World Progress in Surgery

Information Age Technologies for Surgeons: Overview

Richard M. Satava, M.D.1,2

1Department of Surgery, Yale University School of Medicine, 40 Temple Street, New Haven, Connecticut 06510, USA
2Telemedicine and Advanced Research Center (TATRC), US Army Medical Research and Material Command (USAMRMC), 504 Scott Street, Fort Detrick, Maryland 21702, USA

Published Online: September 28, 2001

Abstract. This overview summarizes the revolutionary changes that are occurring in medicine today and looks beyond medicine to the other disciplines of science that contribute to the overall revolution of the Information Age. The concept of “information equivalent,” representing real objects within a computer as information, is explained. The application of today’s emerging information technologies is divided into the components of patient care—diagnosis, consultation, treatment, and education—and illustrations are given of how information sciences are changing the practice of surgery.

This symposium looks at the Information Age technologies that are shaping the world around us and identifies those technologies with the most influence on the future directions of surgery. There is a cohesiveness to these technologies, and together they define the fundamental revolution which the Information Age has brought to surgery. Probably the most glaring absence in the symposium is laparoscopic surgery. Laparoscopic surgery is the revolution from the past, the revolution on the cusp of the Information Age that will recede in importance as newer modalities come forward. Laparoscopic surgery is a transition technology, from the era of open surgery to the next generation of minimally invasive surgery such as telepresence surgery, robotic surgery, image guided surgery, and others that have yet to emerge. Laparoscopic surgery will continue to have an important role in the future of surgery, just as open surgery continues today. Ultimately, laparoscopic surgery will find its appropriate niche in the overall armamentarium of the surgeon and become a foundation upon which the newer modalities will stand.

The invited faculty consists of world class clinicians and researchers, including surgeons, radiologists, and bioengineers. This diversity is significant, since one of the hallmarks of the Information Age is the importance of cross-disciplinary research and applications. Many of our advances in laparoscopic surgery arose from the engineering, computer science, and imaging technologies, and interdisciplinary medicine will play an even more important role in the future of surgery.

A number of the areas may not initially appear as “information” technologies, such as sensors for biomedical applications or image acquisition. I have taken a broad view of the Information Age sciences to include those technologies that have the critical functions of information acquisition with various sensors and imagers, use computers and robotics to perform surgical procedures, require sophisticated three dimensional software programs that enhance surgical education, and rely upon telecommunications and networking systems to distribute our surgical healthcare. All these components of the Information Age interact to form an integrated whole that defines this cataclysmic change in surgery.

The most important concept in the revolution is understanding the importance of information as an actual entity. This was first proposed by Negroponte [1] in his book, Being Digital, where he defined the essence of the Information Age as “bits instead of atoms.” The example is the facsimile machine. For thousands of years, people communicated by sending actual objects (atoms), such as papyrus, clay tablets, and letters; then came the facsimile machine, where the document is scanned in (bits) and electronically sent instantly to the destination—faster, cheaper, and more reliable. At a National Academy of Sciences workshop in 1995 [2], the question was raised as to how much work a physician performs is actually information related (Fig. 1). For example, in laparoscopic surgery, the surgeon no longer looks at the patient’s organs (atoms) but rather at the video monitor with the electronic image or “information equivalent” (bits) which represent the organs. When checking the patient in the recovery room, the surgeon looks at the vital signs monitors for the pulse and blood pressure (information equivalent of the sense of touch). The medical record is becoming computer based, and our x-rays and other imaging studies are changing from film (atoms) to digital images (bits). The educational process is using computer-aided instruction and virtual reality (bits) in addition to books and cadavers (atoms). Even the performance of surgery is moving toward information equivalents with the robotic and telesurgery systems—the surgeon grasps the handle of an instrument, the hand motions
are converted to electronic signals which are sent to the tip of the
instrument inside the patient, and the scalpel cuts. The practice of
surgery is no longer blood and guts, it is bits and bytes [3]. What
all of these tools have in common is working on the “information
equivalent” of the real objects, whether it be in the computed
tomography (CT) scanner, a desktop computer, a telesurgery
workstation, or over the Internet and World Wide Web.

Many would have us totally reengineer the way we provide
healthcare; however, for the near term the change will occur by
the information sciences modifying the basic structure and en-
hancing the methodology in which healthcare and surgery are
delivered. In the long-term, it will result in a radical new ap-
proach, which we shall transition into at a gradual pace, accepting
only those technologies which pass stringent review and evalu-
ation and clearly benefit the physician and the patient. Thus I have
arbitrarily divided the manuscripts into four basic areas, which
conform to the conventional practice of surgery (and medicine) as
a whole. They are diagnosis, consultation (communications),
treatment, and education and training. Together these form the
continuity of healthcare in the chronologic fashion in which pa-
tients present.

In the area of diagnostics, the technology focuses upon acquir-
ing information about the patient, using the next generation non-

![Fig. 1. Information equivalents, the use of information (bits) instead of the actual objects (atoms) to accomplish a part of medical practice (see text for description).](image1)

![Fig. 2. An entire microsensor system capable of acquiring, processing, and transmitting temperature—equivalent to the bedside temperature monitors (courtesy Tom Ferrell, Oak Ridge National Laboratories, Oak Ridge, TN).](image2)

![Fig. 3. Virtual colonoscopy, showing intraluminal view of a polyp (courtesy James Brink, Yale University School of Medicine, New Haven, CT).](image3)