4 Blueprint for the Establishment of a Successful Robotic Surgery Program: Lessons from Admiral Hyman R. Rickover and the Nuclear Navy

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4.1 Introduction

Robotic surgery (RS) is not about a new surgical instrument; rather, RS represents a "Disruptive Vision" which is bringing about a "fundamental change" in surgery. Therefore, the implementation of a successful robotic surgery program needs to follow examples in other areas of human experience where a "Disruptive Vision" has successfully implemented "fundamental change" in an otherwise conservative organizational culture. The most appropriate example of such a phenomenon is the monumental organizational change which was necessary to transform the US Navy from diesel power to nuclear propulsion. Arguably, this single transformation was responsible for the fact that nuclear weapons were not used during the Cold War, and humanity was saved from the horrors of Nuclear War. Robotic surgery can learn many lessons from this experience and the vision of Admiral Hyman Rickover, the "Father of the Nuclear Navy."

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This chapter develops the reasoning by:

- Examining the problem at hand: divergent views of robotic surgery by the business world, industry, patients, and surgeons
- Examining the concepts of culture change and disruptive innovation
- Outlining lessons about implementation of culture change and a disruptive innovation from the Navy.
- Outlining the process for changing the culture to a culture of greatness
- Outlining the need and the importance of changing the culture of the operating room
- Outlining the existential imperative of changing the culture of medicine through changing the culture of medical education
- Outlining how attention to these concepts adds up to the "entire elephant" in understanding and implementing a successful robotic surgery program

4.2 Varying Views of Robotic Surgery

Robotic surgery is a complex surgical, organizational, and social phenomenon which, heretofore, has not been seen in its entirety by the stakeholders. It can be likened to the Indian parable about the "blind men and an elephant." The parable is a story of a group of blind men, who have never come across an elephant before and try to understand it by touching the different parts. They then describe the elephant based on their limited experience. Each one describes the elephant based on the anatomic part that they are feeling. No one appreciates the entire elephant. The moral of the story is that feeling parts of the elephant leaves one with an erroneous impression of the whole, namely, the elephant itself. In a similar manner, it would be a mistake to look at robotic surgery in terms of the various parts. To get a complete understanding, robotic surgery must be viewed in its entirety. Unfortunately, presently robotic surgery is viewed in three very different ways based on the perspective of the examiner.

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4.2.1 Robotic Surgery as Viewed by the Business Community

The surgical robotics market is expected to grow from $3.9 billion in 2018 to $6.5 billion by 2023, at a Compound Annual Growth Rate (CAGR) of 10.4%.

Hospitals are using surgical robots for procedures such as prostatectomy, hysterectomy, hernia repair, cholecystectomy, colon and rectal procedures, nephrectomy, sacrocolpopexy, coronary artery bypass, mitral valve repair, lung lobectomies, and transoral robotic surgery. In addition, companies are now focusing on developing miniature-sized and less expensive surgical robots to target smaller hospitals and ambulatory surgical centers.

The general surgery segment is expected to grow at the highest rate in the foreseeable future. Surgical robots are being used in the areas of bariatric surgery, Heller myotomy, gastrectomy, hernia repair, cholecystectomy, Nissen fundoplication, transoral surgery, pancreatectomy, and other general surgical procedures. The growth in the number of these procedures is likely to fuel market growth. The use of robotic surgeries for various application areas has also grown due to the advantages of minimally invasive techniques. As compared to the large incisions required in traditional surgery, robotic surgeries can reduce pain and recovery time for many patients.

North America is expected to hold a significant share in the market in the next decade. Factors such as the development of advanced surgical robotic technology, increasing adoption of surgical robots, government initiatives, and the availability of funding are driving the growth of the market in North America.

- The major vendors in the global surgical robotics market are Intuitive Surgical (USA), Stryker (USA), and Mazor Robotics (USA). These companies have the largest base of installed surgical robotic systems across hospitals and ambulatory surgical centers. Other emerging players involved in this market are Smith & Nephew (UK), Hansen Medical (USA), Medrobotics (USA), TransEnterix (USA), Medtech (France), Renishaw (UK), THINK Surgical (USA), and Medicaroid (Japan) [1].

4.2.2 Robotic Surgery as Reported in the Media and Perceived by the Public

Between January 2000 and August 2012, thousands of mishaps with robotic surgeries were reported to the FDA. In the vast majority of cases, the patient was not harmed, but among the reports were 174 injuries and 71 deaths related to da Vinci surgery [2].

Researchers at Johns Hopkins have concluded that adverse events associated with the da Vinci are "vastly underreported" [2, 3].

Documents surfacing in the course of legal action against Intuitive Surgical Inc. have outlined the aggressive tactics used to market the equipment and raised questions about the quality of training provided to surgeons, as well as the pressure on doctors and hospitals to use the robot. The documents show that pressure is exerted even in cases where the use of the robot is not the physician's first choice and when the surgeon has little hands-on experience with the robot.

Expansion of robotic surgery has occurred without proper evaluation and monitoring of the benefits.

- Women have been more likely to be harmed during the robotic procedures. Nearly one-third of deaths that were reported to the FDA database occurred during gynecologic procedures, and 43% of the injuries were associated with hysterectomies.

4.2.3 Robotic Surgery as Perceived by the Surgeons

In addition to the risks of open and laparoscopic surgery, including the potential for infection, bleeding, and the cardiopulmonary risks of anesthesia, there are risks that are unique to the robotic surgical system [4, 5]. Not only is there potential for human error in operating the robotic technology, but the surgical robot introduces the added risk of mechanical failure. Multiple components of the system can malfunction, including the camera, binocular lenses, robotic tower, robotic arms, and instruments. The energy source, which is prone to electric arcing, can cause unintended internal burn injuries from the cautery device. Arcing occurs when electrical current from the robotic instrument leaves the robotic arm and is misdirected to surrounding tissue. This can cause sparks and burns leading to tissue damage which may not always be immediately recognized. Cracks in the insulation of the spatula cautery has been reported to cause ventricular fibrillation during cardiac procedures. There is a small risk of temporary, and even permanent, nerve palsies from the extreme body positioning needed to dock the robot and access the pelvis adequately to perform RALP. Direct nerve compression from the robotic arms can also lead to nerve palsies [6]. Robotic surgery has also been shown to take significantly longer than nonrobotic procedures when performed at centers with lower robotic volume and by surgeons with less experience, and overall, it is more expensive than open surgery [7, 8]. Furthermore, excessively long cases are problematic beyond these concerns. Excessively long robotic cases are associated with the phenomenon of "cognitive tunneling" or fixation. This means that the less experienced surgeon is distracted by the technical demands of the robotic procedure and is therefore unable to guide the OR team toward a safe outcome as in a more routine procedure.

Clearly, the outcomes of robotic surgery correlate with individual surgeon experience [9]. For example, in cancer surgery, surgeons with more experience are more likely to have clean margins [10–12]. Other studies have documented lower complication rates with an increasing number of procedures [4, 13]. These findings of practice makes perfect are not specific to robotic surgery and indeed apply to all surgical procedures. There are varying reports of exactly how many cases are required to master the robotic learning curve, and the number varies by surgical procedure. For robotic prostatectomy, the range has been reported from as low as 40 to as many as 250 [14]. For robotic hysterectomies, the literature reports a range of 20–50 cases to master the operation and reports that less experienced surgeons have significantly longer operative times [15]. Two other phenomena are at work in terms of the true learning curve for each specific surgeon. The "forgetting curve" relates the complexity of the case to the frequency of the curve during the learning phase. Low frequency of highly complex cases leads to more forgetting in between cases and a more prolonged learning curve. The phenomenon of "Unlearning" means that some of the rules of open surgery are not appropriate for robotics. New habits (largely related to communication and team management) have to be learned in order to be a safe and effective robotic surgeon. In turn, if there is resistance to learning the new habits, the learning curve will be prolonged.

Complication rates (including all grades of perioperative complications, from minor to life-threatening) for robotic prostatectomy has been reported at 10% [8, 16]. Multiple risk factors can increase the possibility of complications and errors: patient factors (i.e., obesity or underlying comorbidities), surgeon factors (training and experience), and robotic factors (i.e., mechanical malfunction). The reported complication rate related directly to robot malfunction is very low (approximately 0.1–0.5%) [2, 17]. However, when robotic errors do occur, the rates of permanent injury have been reported anywhere from 4.8% to 46.6% [18], and this literature may suffer from underreporting [3]. Although fewer than 800 complications directly attributable to the robotic operating system have been reported to the FDA over the past 10 years, in a Web-based survey among urologists performing robotic prostatectomy, almost 57% of respondents had experienced an irrecoverable intraoperative malfunction of the robot [18, 19]. The most common areas of complications were malfunction of the robotic arms, joint setup, and camera, followed by power error, instrument malfunction, and breakage of the handpiece.

Potential areas for improvement and reduction of error in robotic surgery include more standardized training of surgeons and teams, more rigorous credentialing practices, improved reporting systems for robotic-associated adverse events, and enhanced patient education.

Perhaps an area which has had very little scrutiny, but is well known to the surgical community, is the rate of failure in terms of Robotic Surgical Programs and surgeons who attempt to adopt robotics into their surgical armamentarium. Some of the reasons for this are the lack of data, definition of success or failure of the programs, and the differences in different surgical specialties. Nevertheless, among the surgical community, there is a sense that there is an inconsistency in the rate of growth in the overall number of robotic surgeries, as compared to the rate of individual surgeon adoption and hospital program success. Many surgeons train for robotic surgery, yet few go on to experience success in terms of adoption, and many individual hospital programs do not experience robust growth of their robotic surgery program.

In a retrospective analysis of the data from the Society of Thoracic Surgeons Adult Cardiac Surgery Database between 2006 and 2012, Whellan and coauthors showed that Robotic Coronary Artery Bypass use remained relatively stagnant at 0.97% of total CABG operations despite lower rates of major perioperative complications and no difference in operative deaths [20].

In a presentation at the International Society of Minimally Invasive Cardiothoracic Surgery in 2015, Poston showed that from 2005 until 2015, 372 different institutions instituted a robotic cardiac surgery program. Only 24/372 (6.4%) of the programs performed more than 50 procedures/year. 212/372 (57%) of the programs had failed to perform a single case in the 2 years that preceded the report. This work is yet further evidence of the fact that many institutions have initiated robotic cardiac surgery programs, but few have sustained its integration into routine practice. Furthermore, this author concluded that based on this data, even though surgeon skill plays a role in the high failure rate of adoption of technically demanding robotic procedures, institutional and organizational factors may play an equally, and perhaps more important, role in assuring success [21].

Clearly, the field of robotic surgery is associated with many controversies. Despite the controversies, given the potential benefits of robotic surgery, the only realistic conclusion is that robotic surgery is here to stay. What is required is a rigorous examination of the many factors that are necessary to ensure the success of surgical programs that are based on such a disruptive technology.

4.3 The Rest of the Story: Concepts of Change Culture and Disruptive Innovation

> The future is not what it used to be!
> Yogi Berra [22]

Robotic surgery has brought about the dawn of a fundamental change in surgery where surgeons are moving from "tissue and instruments" or "objects and atoms" to "information and energy" or "bits and bytes." It would be a mistake to see the implementation of such fundamental change as mere introduction of new technology. Successful implementation of such fundamental change requires substantial changes in organizational aspects of surgery and education and, indeed, a different emphasis and vision for the delivery of surgical care.

4.3.1 Changing Cultures

By nature, although all cultures are inherently predisposed to change, there is great resistance to change. There are dynamic processes operating that encourage the acceptance of new ideas and things, while there are others that encourage changeless stability. Ironically, it is likely that social and psychological chaos would result if there were not for the conservative forces that resist change. Within a society, processes leading to change include invention and culture loss. Culture loss is an inevitable result of old cultural patterns being replaced by new ones. Within a society, processes that result in the resistance to change include habit and the integration of culture traits. Older or more established individuals, in particular, are often reticent to replace their comfortable, long familiar cultural patterns. Habitual behavior provides emotional security in a threatening world of change.

Change is an elusive concept. It is inevitable and yet, paradoxically, it depends on the will and the actions of ordinary individuals who are more disposed to continue the status quo. We embrace change, yet something in our nature fiercely resists it. We structure social movements, political campaigns, and business strategies around the need for change; yet we hardly understand how it works.

While a great deal has been written about social change in the fields of history, sociology, organizational theory, and even psychology, much of it focuses on the recalcitrance of social systems—how and why they resist change—rather than the change process itself. The cyclical process of birth, growth, breakdown, and disintegration has been a perennial theme in philosophy dating back to the ancient Greeks, and perhaps further. Heraclitus, who is remembered for his maxims "there is nothing permanent except change" and "you can never step into the same river twice," compared the world order to an ever-living fire, "kindling in measures and going out in measures" [23]. A contemporary of Heraclitus, Empedocles, attributed the changes in the universe to the ebb and flow of two complementary forces which he called "love" and "hate." Correspondingly, the ancient Chinese philosophers viewed reality as the dynamic reflected in the term they use for "crisis"—wei-ji—which is composed of the characters for "danger" and "opportunity."

While the function of change has preoccupied many of the great Western philosophers, it was not until the late nineteenth and early twentieth centuries that the first comprehensive change theories were articulated.

> This is the tragedy of man: Circumstances change and he does not …
> Niccolo Machiavelli: The Prince [24]

> Nothing is more difficult than to introduce a new order; because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.
> Niccolo Machiavelli: The Prince [24]

Based on exhaustive studies of some 30 civilizations, Arnold Toynbee's *A Study of History* postulated that the genesis of a civilization consists of a transition from a static condition to one of dynamic activity characterized by effective change [25]. The civilization continues to grow when its successful response to the initial challenge generates cultural momentum that carries the society beyond a state of equilibrium into an overbalance that presents itself as a fresh challenge. In this way, the initial pattern of challenge-and-response is repeated in successive phases of growth, each successful response producing a disequilibrium that requires new creative adjustments. Indeed, these concepts are clearly delineated in the history of the United States and the vision of its founding fathers.

> All experience hath shown that mankind is more disposed to suffer… than to right themselves by abolishing the forms to which they are accustomed.
> The Declaration of Independence [26]

Toynbee postulated that when social structures and behavior patterns have become so rigid that the society can no longer adapt to changing conditions, it will be unable to carry on the creative process of cultural evolution. It will then break down and eventually disintegrate. Toynbee's ideas echo those of Oswald Spengler, Pitirim Sorokin, and other social thinkers who viewed change as fundamentally cyclical in nature [27, 28].

A more recent perspective on change comes from historian of science, Thomas Kuhn. In *The Structure of Scientific Revolutions*, which has been called the most important book of the twentieth century, he introduced the concept of a *Paradigm*—a conceptual model or set of assumptions about reality that allows researchers to isolate data, elaborate theories, and solve problems [29]. A scientific paradigm, as Kuhn defined it, can be as all-encompassing as Newtonian physics or as specific as the notion that life exists only on earth. The chief characteristic of a paradigm is that it has its own set of rules and illuminates its own set of facts. In this way, it becomes self-validating and therefore resistant to change. When a new paradigm is articulated—such as robotic surgery—a broad paradigmatic shift occurs. In this way, long periods of "normal" science are followed by brief "revolutions" that involve fundamental changes in basic theoretical assumptions. In Kuhn's view, the history of science is not one of linear, rational progress moving toward ever more accurate and complete knowledge of an objective truth. Instead, it is one of radical shifts of vision in which a multitude of nonrational and nonempirical factors come into play. Kuhn's model also sheds light on how change operates in the natural world as exemplified by the metamorphosis of a caterpillar into a butterfly. In metamorphosis, small cells known as imaginal discs begin to appear in the body of the caterpillar. Since they are not recognized by the caterpillar's immune system, they are immediately wiped out. But as they grow in number and begin to link up, they ultimately overwhelm the caterpillar's immune system. The caterpillar's body then goes into meltdown, and the imaginal discs build the butterfly from the spent materials of the caterpillar. These imaginal discs can be likened to the anomalies in Kuhn's model of paradigmatic change. The caterpillar's immune system does not recognize them, just as the dominant paradigm in Kuhn's model fails to account for anomalies. Finally, they overwhelm the system and usher in a new phase. Interesting parallels can also be drawn between imaginal discs and the "creative minorities" in Toynbee's theory of the rise and fall of civilizations. As Toynbee showed, the seeds of the new civilization are contained within the old one just like the blueprint of the butterfly is contained in the cells of the caterpillar.

In a world buffeted by change, many organizations have learned that the only way to survive is by innovating and that the only stability possible is stability in motion. In *Managing the Future: Ten Driving Forces of Change for the 90s*, Robert Tucker writes: "Two years after *In Search of Excellence* reported on forty-three of the 'best run' companies in America, fourteen of the forty-three firms were in financial trouble. The reason, according to a Business Week study: 'failure to react and respond to change.' That 'change' and 'innovation' have become the bywords of organizational management in the 1990s is reflected in a myriad of business books with titles *like Mastering Change: The Key to Business Success*, *Knowledge for Action: A Guide to Overcoming Barriers to Organizational Change* and *The Change Masters*. As Common Cause founder John Gardner has said, 'perhaps the most distinctive thing about innovation today is that we are beginning to pursue it systematically. The large corporation does not set up a research laboratory to solve a specific problem but to engage in continuous innovation'" [30].

One of the more influential management books to emerge in recent years is *The Fifth Discipline* by Peter Senge, director of the Systems Thinking and Organizational Learning Program at MIT's Sloan School of Management [31, 32]. Senge believes that the greatest challenges confronting organizations today involve fundamental cultural changes. Addressing these challenges requires what he calls collective learning. Organizations must be able to learn in order to survive.

The traditional approach to dealing with complex problems is to break them down into smaller, more easily managed problems. But this approach could be fatal to organizations, according to Senge. When we reduce complex problems and try to isolate their various parts, we "can no longer see the consequences of our actions; we lose our intrinsic sense of connection to a larger whole," he writes. "As daunting as it may seem, we must destroy the illusion that the world is created of separate, unrelated forces. When we give up this illusion, we can then build learning organizations." Unfortunately, these concepts are rarely considered in the process of developing a surgical program or in assessing the need for change in medicine as a whole.

The learning organization is one in which various learning disciplines are continually pursued:

Personal mastery, "the discipline of continually clarifying and deepening our personal vision, of focusing our energies, of developing patience, and of seeing reality objectively." Analyzing one's mental models and envisioning alternative ways of thinking about the world. Working with mental models means exposing our own ways of thinking, as well as making that thinking more open to the influence of others.

Building a shared vision, "unearthing shared pictures of the future that foster genuine commitment and enrollment rather than compliance." Learning as a team, which starts with dialogue and the skill of overcoming defensiveness and other patterns of interaction that keep members from learning—individually and as a team.

Thinking systemically, seeing patterns and the "invisible fabrics of interrelated actions, which often take years to fully play out their effects on each other." Systems thinking ties all the other disciplines together. This kind of thinking involves "a shift of mind from seeing parts to seeing wholes, from seeing people as helpless reactors to seeing them as active participants in shaping their reality." If one were to explain systems thinking in terms of an equation, he says, it would not be "A causes B" but rather "A causes B while B causes A, and both continually interrelate with C and D."

Senge notes that the significant and enduring innovations come about when people from multiple constituencies work together.

Many of Senge's ideas are echoed by Kanter, Stein, and Jick in *The Challenge of Organizational Change* [33]. They focus on how organizations learn to change, emphasizing "the sad fact … that, almost universally organizations change as little as they must, rather than as much as they should." They characterize learning organizations as "self-designing," "self-renewing," and "post-entrepreneurial." They are flexible and open, and all levels of development—individual, team, work group, and organizational—occur simultaneously and synergistically.

Successful change requires (crucial for Robotic Surgery Programs):

- *Build new relationships*. A crucial first step in any process of effecting change is what David Mathews calls "banding together." It means forming relationships, organizing, and claiming collective responsibility for a given issue or situation. The key is to develop a sense of group identity as well as a sense of agency. Banding together generates "a sense of the possibility for change." Being associated with and committed to others gives people a feeling that they are equal to their problems. It is therefore an essential prerequisite to bringing about desired changes.
- *Discuss and deliberate*. All effective change strategies hinge on discussion and deliberation. At a minimum, discussion allows the issues to be named and framed. It also helps individuals develop a shared perspective. Most fundamental change activities break down because those involved in them do not take the time to gain a shared model of reality. At a more fundamental level, dialogue allows a "higher social intelligence." One of the chief obstacles to change is that we've organized our societies by algorithms—that is, by sets of rules by which we try to affect each other like parts of a machine. The result is that we can't talk with each other about things that are really important. Dialogue helps to eliminate false divisions among people, builds common ground, and allows for the emergence of a more systemic perspective.
- *Develop shared visions and goals.* Setting new directions for the future is one of the most powerful ways of effecting change. When people come together "in such a way that their individual visions can start to interact," as Peter Senge puts it, a creative tension is established that gives focus, direction, and context to changes as they occur. Some techniques for developing common visions include future commissions, research conferences, and visioning meetings in which participants develop "best-case" scenarios and articulate common goals. As Senge says, "we communicate our individual visions to one another and eventually start to create a field of shared meaning where there really is a deep level of trust and understanding—and we gradually begin to build a shared vision." This process is very different from such perfunctory strategies as writing "vision" statements. It often involves a great deal of reflection, listening, and mutual understanding.
- *Foster social capital.* The term "social capital" is used to denote the networks and norms of trust and reciprocity that characterize healthy social orders. The term suggests that capital can be measured in social as well as economic terms and that relationships have an inherent value.
- *Ensure broad participation and diversity*. Fundamental change is impossible without the participation of everyone who has a stake in the problem or issue. Without the full participation of all concerned, perspectives will be missing, and there is a good chance that some of the issues involved will go unaddressed. Another aspect of this is the inherent value of diversity. Research has shown that homogeneity fosters stability, while diversity invariably produces change. It follows that planned change is best achieved by promoting diversity.
- *Determine leadership roles*. There are many types of leaders, but the "right" leaders lend cohesion to a group and act as the catalyst for change. Their vision, drive, and personal commitment can be keys to galvanizing a group into action. Also, leaders are able to champion and protect those who are most willing to risk change.
- *Identify outside resources*. Fundamental change tends to be difficult and painful and always involves uncertainty and risk. Since most communities and organizations that embark on the journey need outside help, they need to develop linkages to outside sources of capital and information. These linkages not only facilitate the process of change but also often provide opportunities for lateral learning and growth.
- *Set clear boundaries*. When planning for specific kinds of change, it is important to operate within clearly defined boundaries—for both psychological and practical reasons. Boundaries provide frameworks for measuring change and give focus and direction to one's efforts. Realistic boundaries also provide a sense of what is feasible. On a practical level, clearly defined goals allow one to make realistic plans.
- *Draw on the examples of others*. Change takes place in an infinite variety of ways, and there is no single strategy that will work for every individual or group. Still, those seeking to effect change may take comfort and inspiration from the examples of others. Not only does this provide mentors from whom they can learn, but it offers them conviction that their goal is attainable.
- *Adopt a change mindset*. It is natural to seek change after a crisis. Necessity, after all, is the mother of invention. However, to be successful, one has to adopt a crisis perspective without a crisis or at least a mindset that is constantly attuned to change. What is required is a shift of perception from seeing change as disequilibrium to seeing it as a constant. Strategizing for change ultimately comes down to whether individuals are motivated to change, learn, and grow.

4.3.2 Disruptive Innovation

Disruptive Innovation (DI) theory was advanced by the Harvard Business School Professor, Clayton M. Christensen, in 1997, in the book *The Innovator's Dilemma* [34–37]. According to Christensen, a disruptive innovation is an innovation that creates a new market and value network and eventually disrupts an existing market and value network, displacing established market-leading firms, products, and alliances. According to Christensen, disruptive technologies are technologies that provide different values from mainstream technologies and are initially inferior to mainstream technologies along the dimensions of performance that are most important to mainstream customers. He introduced the important aspects of changing performance with time and plotted the trajectories of product performance provided by firms and demanded by customers for different technologies and market segments and showed that technology disruptions occur when these trajectories intersect (Fig. 4.1).

In its early development stage, each product based on a disruptive technology can only serve niche segments that value its nonstandard performance attributes. Subsequently, further development raises the disruptive technology's performance onto a level which is sufficient to satisfy mainstream customers. While improved, the performance of the disruptive technology remains inferior compared with the performance offered by the established mainstream technology, which itself is improving as well. In fact, the performance of the mainstream technology could have exceeded the demand of mainstream customers, resulting in "performance overshoot" with overserved customers. The market disruption occurs when, despite its inferior performance on focal attributes valued by existing customers, the new product displaces the mainstream product in the mainstream market. There are two preconditions for such a market disruption to occur: performance overshoot on the focal mainstream attributes of the existing product and asymmetric incentives between existing healthy business and potential disruptive business. Christensen documented these technology and market dynamics in numerous contexts such as hard disk drives, earthmoving equipment, and motor controls.

The problem with conflating a disruptive innovation with any breakthrough that changes an industry's competitive patterns is that different types of innovation require different strategic approaches. To put it another way, the lessons we've learned about succeeding as a disruptive innovator (or defending against a disruptive challenger) will not apply to every instance in a shifting market. If we get sloppy, then managers may end up using the wrong tools for their specific context and reduce their chances of success (think RS).

Disruptive innovations are made possible because they get started in two types of markets that are usually overlooked by incumbents: *low-end footholds and new market footholds. Low-end footholds* exist because incumbents typically try to provide their most profitable and demanding customers with ever-improving products and services, and they pay less attention to less-demanding customers. In fact, incumbents' offerings often overshoot the performance requirements of the latter. This opens the door to a disrupter that is focused on providing those low-end customers with a "good enough" product.

In the case of *new market footholds* (think RS), disrupters create a market where none existed. Put simply, they find a way to turn nonconsumers into consumers. For example, in the early days of photocopying technology, Xerox targeted large corporations and charged high prices in order to provide the performance that those customers required. School librarians, bowling-league operators, and other small customers, priced out of the market, made do with carbon paper or mimeograph machines. Then in the late 1970s, new challengers introduced personal copiers, offering an affordable solution to individuals and small organizations—and a new market was created. From this relatively modest beginning, personal photocopier makers gradually built a major position in the mainstream photocopier market that Xerox valued.

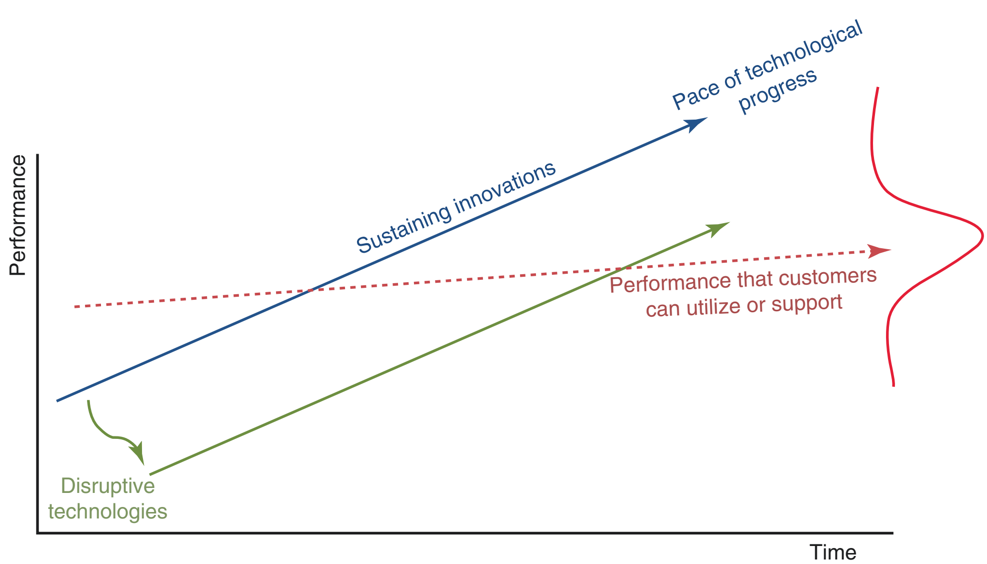

Fig. 4.1 Three critical elements of disruptive innovation are depicted in this figure. First, in every market, there is a rate of improvement that customers can utilize or absorb, represented by the dotted line sloping gently upward across the chart. Second, in every market, there is a distinctly different trajectory of improvement that innovating companies provide as they introduce new and improved products. The third critical element of the model is the distinction between sustaining and disruptive innovation

Disruptive innovations don't catch on with mainstream customers until quality catches up to their standards. Disruption theory differentiates "disruptive innovations" from "sustaining innovations." "Sustaining innovations" make good products better in the eyes of an incumbent's existing customers. "Disruptive innovations," on the other hand, are initially considered inferior by most of an incumbent's customers. Typically, customers are not willing to switch to the new offering merely because it is new, has future potential, or is less expensive. Instead, they wait until its quality rises enough and early wins are recorded.

There are subtle aspects to disruptive innovation:

- Most every innovation—disruptive or not—begins life as a small-scale experiment. Disrupters tend to focus on getting the business model, rather than merely the product, just right. When they succeed, their movement from the fringe to the mainstream first erodes the incumbents' market share and then their profitability. This process can take time, and incumbents can get quite creative in the defense of their established franchises. Complete substitution, if it comes at all, may take decades because the incremental profit from staying with the old model for one more year invariably trumps proposals to write off the assets in one stroke. The fact that disruption can take time helps to explain why incumbents frequently overlook disrupters.
- Disrupters often build business models that are very different from those of incumbents. For example, by building a facilitated network connecting application developers with phone users, Apple changed the computer game. The iPhone created a new market for internet access and eventually was able to challenge desktops and laptops as mainstream users' device of choice for going online.
- Some disruptive innovations succeed; most don't. A common mistake is to claim that a company is disruptive by virtue of its success. But success is not built into the definition of disruption: Not every disruptive path leads to a triumph. Rather, it is the manner in which the path is implemented that dictates triumph (think RS).

In order to drive disruptive innovation, it is imperative to pay attention to more than the product. Organizational change is the foundation of implementing disruptive innovation in a successful manner. There are four components of organizational preparedness for a disruptive innovation: (1) human resources, (2) organizational culture, (3) resource allocation, and (4) organizational structure. These concepts are highly relevant to RS.

Human Resources There are two subgroups within the scope of human resources, managers and employees. Each subgroup may be responsible for the success or failure of meeting the challenge of implementing a disruptive innovation. First, senior managers may not understand the promise of the disruptive innovation because their views of the world are deeply entrenched and largely shaped by their current experiences. Most of them have been trained in conventional business programs which teach them to manage organizations that serve established markets with well-defined product lines. Therefore, an additional team at the corporate level is required to be particularly responsible for collecting disruptive innovation ideas and seeing them through to implementation. Moreover, long-term-oriented, subjective-based incentive plans should be adopted instead of short-term-oriented, formula-based incentive plans for key executives. This concept ensures that the senior managers will not be confined by rigid incentives which will lead them to avoid the risks of disruptive innovation. Second, since most strategic proposals take their fundamental shape at the lower levels of hierarchical organizations, middle managers also matter. As middle managers usually have the most to lose in any basic change, they are likely to allocate their resources to Sustaining Innovations that bolster their current fiefdom and careers. Third, there may be different performances between founders and professional managers in disruptive innovations. Founders have an advantage in tackling disruption because not only they wield the requisite political clout but also they have the self-confidence to override established processes.

Research has also been done to explain the success or failure of disruptive innovations from the employees' perspective. For example, the team research on a successful disruptive project found that the team members were composed of carefully selected risk-takers and that the firm also recruited outside expertise. In terms of decision-making, Christensen argued that capturing ideas for new growth businesses from people in direct contact with markets and technologies can be far more productive than relying on analyst-laden corporate strategy or business development departments as long as the troops have the intuition to do the first-level screening and shaping themselves. In following process of implementation for the disruptive idea, instead of accepting one-size-fits-all policies, executives should spend time ensuring that capable people work in organizations with processes and values that match the task. Another interesting observation is that disruptive companies are usually founded by frustrated engineering teams from established firms. Hence, the incumbent firms should take measures to prevent disruption from outside due to brain drain of talents and disruptive ideas. One solution to this problem would be to establish spin-offs within the larger organization (think semiautonomous specialty robotic teams).

Organizational Culture A firm's culture is a critical component of its success. Culture is an effective way of controlling and coordinating people without elaborate and rigid formal control systems. However, culture is a double-edged sword that sometimes results in the failure of innovation. Without constant vigilance, at times cultural inertia is difficult to overcome by managers even when they know that it is needed. Hence, it is important for incumbents to prepare for, and institute, organizational change and unlearn deeply entrenched values in the early phases of instituting a potentially disruptive innovation. On the other hand, some integral elements of culture, such as entrepreneurship, risk-taking, flexibility, and creativity, should be preserved and valued in order to develop disruptive innovations.

Therefore, it is appropriate to conclude that:

- Although implementing change is necessary and is indeed the lifeline of any organization and humanity as a whole, it is difficult to implement change, especially in a highly established conservative organization.
- Introduction and successful implementation of disruptive innovation and change require a multifaceted approach.
- Robotic surgery is a disruptive innovation which is introduced to the highly conservative world of surgery, and therefore, the implementation of a successful program in robotic surgery needs to follow the complex and multifaceted approach.
- The implementation of nuclear propulsion into the United States Navy is an excellent example of the introduction of a disruptive innovation into a very conservative culture and, therefore, can provide valuable insights and a blueprint for the implementation of a successful program in robotic surgery.

4.4 Lessons About Organizational Change and Implantation of Disruptive Innovation from the Nuclear Navy

4.4.1 Hyman G. Rickover

Hyman George Rickover was born in the Polish city of Makow, then part of the Russian Empire, on January 27, 1900. Fleeing from anti-Semitic Russian pogroms during the Revolution of 1905, Rickover made passage to New York City with his mother and sister in March 1906. Rickover gained admission to the United States Naval Academy in 1918 and was commissioned an ensign in 1922. After services on the destroyer USS Nevada, he returned to the Naval Academy for additional training in electrical engineering. In addition, he received a Master of Science degree in Electrical Engineering from Columbia University in 1929.

From 1929 to 1933, he was assigned to the submarine service. While posted to the Office of the Inspector of Naval Material in Philadelphia, Pennsylvania, in 1933, he translated the German book on submarines, *Das Unterseeboot*. The only command of his naval career came in 1937, when he was put in charge of the minesweeper *USS Finch*. His acceptance as an engineering duty officer in 1939 removed him from consideration for any further commands. During World War II, Rickover served in the Navy's Bureau of Ships as head of the Electrical Section, where his performance earned him a Legion of Merit medal.

Following the war, in 1946, Rickover was one of a group of naval officers sent to the Oak Ridge National Laboratory, Tennessee, to study nuclear engineering. Later, Rickover was reassigned to the Bureau of Ships but also managed an assignment with the newly formed Atomic Energy Commission in its Division of Reactor Development. Skillfully using these twin roles, Rickover built support for the concept of nuclear submarines. When the Bureau of Ships created a Nuclear Power Branch of its Research Division in August 1948, Rickover was made its head. By 1949, Rickover was using his industry connections to advance research initiatives. At the time, two competing concepts for cooling nuclear submarine reactors were available: (1) cooling by pressurized water and (2) cooling by liquid metal. Rickover wanted to try both of them, so he arranged with Westinghouse in 1949 to investigate the pressurized water approach and with General Electric in 1950 to pursue a liquid sodium approach [38, 39].

Hyman Rickover is universally regarded as the father of the US Navy's nuclear submarine program and indeed "Father of the Nuclear Navy." Having experienced submarine service before World War II, after the war, Rickover realized that nuclear power had the potential to remove many limitations on submarine design.

During the Second World War, submarines comprised less than 2% of the US Navy but sank over 30% of Japan's navy, including eight aircraft carriers. More importantly, American submarines contributed to the virtual strangling of the Japanese economy by sinking almost 5 million tons of shipping—over 60% of the Japanese merchant marine. However, victory at sea did not come cheaply. The submarine force lost 52 boats and 3506 men. World War II submarines were basically surface ships that could travel underwater for a limited time. Diesel engines gave them high-surface speed and long range, but speed and range were severely reduced underwater, where they relied on electric motors powered by relatively short-lived storage batteries. Recharging the storage batteries meant surfacing to run the air-breathing diesels. Even combat patrols routinely involved 90% or more surface operations. Submarine service was deadly for the enemy, but unfortunately due to the shortcomings of the diesel propulsion technology, it was even more deadly for the men who served on the submarine.

Rickover's vision resulted in the launching of the world's first nuclear-powered submarine in 1954, the USS Nautilus. Rickover's faith in nuclear submarines was vindicated, when the USS Nautilus became the first submarine or naval vessel of any kind to be propelled entirely with nuclear power and sailed silently and without detection under the North Pole during a 4-day, 1830 mile cruise from the Atlantic to the Pacific on August 3, 1958. The Nautilus employed the pressurized water method of reactor cooling. The Navy's second nuclear submarine, USS Seawolf, was powered by a reactor using liquid sodium cooling.

Rickover was the only officer in the history of the US Navy to be promoted by an act of Congress. When Rickover was not promoted to rear admiral twice due to political issues in the Navy, his many supporters in Congress forced hearings, and by an act of Congress, Rickover was promoted to rear admiral in 1953, vice admiral in 1958, and admiral in 1973.

President Richard Nixon attended Rickover's promotion to admiral in 1973. Nixon's words clearly summarize Rickover's legacy:

> I don't mean to suggest that he is a man who is without controversy. He spoke his mind… But the greatness of the American Military Service … is symbolized in this ceremony today, because this man, who is controversial, this man, who comes up with unorthodox ideas, did not become submerged by the bureaucracy, because once genius is submerged by bureaucracy, a nation is doomed to mediocrity [40].

Not only did Rickover build the first nuclear submarine, but through his "Leadership and Organizational Principles" which were woven into the fabric of the "New" Navy, he transformed the Navy, America, and indeed the entire World. The US Navy's fleet of nuclear submarines, starting with the 1954 launching of the Nautilus, undermined the USSR's assured second-strike capabilities and tilted Cold War geopolitics in the favor of the United States.

Admiral Hyman G. Rickover oversaw the successful development of the nuclear submarine, and in the process, he gathered a team of people that would inculcate a system of continuous improvement into submarines. The technical breakthrough that he oversaw was so significant, and the cultural change he imposed was so vast, that in a few years after the submarine Nautilus first took to the seas, nuclear power had transformed an auxiliary warship of World War I and World War II into a stealth platform that ruled the oceans and unbalanced the Cold War.

With nuclear submarines, the United States controlled the surface as well as what moved in the waters below the sea. A warship that had been an afterthought in previous history became, with nuclear power, the point of the spear in the Cold War. Rickover and the Navy built such a superior platform that the US nuclear submarines could go under the ice and into Soviet waters at will. In addition, shrouded in secrecy, Nautilus' successors could penetrate any and all underwater defenses that the Soviets could develop.

Interestingly, in December 3, 1989, during the summit meeting that marked the end of the Cold War, Sergei Akhromeyev—a marshal of the Soviet Union and Mikhail Gorbachev's personal military advisor—told George H. W. Bush, "We have read every one of your submarine messages for ten years and have been unable to find or kill even one of them. We quit" [41].

On January 31, 1982, after 63 years of service to his adopted country under 13 different presidential administrations, Admiral Rickover retired. His tenure as head of the Navy's nuclear program ran so long because, due to his unparalleled insight and knowledge, he was declared exempt from the mandatory retirement age for senior admirals by a Congressional Resolution.

Admiral Rickover died on July 8, 1986. Quite fittingly, he is memorialized in the attack submarine USS Hyman G. Rickover (SSN 709).

4.4.2 Why Is Rickover Important?

What lessons can robotic surgery learn from Rickover? Until the early nineteenth century, oars powered by men, or the wind, were the principal means of watercraft propulsion. Steam propulsion was introduced and developed in the nineteenth century. First steam was generated using coal. In the early part of the twentieth century, the British Navy, the most powerful navy of the time, switched to using diesel oil for generating steam and later for use in diesel electric propulsion systems. Of interest, the dependence of the British and other Navies on oil became the important determinant of political struggles of the twentieth century. By the end of World War II, diesel electric naval propulsion was the state of the art. Until the dawn of the nuclear age, all naval propulsion systems depended on fuel which was finite and needed to be reloaded at intervals. This represented the "Achilles heel" of the naval vessels. The dawn of the nuclear age brought about the potential of a quantum change in naval propulsion. A nuclear reactor held the promise of inexhaustible fuel and, by extension, allowed for stealth and omnipresence of the naval vessels throughout the world's waters. As the nuclear propulsion system represented a quantum leap in technology, the resultant organizational changes to the Navy represented a quantum leap in culture change that was necessary for the safe implementation of this potentially uncontrollable force.

America's nuclear fleet was not built in a vacuum. Rather, it was built by the vision and leadership skills of one man, Hyman G. Rickover. The best measurement of Rickover's success is in the record for "reactor accidents." The United States has never had a nuclear reactor accident aboard a submarine. This is in sharp contrast to the Soviet Navy that has had at least 13 "reported" nuclear accidents.

What were Rickover's management methods, and to what extent can robotic surgery learn from that experience?

Culture Change: Rickover believed that nuclear technology could not be safely introduced unless the naval culture changed dramatically. Rickover believed that "culture" tends to stifle change and reform. He referred to culture as a "window shade." The lower the shade, the less glare from the sun inside and the more comfortable it is for the people working in the room. However, with the shades down, outside events may pass unseen. With the shades down, few people inside can recognize that the outside world is changing. As a culture becomes stronger, it is equivalent to pulling the shades even lower. Rickover believed that without change, the very military culture that helps people aggressively engage in conflict and assures individuals that the travails of military service are natural, courageous and patriotic can spell their doom. He believed that military or organizational culture encourages preparation "to fight the last war" as opposed to preparing to fight "the next war." Indeed, resistance to culture change is the most dangerous path for a military force or any organization. He believed that culture needed to change in order to assure the continued survival of the military, the country, and the species. Rickover believed that humanity's resistance to change, which emanates from fear and a sense of complacency and weakness, is in direct conflict with nature's need for evolution and change.

It does not require great imagination to extrapolate from the experiences of the military to the culture in the surgical theater and medicine in general.

> Good ideas are not adopted automatically they must be driven into practice with courageous impatience.
> Hyman G. Rickover [42]

At great personal and political cost, and at the great displeasure of the Navy, Rickover started by advocating that his nuclear submarines be built by privately owned shipyards. Under this scenario, he believed that the boats would be built to his standards, as he controlled the money. He avoided shipyards commanded by Navy's admirals who may not have shared his vision. He believed that public shipyards used old processes and procedures and consequently were not suitable for the new nuclear propulsion technology.

In what was the most disruptive aspect of the nuclear transformation, Rickover made it clear that most of the officers who had previously served on diesel submarines, the same individuals who had just won the war in the Pacific, were not welcome on nuclear submarines. Clearly, this decision reflected his conviction that the culture needed to change and all efforts needed to be undertaken to be certain that the new culture would not be hindered by habits of old. He respected the culture of the "Old" Navy which was represented by the extraordinary group of brave sailors whose personal boldness compensated for the World War II era submarines' lack of armor, stealth, and speed. However, he felt that the "new" nuclear submarine force needed a culture that emphasized science and safety, in addition to bravery. In short, though the diesel submariners of World War II comprised the highest percentage of servicemen of any branch of the armed forces to have been killed in action during the war, Rickover believed that the nuclear Navy required brains over brawn. Therefore, he set out to train a whole new breed of sailors for America's Silent Service.

Rickover interviewed and personally selected all the officers of the nuclear submarine force.

Rickover believed that the "New" culture needed to emphasize absolute safety of the nuclear fleet to the men who served on the ships and, equally importantly, demonstrate safety to the American public. He was convinced that any deviation from perfection of the systems and personnel would bring an end to the nuclear Navy. Therefore, the only requirement demanded by Rickover for his officers and the entire nuclear Navy was *absolute perfection*.

Robotic surgery has a lot to learn from this vision!

4.4.2.1 Planning for Success

Many maintain that a real leader can do it all and manage anything. Rickover knew that this was incorrect. He believed that a real leader needs to depend both on a dynamic personality, as well as an absolute knowledge of the field.

Rickover believed that all that matters is the job at hand. He believed that the leader needed to have the ability to evaluate a situation without worrying about how the assessment would affect his relationships with other stakeholders. He believed that the difference between a manager and a leader was that a leader had the extraordinary ability to see the future and to recruit individuals who, even though were different from him, could better serve the enterprise.

"More than ambition more than ability it is rules that limit contributions; rules are the lowest common denominator of human behavior. They are a cheap substitute for rational thought" [43].

4.4.2.2 Details, Details, Details

Rickover believed that the person in charge must concern himself with details and be realistic. He warned against the natural naïveté of a startup. He felt that in a new endeavor, people become overenthusiastic. As a consequence, those driven by enthusiasm, rather than the details, may well believe that the endeavor is more robust, capable, and survivable than it actually is. The misplaced enthusiasm about the endeavor results in forgetting the main goal. Rickover believed that absolute attention to detail, clear view of the facts, and perfection were paramount in situations where human life was at stake.

> The devil is in the details but so is salvation
> Hyman G. Rickover [44, 45]

Clearly, the world of robotic surgery needs to learn from Admiral Rickover's principles. There are many examples where enthusiasm about the technology has resulted in adverse results. Surgeons need to be reminded that enthusiasm about the possibilities and potential of robotic surgery cannot take the place of the main goal which is perfection of surgery and the absolute conviction to assure the needs and safety of the human patient.

4.4.2.3 Education

Admiral Rickover was an education expert. He believed that he well understood what could be taught and what could not. Rickover believed in education as opposed to indoctrination. Rather than picking engineers like himself and trying to teach charisma, he instead recruited natural leaders who could learn engineering.

Rickover believed that just like the natural and much-needed periodic change in culture, educational systems, which had been designed for different points in time, needed to change in order to reflect a new paradigm. He believed that the system of education in the military was rooted in the past, and he single-handedly transformed the system and set its path for the future.

> What it takes to do a job will not be learned from a management course …Human experience shows that people, not organizations or management systems get things done.
> Hyman G. Rickover [46]

Following Rickover's example, medical education needs to set aside the ideas of the twentieth century and undertake a different path which is designed to respond to the needs and expectations of the twenty-first century.

4.4.2.4 Responsibility and Owning the Problem

Rickover believed that each individual member of the team needs to be responsible for the success of the entire project. He believed that being a cog in a wheel is not a stigma, but to the contrary, depending on how it is perceived, should be a great source of pride. Rickover emphasized that if safety was of paramount concern, no jobs or roles in the nuclear Navy were less important to others. Each role mattered if the ultimate goal was service to a higher ideal, such as safety of a nuclear warship or safety of a nation, as opposed to service to self. Unfortunately, the concept of pride of membership in a collective enterprise is at times mistaken for lack of individualism. Rickover, who was an immigrant to the United States, believed that the greatest source of pride and personal fulfillment was citizenship and service to America.

> Responsibility is a unique concept … You may share it with others, but your portion is not diminished, You may delegate it, but it is still with you … If responsibility is rightfully yours, no evasion, or ignorance or passing the blame can shift the burden to someone else.
> Hyman G. Rickover [47]

Other quotes from Admiral Rickover which clearly reflect his extraordinary vision:

> sit down before fact with an open mind. Be prepared to give up every preconceived notion. Follow humbly were ever into *whatever* abyss nature leads or you learn nothing. Don't push out figures when facts are going in the opposite direction.
> Hyman G. Rickover [48, 49]

> One must permit his people the freedom to seek added work and greater responsibility. In my organization, there are no formal job descriptions or organizational charts. Responsibilities are defined in a general way, so that people are not circumscribed. All are permitted to do as they think best and to go to anyone and anywhere for help. Each person then is limited only by his own ability.
> Hyman G. Rickover [50]

> It's a human inclination to hope things will work out, despite evidence or doubts to the contrary. A successful manager must resist this temptation.
> Hyman G. Rickover [51]

> Do not regard loyalty as a personal matter. A greater loyalty is one to the Navy or to the country.
> Hyman G. Rickover [52]

> All men are by nature conservative but conservatism in the military profession is a source of danger to the country.
> Hyman G. Rickover [53]

> To doubt one's own first principles is the mark of a civilized man. Don't defend past actions; what is right today may be wrong tomorrow.
> Hyman G. Rickover [54]

> We should value the faculty of knowing what we ought to do and having the will to do it…The great end of life is not knowledge, but action.
> Hyman G. Rickover [55]

To summarize, a robotic surgery program, in fact any successful enterprise, would do well to follow the leadership principles from Admiral Rickover that were instrumental in bringing about fundamental change to the United States Navy. Admiral Rickover understood the need for a culture change not only in his program but the entire organization of the Navy, handpicked the naval officers, demanded perfection and ownership of the enterprise, was driven by the truth, focused on the details, instituted a new paradigm in education, and ironically but quite appropriately, was dedicated not to the success of his program but the best interest of the nation. Undoubtedly, success would be the only possible outcome for a robotic surgery program which is designed using this blueprint.

4.4.3 Changing to a Culture That Strives for Greatness

In following the Rickover blueprint, culture change is Job One. However, the culture needs to change not to any culture but a culture of greatness.

The complex problems which face American medicine are well known. However, despite all the challenges in terms of cost and availability of health care, medical care in America remains the envy of the world. Yet, from the standpoint of patients and physicians, there are many shortcomings that must be addressed urgently. This paradox has its roots in the fact that at the point of delivery of health care, everyone expects greatness. Good is not good enough!

When it comes to the delivery of health care, and especially complex programs such as those which offer robotic surgery, the expectation, no the demand, of the patients and therefore the surgeons and the entire health-care delivery system must be greatness.

In medicine, good does not exist. There is bad, there is great, and all in between is mediocrity.

It is imperative to understand that based on the data and observations of the past 20 years, robotic surgery programs, which have been built based on surgical greatness, great patient experience, and the underlying foundation of a great institution, have enjoyed exceptional success. On the other hand, if any of the pillars of greatness were absent, the robotic surgery program has been doomed to fail.

These observations lead to one paramount question. How can greatness be assured?

In part, the answer comes from the Business Sector.

Almost 20 years ago, Jim Collins of Stanford Business School asked the question: Why do some companies make the leap to greatness and others don't? The answer to this question is the subject of the book *Good to Great* [56].

Collins and 21 researchers from Stanford Business School examined the business performance of over 1400 companies from 1965 to 1995. They defined business greatness very rigorously. To be included in the study, the company needed to begin with a 15-year cumulative stock return at or below the stock market. To be considered a great company, it needed to go through a transition point, after which its cumulative return was to rise to at least three times the market for the next 15 years. In addition, the growth of the company needed to be independent of its industry. In fact, to be considered as great, the company had to achieve its astronomical market growth in a sagging industry. To illustrate the very high standard for the definition of greatness, Collins pointed out that between 1985 and 2000, a mutual fund comprised of the most successful companies in the United States, 3M, Boeing, Coca Cola, HE, HP, Intel, J&J, Motorola, Pepsi, Proctor and Gamble, Walmart, and Walt Disney, only achieved a cumulative stock return 2.5 times the market, and therefore none of the companies, alone or even as a group, would meet the criteria for greatness.

Of the over 1400 companies, 11 met the very high standards for greatness: Abbott, Circuit City, Fannie Mae, Gillette, Kroger, News Corp, Phillip Morris, Pitney Bowes, Walgreen, and Well Fargo. All these historically underperforming companies went through a specific transition point after which they reached the degree of success which could meet the inclusion criteria for greatness. The factors which were responsible for the transition point can provide a clear path to achieving greatness for a company, a program, or an institution. In our experience, these are the very factors that are crucial for building a successful robotic surgery program.

Greatness was achieved by the combination of three components: (1) disciplined people, (2) disciplined thought, and (3) disciplined action.

4.4.3.1 Disciplined People

An organization achieved greatness by combining "Level V" leadership with the "right" people.

Leadership is defined in five levels. A "Level I" leader is a capable individual. A "Level II" leader is a contributing team member. A "Level III" leader is a competent manager. A "Level IV" leader is an effective manager. A "Level V" leader is an individual with an unwavering will to succeed. This leader shows uncompromising commitment to the enterprise rather than self, accepts all responsibility, and attributes all the success to the members of the organization.

A "Level V" leader is rigorous but not ruthless and sets the tone for the rest of the organization.

In turn, a great organization concentrates on recruiting and retaining the "right" people and, more importantly, disinheriting the "wrong" people. A great organization sees that people are not its most important asset; rather, the "right" people are its more important asset. Unlike most companies, a great organization directs its best people to the biggest opportunities instead of the biggest problems.

4.4.3.2 Disciplined Thought

A great organization does not avoid reality; rather, it actively seeks to face the "brutal" facts. It provides a forum in which the truth is heard, adversity is confronted, and decisions are made only after facing the brutal facts. A great organization adheres to the "Stockdale Principle," named after the senior US prisoner of war officer in the Hanoi Hilton Prison of War Camp during Viet Nam, which outlines an unwavering commitment to prevail regardless of difficulties.

> We will never give up, we will never capitulate. It might take a long time, but we will find a way to prevail.
> James Stockdale, Admiral USN [57]

Finally, as the ultimate expression of disciplined thought, a great organization builds a culture around an entrepreneurial spirit which juxtaposes freedom as well as responsibility within the organizational framework. A great organization fills its culture with self-disciplined people with a sense of ownership, who will go to extreme lengths to fulfill their responsibility.

4.4.3.3 Disciplined Action

A great organization defines its mission and work product with absolute clarity and pursues success with a combination of passion, unparalleled excellence, and attention to the economic engine of the enterprise.

A great organization strives to be a pioneer in the careful application of technology ahead of the competition. It strives to be a "clock maker" rather than a "time teller." With absolute compulsion, a great organization pursues a path of driving unrealized potential into results. Finally, a great organization remains on the same path for the long term and resists the doom loop.

The doom loop, which characterizes failed organizations, is defined as frequent course changes by leaders who are motivated by ego and self-interest in search of short-term success. Organizations in the doom loop invariably experience greater disappointment and poor performance. In response to these disappointments, without insight into the complex factors, the organizations in the doom loop change leadership, only to begin the doom loop yet again.

On the other hand, a great organization sustains its greatness by emphasizing purpose and profit, continuity and change, freedom, and responsibility.

4.4.4 Culture of Greatness in the Operating Room

> We want to believe that the failure of others is due to lack of intelligence or skill because we want to convince ourselves that we would succeed at a similar endeavor despite the obvious risks, when, in fact, most of the mistakes are cognitive traps, independent of intellect or expertise.
> Educator Michael Roberto [58]

The operating room is a complex environment with a culture that, amazingly, has not changed greatly in more than a century. Recently, there has been recognition of the myriad of cultural problems in the operating room that result in poor patient outcomes. Ironically, despite multiple nationwide and global patient safety initiatives over the past decade, recent reports reveal that adverse event rates for surgical conditions remain unacceptably high and, disappointingly, have remained almost unchanged [59–61]. Adverse events resulting from surgical interventions are actually more frequently related to errors occurring before or after the procedure than by technical surgical mistakes during the operation. These include (i) breakdown in communication within and among the individuals in the operating room, care providers, patients, and their families, (ii) delay in diagnosis or failure to diagnose, and (iii) delay in treatment or failure to treat [62–64]. In general, there is broad agreement that the adverse events in the operating room are mostly the result of (1) communication gaps between the surgeons and staff and/or patient, (2) lack of organizational processes to prevent errors, (3) miscommunication, (4) lack of a culture of safety, (5) ineffective conflict resolutions, (6) inappropriate leadership and oversight, and (7) lack of specialty-specific surgical and anesthesia teams. Although these factors are crucial for the safe conduct of any surgical procedure, they become even more paramount in establishing a successful robotic surgery program.

The most logical processes to improve patient safety in the operating room are as follows: (1) Identify current issues regarding patient safety. (2) Revise systems, education, and training to address known patient safety issues. (3) Educate health-care professionals about the importance of patient safety concepts. Establish a system of checks and balances to reduce medical errors. Ensure practical application of patient safety concepts by training. (4) Enhance patient interaction to reduce errors. It is important to emphasize that based on recent data, even though these and other measures have been instituted throughout the health-care system, in the operating room, the rate of errors has not diminished.

Errors are inevitable, but having a system in place to prevent them from occurring, and remedying them when they do occur, improves overall patient safety in the health-care environment. Dante Orlandella and James T. Reason of the University of Manchester originally proposed a model which can help to conceptualize system failure, commonly called the "Swiss cheese model" [65, 66]. Based on this model, to varying degrees, every step in a process has the potential for failure. The ideal system is analogous to a stack of slices of Swiss cheese. Consider the holes to be opportunities for a process to fail, and each of the slices as "defensive layers" in the process. An error may allow a problem to pass through a hole in one layer, but in the next layer, the holes are in different places, and the problem should be caught. Each layer would work as a defense against potential error impacting the outcome. The greater number of defenses, the fewer and the smaller the holes, the more likely you are to catch and stop errors that may occur. The Swiss cheese model of accident causation illustrates that if hazards and accidents are aligned and the layers of defense do not lie between, the flaws in each layer can allow the accident to occur. In the operating room, the "Swiss cheese" concept can be *prevented with the implementation of teams*.

Elite military forces such as the Navy Seals and surgery have a lot in common. They are both examples of high-risk endeavors and environments that result in high risk and high stress. In these and other similar environments, time pressure is significant, there is dependence on functioning proper equipment, and lives are at stake. Elite military forces and all other examples in industry and other fields have learned that a "team" is the key to minimizing risk and maximizing the chances for the successful execution of mission.

A number of studies have emphasized that without specific functioning specialty-specific surgical and anesthesia teams, all other measures that are aimed at reduction of surgical errors are doomed to fail. In addition, data from a number of fields, including medicine, has shown repeatedly that "catastrophes" are the result of the failure in communication and lack of coordination of action among individuals who are not part of a team. Nevertheless, the operating room remains the only high-stakes environment that uses interchangeable staff in the conduct of surgical procedures. In the operating room, teams are the exception rather than the norm!

Consider this all too common scenario: A complex surgical procedure is scheduled. On the morning of surgery, one of several anesthesiologists is assigned to deliver anesthesia. Operating room (OR) personnel which consist of nurses and surgical technicians are assigned from a general pool to the room. The anesthesiologist and the OR personnel are generalists and work with many surgeons and many surgical specialties. A great of attention is focused on consent forms and the "time-out" procedures. Prior to the start of the surgery, the instruments and sponges are counted by the scrub nurse who begins the case. In the middle of the case, the OR personnel are replaced by other scrub technicians and nurses for "breaks" and "lunch relief." With each change of personnel, the instruments and sponges are counted again. During the procedure, several changes also occur for the anesthesia personnel. Invariably, by the end of the procedure, a number of OR personnel and anesthesia personnel changes have occurred, the instruments and sponges have been counted multiple times by multiple different people, and the personnel who finish the operation are rarely the same people who started the case. The only constant factor in the operating room was the surgeon and the patient. Clearly, such a common scenario is a potential formula for catastrophic outcomes and is, in large part, responsible for the all too common system-related complications that are reported.

Weigmann et al. showed that lack of operating room teams results in increased surgical errors and disruption of workflow as well as significant loss of overall revenue for the institution [67]. A number of recent studies have shown a correlation between implementation of operating room teams and decreased surgical mortality [68–70]. Neily showed the implementation of formal teams in the operating room correlated with increased efficiency, decreased turnover times, reduced errors, increased staff satisfaction, and increased institutional revenue [69].

Surgery and the aviation industry share some common ground. They are both high-risk and high-stress environments which function based on absolute dependence on the proper function and safety of their respective equipment. An additional area of similarity is that historically both disciplines have relied on a rigid hierarchy for leadership. However, whereas in an attempt to decrease tragic events the aviation industry has changed its approach to leadership and teams, regrettably, surgery has remained in the past. Historically, surgeons have used hierarchy in place of a leadership of functioning effective team. In a study by Sexton et al., surgery teamwork was judged to be far inferior to cockpit crews. The same study found that surgeons have a disproportionately high perception of teamwork and communication in the operating room. 95% of pilots rejected hierarchy and preferred a functioning team. On the other hand, only 55% of surgeons rejected hierarchy [71].

Clearly, a change in the manner of leadership which is provided by surgeons is imperative for a change in culture in the operating room. Surgeon leadership needs to adopt the cockpit crew model. Each individual team member needs to be empowered by ownership and expertise. The surgeon needs to go from being the conductor of the orchestra to becoming the lead in an exquisite ballot that, by definition, does not require a conductor. Much like a world-class ballet company, the hierarchy in the operating room is flattened by the expertise of the team members.

Leadership in a crisis is best learned from firefighters whose crisis management and teamwork have been actively studied and improved over time. A sentinel event occurred during a forest fire in Helena Montana in 1949 which revolutionized the training of firefighters for crisis management. In response to a fire in Helena, Montana, 15 randomly selected firefighters were dispatched under the leadership of a senior firefighter, Wag Dodge. These individuals had seldom worked together. Dodge's initial impression was that the fire was routine. All the team members followed his lead and let their guards down. Suddenly, Dodge sensed that the character of the fire was changing. He ordered the men to go down the hill toward the river. The fire became stronger, raged more quickly, and began to surround them from all directions. Sensing that the situation was out of control, he abruptly ordered the men to drop their tools and run. The men who had not worked with him hesitated and, as the fire began to surround them, instead began running up hill. Seeing that the fire was all around them, Dodge ordered the men to stop and burn the ground around them in order to stop the fire from reaching them. The men who were not familiar with Dodge or the tactic that he was proposing kept running away from the fire. Tragically, 12 of the 14 men died in the fire. Investigation of the tragedy pointed to the need for teams and the importance of team training in response to the crisis. The lessons of the Helena fire are vital for surgery in general and for robotic surgery in particular. Even routine can quickly become a catastrophe as a result of errors in analysis and critical decision-making at the time of changing events and a crisis. A crisis requires skills in advanced technical, communication, and leadership skills. Team dynamics play a fundamental role in the successful management of crises.

Teams are the nucleus around which the majority of the US military forces are built. This structure allows military teams to accomplish tasks larger in scale and complexity than can readily be accomplished by individual members alone. The collective skills and actions that result when using small units or teams enable the military to quickly and more efficiently accomplish missions [72, 73]. Furthermore, the combination of unique perspectives and backgrounds of team members can enhance creativity and problem-solving. Team science, which has been refined by the military, highlights five major areas: (1) team performance, (2) team processes, (3) team leadership, (4) team staffing, and (5) team training. These lessons are paramount to the establishment of a successful robotic surgery program.

Having reviewed more than six decades of research across five areas of team science—performance, processes, leadership, composition and staffing, and training—a number of themes are evident.

- Teams can be more effective than the sum of individual team members. Cohesive teams (i.e., strong bonds among members) perform better and stay together longer than do noncohesive teams. Teams can absorb more task demands, perform with fewer errors, and exceed performance based on linear composites of individual performance.
- Team cognitive processes play a significant role in team performance. What teams think, how team members think together, and how synchronized team members are in their perceptions and beliefs all significantly contribute to a team's ability to perform well.
- Team processes and performance are cyclical, dynamic, and episodic. Process models provide a structure for understanding and measuring teamwork behavior within and between performance episodes.
- Multiteam systems (MTSs) matter. Many teams exist within a broader system of teams; understanding the inter-team leadership, processes, and performance interdependencies is critical to understanding and influencing the performance of any one team. Furthermore, the countervailing and confluent forces within the MTS relationships can create unexpected effects where constructs acting at different levels can reinforce or nullify each other. MTS relationships

give teams the on-the-job tools to reflect on their own performance. Synthetic task environments, simulation, give teams a robust environment to focus on learning to work effectively together while performing realistic tasks.

Clearly, a successful robotic surgery program needs to be based on a *Specialty-Specific Team* of individuals comprised of surgeons, anesthesiologist, nurse anesthetists, operating room, and postoperative personnel. The concept of a general robotic team is flawed and has been shown to be ineffective. A functioning effective team should replace the age-old ineffective method of hierarchical leadership by the surgeon. A functioning and effective team overcomes failure in communication, ensures effective coordination of actions, and ultimately prevents catastrophes. Each individual on the team needs to be empowered, own the enterprise, and strive to excellence in their skill set. The skill of the team members serves to flatten the hierarchy among the various team members.

In robotic surgery, even the routine can quickly become a catastrophe through errors in analysis and critical decision-making. A crisis requires advanced technical, communication, and leadership skills. Team dynamics play a fundamental role in the successful management of crises.

4.4.5 The Culture of Medicine Through Changing Medical Education from Emphasis on Science to Emphasis on the Patient

As we will develop in the following discussion about medical education, one of the most important shortcomings of the system which introduces advances in surgery, and in fact the entire mindset in medicine, is that such advances are seen within the context of scientific progress as opposed to the ultimate well-being of the patient. Medicine in the twentieth century developed by attending to science first and patients second. Medicine in the twenty-first century will only succeed by attending to patients first. By extension, the ultimate secret for the success of a robotic surgery program is a change of mindset and singular attention to the ultimate well-being of the patient.

Robotics is introduced into medical practice at a watershed moment in the history of medicine. By all accounts, medical education and medical care in the twenty-first century are in a state of turmoil. Consider these facts:

- The trust and respect that were extended to the profession have been substantially eroded.
- There has been a fall from grace of the "vaunted profession."
- Physicians have lost their authenticity as trusted healers.
- The discontent with the doctors' errors, doctors' silence about problems in medicine, doctors' experimentation, doctors' lack of interest in their patients, and the crass monetary orientation of the profession has been unprecedented and has rivaled similar behavior which stigmatized the profession during the nineteenth century.
- The profession appears to have lost its soul while its body is cloaked in a luminous garment of scientific knowledge.
- With the loss of its soul, the profession has surrendered its Hippocratic and sacred mission of caring for the sick to

business concerns such as health-care organizations and insurance companies which are driven by financial gain and see patients and the ill as a commodity for attaining healthier bottom lines.
- Increasingly the direction of health care is determined by individuals with a background in business as opposed to medicine and the healing arts.
- "Patient first" has become an overused cliché and a meaningless logo for "big business" in medicine.

4.5 How Did This Situation Arise and What Can Be Done to Save Medicine in the Twenty-First Century?

Undoubtedly, the answer to the future success of health care lies in medical education. Although some believe that medicine is beyond repair or that it needs to be saved by governmental and health-care organizations or even the public, clearly, medicine in the twenty-first century can only be saved by a humanistic system of medical education where future physicians acquire a crucial set of professional values and qualities, at the heart of which is the unwavering commitment to put the *needs of the patient first*.

4.5.1 Twentieth-Century Medical Education: The First Part of the Story

In the early part of the twentieth century, Abraham Flexner undertook an assessment of medical education in North America. His landmark 1910 report changed the face of American medical education.

In the dawn of the twentieth century, medical education was a for-profit enterprise that was producing poorly trained physicians with very little knowledge in the scientific aspects of medicine and even lesser interest in the humanity of their patients. By most accounts, medicine was just another business where financial gain trumped all other considerations. In preparation for his monumental task, Flexner immersed himself in the literature of medical education during the latter part of the nineteenth century and specifically identified with the book *Medical Education in German Universities* written by the leading surgeon of the time, Theodor Billroth.

After visiting some 155 medical schools in the United States, Flexner chose Johns Hopkins as the gold standard for American medical education in the new century. The Hopkins Model which became the standard for university medical education was implemented by William Welch, a pathologist and the founding dean of the Johns Hopkins School of Medicine. Welch had studied the German pedagogic style of medical education and was resolute in the belief that medicine was a scientific discipline that could best be realized by a system in which physician scientists were trained in laboratory investigation as a prelude and foundation for clinical training and investigation in university hospitals. In accordance to Welch's vision, the Hopkins Model was instituted by the first faculty of Johns Hopkins School of Medicine, "The Four Doctors": William Henry Welch, a Yale-trained Connecticut Yankee and a pathologist; William Osler, a Canadian son of a frontier minister and the first chief of medicine; William Stewart Halsted, a New Yorker, a graduate of Columbia College of Physicians and Surgeons, a student of Theodor Billroth, and the first chief of surgery; and Howard Atwood Kelly, a University of Pennsylvania-trained gynecologist and the first chief of gynecology. The Hopkins Model dictated that all physicians had the responsibility to generate new information and create progress in medical science. Science as the animating force in the physician's life was the overarching theme in the Hopkins Model. This concept coincided with the vision for the ideal physician in Flexner's landmark report. The Flexner report and the Hopkins Model of medical education erected an edifice, not of bricks and mortar but of *tradition and science, that became the system of American medical education during the twentieth century*.

Without a doubt, during the twentieth century, the successful reorganization of medical training had an awesome effect on the breadth and depth of understanding and discovery of disease. Flexner and the Hopkins Model were indeed responsible for creating a pathway that in a short time has taken humankind to the stars. The awe-inspiring achievements of the last century are so evident and widely appreciated as to obviate the need for enumeration. It is hard to believe that in less than a century, medicine has gone from believing in evil humors and ignorance of the microbial world to sequencing the genome.

In the face of these monumental strides in human knowledge, ironically, as we enter the twenty-first century, medical education faces yet another period of self-assessment and reform. In the past two decades, more than a score of reports from professional task forces, educational bodies, as well as governmental and nongovernmental organizations have criticized medical education for emphasizing scientific knowledge over the development of a culture of medical education which emphasizes character, compassion, and integrity in the physician who is trained to use an understanding of human biology, clinical reasoning, and practical skills to *alleviate human suffering rather than to cure disease.*

In the century since Flexner's report, the academic environment has been transformed. Ironically, in academic hospitals, research outstripped teaching in importance, and a "publish or perish culture" emerged. Research productivity became the metric by which faculty accomplishment was judged, and teaching, caring for patients, and addressing broader public health issues were viewed as less important activities. In addition to the shift in the importance of research relative to teaching and patient care, medicine in the twentieth century witnessed a transformation in the process of research on human disease from clinical investigation to the molecular aspects of disease. Whereas prior to the 1960s the distinctive feature of American medical education was the integration of investigation with teaching and patient care, with each serving the other's purposes, after the 1960s, patients were bypassed in most cutting-edge investigations, and immersion in the laboratory became necessary for the most prestigious scientific projects. Clinical teachers found it increasingly difficult to be first tier researchers, and fewer and fewer investigators and medical faculty could bring the depth of clinical knowledge and experience to the education of the new physicians. The education of new physicians was gradually relegated to young inexperienced faculty or physicians outside the university who are engaged in the private practice of medicine. Many clinical teachers in universities across America no longer exemplify Flexner's model of the clinician investigator. Medical students and residents are often taught clinical medicine either by faculty who spend very limited time seeing patients and honing their clinical skills, and unfortunately see this practice of medicine as a necessary chore for the advancement of their careers as basic science investigators, or by practitioners who have little familiarity with modern biomedical science and see teaching as a distraction to their busy clinical practices.

The increasing turbulence of the health-care environment in the past 20 years has generated a second set of conditions which have further eroded the education of new physicians. Clinical teachers have been under intensifying pressure to increase their clinical productivity and generate revenue by providing patient care. The harsh commercial atmosphere of the marketplace has permeated many academic medical centers and is characterized by new terms that have been introduced into the teaching environment: "throughput," "market share," "units of service," and "the bottom line." The emphasis on the science rather than the patient, and the culture of medical practice which has resulted from the Flexnerian twentieth century system of medical education, has forced physicians in all aspects of medical practice and education to relinquish control to those in the business of medicine. Indeed, at this time, health care as a "big business" threatens the primary mission of medicine as a "calling in service of the ill and humankind."

In the twenty-first century, medical education of the twentieth century is indicted for emphasizing the discovery and transmission of knowledge instead of teaching the values of the profession with an emphasis on humanism as a framework for imparting skills and transmitting knowledge to the new physicians.

Did the Hopkins model take the profession down a pathway that threatened the loss of what should be nonnegotiable to all physicians? Did this model overlook the ethos of medicine in its blind passion for science and the advancement of medical knowledge?

In truth, a firsthand examination of the Flexner report reveals the unfortunate fact that, indeed, in addition to a scientific foundation for medical education, Flexner envisioned a clinical phase of education in academically oriented hospitals, where thoughtful clinicians would pursue research stimulated by the questions that arose in the course of patient care and teach their students to do the same. Counter to widely held yet mistaken belief, to Flexner, research was not an end in its own right; research into disease was important because it led to better patient care and teaching.

Clearly during the twentieth century, the way in which future physicians encountered the knowledge base of medicine was profoundly influenced by the assimilation of medical education into the investigational culture of the university. Theoretical, scientific knowledge formulated in context-free and value neutral terms became the primary basis for medical knowledge and reasoning. This knowledge was grounded in the basic sciences; however, by all accounts, there was a less robust accommodation for the practical skills and distinct moral orientation required for successful practice of medicine in the twenty-first century. It is important to note that Flexner had not intended that such knowledge should be the sole or even the predominant basis for clinical decision-making. Within 15 years after issuing his report, Flexner had come to believe that the medical curriculum placed too much weight on the scientific aspects of medicine to the exclusion of the social and humanistic aspects. In fact, in 1925, he wrote, "Scientific medicine in America—young, vigorous and positivistic—is today sadly deficient in cultural and philosophic background." Clearly, it appears that medical education of the twentieth century came away with only part of the Flexner vision for reforming medical education. Undoubtedly, he and the architects of the medical education of the twentieth century would be greatly disappointed to see that at some point, the path that they envisioned went awry.

Interestingly, the predicament faced by medical education in the twenty-first century was foreseen by one of the "Four Doctors," William Osler. Osler, who a few years after the establishment of Hopkins Model moved to Oxford, believed that the so-called Flexnerians had their priorities wrong in situating the advancement of knowledge as the overriding aspiration of the academic physician. Although he had great reverence for investigation into new scientific knowledge, he considered the welfare of the patient and the education of the student to that effect as more important priorities.

Since Flexner's day, clearly the knowledge base for medical practice has reached unprecedented levels. However, the education of physicians in today's vastly more complicated health-care delivery system for a public, which has much higher expectations, clearly requires a culture of humanism as the solid foundation for that knowledge. Regrettably, this is where the twentieth-century system of medical education has failed. This lapse has not escaped the patient population or the critics of the medical system, who have richly documented the poverty of professional ideals now current in medicine. Many from outside and inside of medicine have called for a new Flexner report, a centennial taking stock, to address the shortcomings in medical education that have occurred in the aftermath of the original report.

4.5.2 Twentieth-Century Medical Education: The Rest of the Story

In the turn of the twentieth century when the future of American medical education and American medicine was being debated in Europe and institutions of higher learning in the eastern United States, without notice by the eastern medical intelligentsia, a different seed for the path of American medicine was being planted in the barren plains of southern Minnesota.

In an ungodly cold January day in 1864, Dr. William Worrall Mayo placed an ad in the area newspapers announcing that his medical practice was open for business in downtown Rochester, Minnesota, a town of 1400 people, and thus the Mayo Clinic was born. Soon Dr. William and his two sons, Will and Charlie Mayo, transformed American medicine in a different way from Flexnerians and the Hopkins Model and created a mammoth enterprise of medical care which is the envy of the world in terms of patient care, undergraduate and graduate medical education, and the discovery of new knowledge. William Worrall Mayo, a diminutive man in stature referred to by patients as "the little Dr.," and his surgically gifted sons, "Dr. Will" and "Dr. Charlie," emphasized the fact that the *patients* are what really mattered and that the education of physicians and discovery of new knowledge were to be in the service and healing of the sick.

It is important to note that Doctors Mayo and the Mayo Clinic entered the same period of turmoil and rapid change in health care as the Flexnerians. Furthermore, the health-care environment in the latter part of the nineteenth century was every bit as challenging as the issues that face medicine and medical education today. However, the success of the Mayo Model over the long term was rooted in the singular concept that the work of the physician, the education of the future generations, and the quest for new knowledge were solely for the purpose of meeting the needs of patients. This open secret of being deeply rooted in the primary value of putting "humans with an illness first" was the engine which drove education of the future generations of physicians and the discovery of new knowledge at Mayo Clinic. In the same year as the Flexner report, in 1910, Dr. Will Mayo spoke at Rush Medical College in Chicago. In that speech, he emphasized that "the best interest of the patient is the only interest to be considered." He went on to emphasize that with the interest of the patient and the healing of the sick as the starting point, the training of the future generations of physicians would result in a culture of medicine which better represents the ideals of the profession and assures its survival through the episodic turmoil which characterizes health care.

Whereas the Hopkins Model of medical education prioritized investigation and discovery of new knowledge over the training of new physicians and the care of patients, the three shields which comprise the logo of Mayo Clinic exemplified the different approach in terms of priorities in health care in the Mayo Model. The larger central shield symbolizes caring for the sick, while the two smaller shields that juxtapose and intersect the central shield symbolize the integral aspects of educating the next generations and the discovery of new knowledge. Indeed, this concept has been responsible for the constant growth and expansion of the Mayo Clinic during its 150-year history and seems to represent a more appropriate model for health care and medical education in the twenty-first century.

4.5.3 Medical Education in the Twenty-First Century

The key goals of medical education in the twenty-first century need to be the inculcation of the humanistic values and culture of the profession as the sound foundation upon which knowledge and skills are taught to the new physicians.

Starting with respect for the needs of the patient and dedication to the central mission of alleviating suffering, the manner in which knowledge is imparted and skills are attained requires a radical departure from the past. Although the dictum "see one, do one, teach one" may have characterized the way in which clinical skills were learned in the past, it is now clear that for training in skills to be effective, learners at all levels must have the opportunity to compare their performance with the standard and practice until an acceptable level of proficiency is attained. The appreciation of the importance of practice and the honest admission that neophytes cannot perform high-stakes procedures at an acceptable level of proficiency demand that we develop approaches to skills training that do not put our patients at risk in service to education.

The use of increasingly sophisticated simulators and virtual reality offers physicians at all levels the opportunity to refresh skills and learn new ones in a safe practice environment. Educational methods that allow the demonstration of mastery at one level, with respect to both technique and judgment, before progression to the next level, teach an important lesson in professionalism.

At all phases of medical education, whether in medical school or in residency training, the young physician needs to be mentored by senior faculty who not only impart knowledge and skill but serve as role models and shining examples of the profession. Sociologic studies have noted the importance of socialization and implicit learning in the development of professional attitudes and behaviors. Therefore, explicit instruction in professionalism, combined with effective role modeling and attention to the curriculum of the practice environment, can support the development of a comprehensive and sophisticated understanding of the profession by the new physician.

The model of medical education in the twenty-first century needs to emphasize that medical students and residents become sensitive and compassionate "*healers*" as well as knowledgeable technicians and skillful practitioners. Rigorous assessment of the acquisition of the humanistic healing attributes by the new physician is even more important than the assessment of their knowledge and skills. Undoubtedly, in all areas, assessment drives learning. The new model of medical education needs to rigorously assess the new physician's embodiment of the culture, the professionalism, procedural skills, judgment, and commitment to patients as human beings. Self-assessment, peer evaluations, portfolios of the learner's work, written assessments of clinical reasoning, standardized patient examinations, oral examinations, and sophisticated simulations are to be used in order to assess the acquisition of appropriate professional values as well as knowledge, reasoning, and skills. Such a rigorous program of assessments has the potential to inspire learning, influence values, reinforce competence, and reassure the public.

Arguably, the most important aspect of medical education of the twenty-first century is to require that the new physicians learn from outstanding experienced senior clinical teachers side by side with the laboratory scientists and physician scientists. The role of the senior clinical teachers is not only to impart knowledge and skill but act and become shining examples of professionalism, the humanity, and the morality of the profession.

One hundred years ago, Flexner's critique of medical education converted an evolutionary change already underway in North American medical education into a revolution. With the institution of Flexner's recommendations, medicine has made transformative advances in the twentieth century. However, after a century, once again, our approach to medical education is inadequate to meet the needs of medicine in the twenty-first century. No one would cheer more loudly for a change in medical education than Abraham Flexner. He recognized that medical education had to reconfigure itself in response to changing scientific social and economic circumstances in order to flourish from one generation to the next. Interestingly, the same understanding for the need of medicine to change is illustrated in the quote from Charles Mayo who said, "The only constant in medicine is change." Clearly, the flexibility and freedom to change, indeed the mandate to do so, were part of the essential message delivered to American medicine by Flexner, the Hopkins Model, and the Mayo Clinic Model. The only hope for the salvation and future of medicine is a change in medical education.

Historically, medicine has been defined by three intersecting circles of patient care, teaching, and research. By this model although the patient has been important, the patient has not been paramount (Fig. 4.2). The modern vision for the interaction of patient care, teaching, and research forms concentric circles with the patient in the center. Teaching and research efforts are only relevant if they can enhance the outcome for the patient (Fig. 4.3).

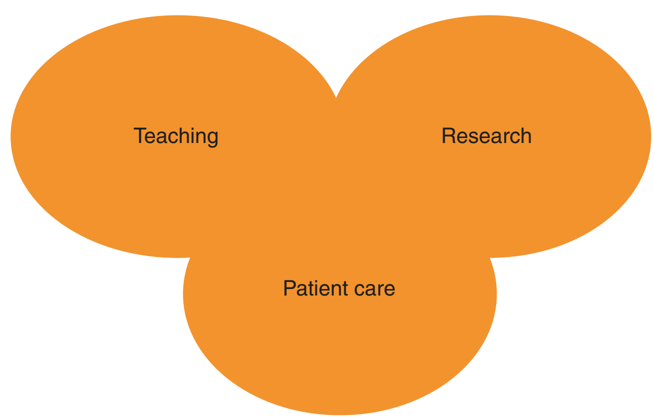

Fig. 4.2 Historically, medicine has been defined by three intersecting circles of patient care, teaching, and research. By this model although the patient has been important, the patient has not been paramount

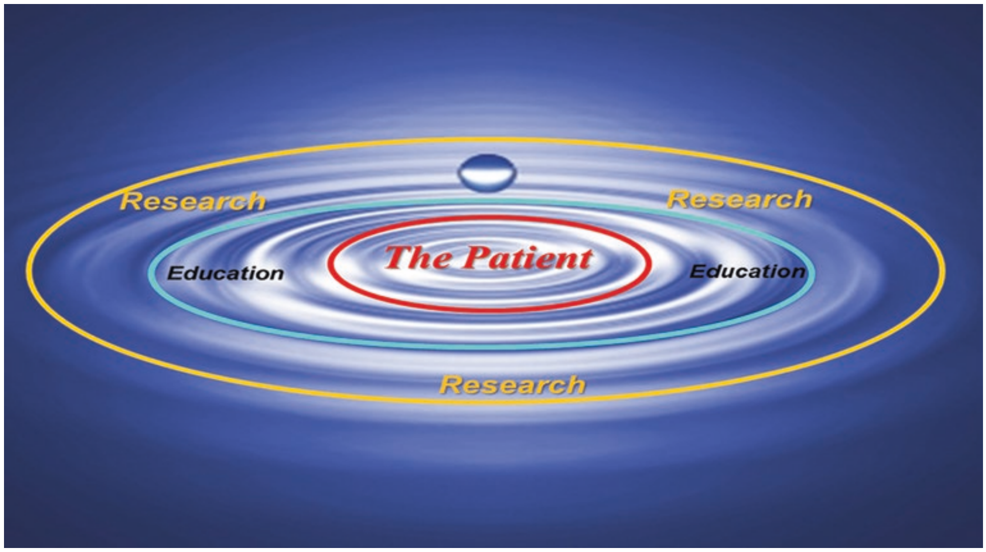

Fig. 4.3 This illustration depicts the modern vision for the interaction of patient care, teaching, and research, which form concentric circles with the patient in the center. Teaching and research efforts are only relevant if they can enhance the outcome for the patient

4.6 In Summary

A successful robotic surgery program is based on many factors. Although the skill, training, and experience of the robotic surgeon are paramount, there are many other programmatic and institutional factors that can "make or break a robotic surgery program." Without absolute attention to these factors, a robotic surgery program will never reach its potential.

These factors are as follows:

- Culture change in the institution and the operating room
- Institution of specialty-specific robotic surgery teams. Attention to team dynamics, training, proficiency, and experience
- Level V leadership by the surgeon
- Placing the patient at the center of the three concentric circles with education and research revolving around the needs and well-being of the patient
- An absolute insistence on perfection of surgery and refusal to accept anything less than perfection in all aspects of the robotic surgery program

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