Commentary

The future of surgery—and medicine in general—is not in blood and guts, but in bits and bytes.

—Richard M. Satava

This report by Dr Mohr and his innovative group from Leipzig heralds the beginning of a new era in our specialty—computer-assisted surgery. Although computers have revolutionized our modern society, their impact in the operating room has been limited to date. This report demonstrates the power of digitally enhancing both the surgeon's movements and his or her visual image. This technology not only has the capacity to improve our ability to do conventional procedures, but in the future, it likely will allow us to perform new procedures that are now considered beyond the realm of human manual dexterity.

At present, there are several different robotic microsurgical systems in development.¹⁻⁴ Although all of these systems have different features, they basically consist of three components:

1. A surgeon console
2. A computer control system
3. A robotic manipulator.

The surgeon sits comfortably at a console that is often removed from the operating room table. At this console, the surgeon grips instrument handles or rings that relay his or her motions to a computer control system. The motion is digitized and the computer uses this information to direct robotic arms or manipulators that are attached to the operating room table. These robotic arms hold the instrument tips, which are inside the patient and perform the surgical procedure. The end result of this technology is that the traditional surgical instrument is divided in half, and a computer is interposed between the instrument handle and the instrument tip. The computer can manipulate the digitized motion to improve surgical dexterity. By filtering high-frequency movement, the computer can eliminate tremor. The computer can also scale the surgeon's motion so that macroscopic, easy-to-perform movements by the surgeon at the console can be scaled down to a microscopic level inside the patient. Both tremor elimination and motion scaling allow the surgeon to operate pre-

cisely in confined spaces. Importantly, these features provide the surgeon with the precision necessary to perform microsurgery with long endoscopic instruments.

This added precision will allow for the introduction of minimally invasive techniques into specialties, such as our own, that heretofore have not been amenable to traditional endoscopic techniques. For cardiac surgeons, this will allow us to continue the evolution of minimally invasive coronary bypass surgery and reach the ultimate goal of a completely endoscopic coronary artery bypass procedure. Computer and robotic assistance has allowed several groups to perform endoscopic coronary artery bypass grafting in both experimental animals and isolated clinical cases.⁵⁻⁷ This report clearly demonstrates the feasibility of endoscopic coronary bypass grafting.

It should be remembered that there are several limitations to this technology and the widespread performance of computer-assisted endoscopic coronary bypass grafting. First, these systems are expensive and must be shown to be cost-effective. Second, endoscopic procedures are lengthy and have been limited to patients with single vessel disease. Thus, they are applicable to only a small percentage of the population referred for coronary artery bypass. However, endoscopic cardiac surgery is in its infancy. As surgeons begin to address the technical and procedural issues raised in this new environment, these operations will decrease in length, their applicability will increase, and we will begin to see their acceptance by the surgical community at large, as has been the case with arthroscopy and laparoscopy. The maturation of this technology will remain a challenge to both surgeons and industry over the upcoming years.

The litmus test for this technology will be the degree to which it benefits the patient. New technologies and concepts eventually must prove themselves in rigorous clinical evaluations and careful follow-up studies. Although the final verdict on the value of computer-assisted surgery has not yet been rendered, it appears to be a critical enabling technology to allow for endoscopic coronary bypass to become a reality. While there are challenges ahead, the future is an exciting one. Computer-assisted surgery has the potential to transform our specialty and usher in an era of truly minimally invasive cardiac surgery.

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