of them terribly wrong. It is a case of *Surgical Parallax*! In neurological surgery, for example, we have taken medulloblastoma (*Fig. 7.14*), which was 100% fatal in Cushing's time, to between a 60 and 80% survival rate because of the team efforts of surgeons and oncologists. Another paradigm shift: From 1900 to 2000, our life expectancy has increased from only 49 years to almost 80 years.[8] Amazing!!! Admittedly, the early life expectancy gains have been a result of public health initiatives, such as clean water, safe food sources, and control of epidemic infectious diseases. But, since 1960, direct disease treatment has made the majority of the contributions. Since 1950, age-adjusted mortality for stroke, our number three killer, has decreased by 70%. Since 1960, age-adjusted mortality from heart disease, our number one killer, has decreased by nearly 60%, increasing life expectancy by almost 5 years. Although medical spending has increased astronomically in the past 40 years, the money spent has had good value.[2] In other words, when we talk about health care costs and failures, we need to balance that mathematics by the benefits of the care received over decades. From 1960 to 2000, the life expectancy increased nearly 7 years in the United States[8] (*Fig. 7.15*). Although consistent data on the quality of life is not available, studies show that there is a substantial improvement in quality.

In conclusion, as with most of our great risks and spectacular failures, one must take into account the mathe-

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matical principal of *Surgical Parallax*: it all depends on how we, as clinical neurosurgeons, choose to view our often tortuous evolution. We have the most fun, technically and intellectually challenging field in medicine. Yet, we routinely achieve miracles (*Fig. 7.16*)! And, we can continue that trend if we, as individuals and as a specialty, *boldly focus on building bridges over the Valley of Death*.

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