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FROM KNIFE TO NEEDLE TO NOTHING: THE WANING OF THE WOUND

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ABSTRACT

During the last 25 years, probably urology was the surgical specialty that presented the most extraordinary technological development. In no specialty has the evolution from maximally invasive to minimally invasive to noninvasive surgery been better demonstrated than in the field of urology.

Now, on the dawn of the third millennium, the wound itself is under attack. Literally shrinking to an unrecognizable size under the onslaught of modern day technology. This presentation is an update of where we are today and where we might be tomorrow due to advances in the following areas: Laparoscopy, microinstrumentation, robotics, telepresence, needle ablative surgery, and noninvasive technology.

Key words: endourology; endoscopy; laparoscopy; minimally invasive surgery; urogenital system
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INTRODUCTION

In 1550 in Milan Italy, Cardan incised a loin abscess and extracted several renal calculi, thereby providing the first authentic account of a renal operation. In that same century, Shakespeare unwittingly immortalized the craft of the surgeon, as he wrote in Hamlet, "Diseases desperate grown by desperate appliance are relieved ... or not at all". Four hundred years later, the knife and its attendant wound remained the hallmark of the surgeon. While advances in anesthesia and antibiotic therapy permitted the surgeon to cure more patients, the wound remained untouched … its gaping morbidity, and occasional mortality an accepted *Price for the cost of "Cure"*.

Now on the dawn of the next millennium, the wound itself is under attack. Literally shrinking to an unrecognizable size under the onslaught of modern day technology.

This is a work in progress, and this presentation merely an update of where we are today and where we might be tomorrow due to advances in the following areas: laparoscopy, microinstrumentation, robotics, telepresence, needle ablative surgery, and noninvasive technology.

In the 1970's Cortessi et al. (1) in Italy first introduced laparoscopy into urology with his report of laparoscopic exploration for the cryptorchid testicle. It took 20 years before Schuessler et al., in the 1990's (2), in a cooperative effort of urologists and a gynecologist, performed the first major adult laparoscopic urological procedure, a laparoscopic pelvic lymphadenectomy in a patient with prostate cancer. In short order laparoscopy spread into all surgical realms of urology. Indeed, it has now been a decade since I had the privilege to work with Lou Kavoussi, in cooperation with Nat Soper, a general surgeon, and a fine team of other urologists and engineers to introduce laparoscopic nephrectomy, a technique which has today gained widespread acceptance (3). With increasing experience, skill, and improved instrumentation, laparoscopy is continuing to move further into surgical urology. To wit, the exciting area of laparoscopic donor nephrectomy introduced in 1995 by Lou Kavoussi and Lloyd Ratner (4), a transplant surgeon, and the pioneering work, on laparoscopic prostatectomy, reported by Guilloneau & Vallancien (5) and so beautifully demonstrated at the 18th World Congress of Endourology – 2000, by Abbou et al. (6). At the 18th World Congress of Endourology – 2000 we have witnessed the complete realization of laparoscopic reconstructive surgery in the innovative work of Drs. Gill, Kaouk, Meraney et al. (7,8). In the laboratory they have forged ahead with neobladders and autotransplantation while in the clinical realm they have successfully brought laparoscopic techniques to bear on cystectomy and both ileal and continent diversion.

The upshot and drive behind all of these efforts has been the single unifying desire of endourologists to bring to their patients a surgical cure with less surgical morbidity. To this end laparoscopy has succeeded, as each report reveals that the laparoscopic technique has provided the patient with less pain, less disfigurement, and a more rapid convalescence.

However, for laparoscopy to spread into the hands of more urologists, we need better and more training courses and improved instrumentation. On a practical level, the introduction of the "hand-assist" device provides a tremendous boost in this direction. Certainly for those procedures in which the specimen is to be removed intact, the hand assist device facilitates the procedure without significantly adding to the morbidity. Papers at the 18th World Congress of Endourology – 2000, by Stifelman, Sosa, Nakada & Schichman (9), and by Seifman & Wolf (10) and others have all attested to the user friendly nature of the hand assist devices. As my good friend Doctor Segura from Mayo Clinic, continues to remind me "one hand is worth a 1,000 laparoscopic ports". For the urologist just beginning renal laparoscopy, this technology offers tremendous security as one can more slowly become immersed in the laparoscopic techniques, with one hand literally in the realm of traditional surgery while the other hand is being trained in the realm of the new surgery. Leave no doubt, I believe that it is imperative for our specialty to adopt and become facile with this technology, lest our specialty be passed into the hands of those more laparoscopically skilled than ourselves. One man's homeland, if neglected, becomes another man's frontier.

MICROINSTRUMENTS

To further decrease the wound, our instrumentation is getting smaller. Microinstruments in the 2 mm range have now been used successfully for the laparoscopic removal of adrenal glands and are being used in many centers to replace the fourth port during nephrectomies (11). To carry miniaturization a step further, we come to the potential development of surgeon-controlled micromachines, to perform diagnostic and possibly surgical talks (12). At Massachusetts Institute of Technology (MIT), work on the miniaturization of machines has been ongoing for a decade. An example of the potential in this area is Cleo, a 1-inch machine that has the sensory functions of touch and light and the motor function of bilateral grippers along with 3 self-contained batteries and an onboard computer with 256 bytes of RAM and 2,000 bytes of memory. Given this technology, I would like to know why almost every piece of equipment that I currently have for either open or laparoscopic surgery is completely mechanical, with either none or one working part operated by the surgeon's thumb and forefinger as it has always been. Hopefully soon, the operating room will come into the industrial age and instrumentation of power and vision will be placed in the hands of the surgeon. Imagine, an instrument capable of accurately sensing and characterizing the tissues before they are incised, of then proceeding to incise those tissues with just the proper amount of energy to accomplish the job such that none of the surrounding tissue is damaged. Imagine instrumentation capable of sufficient degrees of freedom such that instead of the surgeon assuming various awkward and strained positions in order to access a surgical site, the instrumentation will readily do it for him. These long overdue changes hopefully will be coming soon as companies of vision and compassion design our operating rooms of the future replete with boom technology, voice activation, and sophisticated robotics.

But let us carry miniaturization even one step further, let us now enter the realm of machines with working parts the size of molecules, the realm of nanotechnology. Indeed, scientists are now able to build machines capable of movement and action that are no larger than a red blood cell. What wonders will this technology put into the hands of the surgeon? Will our prosthetic devices of the future be implants of actual working muscle, structures capable of expansion and contraction, as well as devices with the ability to literally sense the needs of the body and respond accordingly? Recently IBM has reported the ability to impregnate different proteins on a silicon finger thereby creating an antigen receptor relationship similar to that which exists in cellular systems. However, in this case when the two bind, the silicon finger actually bends; this mechanical bending action could be used as an energy source to power a microrobot or, to open a valve in a microdelivery system thereby providing for cell specific release of a chemotherapeutic or radiotherapeutic agent. The potential in this arena for the development of robotic delivery systems and prosthetic organ development, appears unlimited.

ROBOTICS

There is a fundamental question to be asked of a technologically advanced society, which is: "Once a machine has been designed to perform a task, should man be removed from the equation?". The painful and unequivocal answer to this question whether it be in the folk song of John Henry and the steam engine or the economical practicalities of the automobile industry, is a mournful but unwavering YES. And so robotics are coming to an operating room near you ... it may be slow but they are coming. The pioneering work of Dr. Yulan Wang and Jonathan Sackier at Computer Motion put the first functional, camera holding, robot into the hands of laparoscopic surgeons in 1993 (14). Over the past 7 years, robotics has evolved beyond the surgical assistant level of holding the camera to the surgeon level of holding the needledriver and grasping forceps. The current rendition of the Zeus robot from Computer Motion or the daVinci robot from Intuitive provide the surgeon with three hands as he or she can now control the camera as well as a right handed robot and a left handed robot. Are these $700-900,000 machines merely expensive parlor toys or truly the way of the future? (15) I believe the latter, as it takes not much more than a videoclip of a laparoscopic coronary artery procedure to demonstrate the preciseness and stability of the robotic hand. With the Zeus robotic features of scaling and tremor recognition, the surgery can be performed more rapidly, precisely and uniformly than heretofore possible. For this kind of patient, coronary artery surgery no longer entails cardiovascular bypass or a painful midline sternotomy. This is not idle talk ... indeed, the very father of modern day laparoscopy, Kurt Semm has supported this concept.

TELEPRESENCE

If the robot can be controlled by the surgeon sitting 3 feet away from the operative table, then why not do the procedure with the surgeon in the next room, the next building, the next state, or even the next country? Indeed, this is the realm of telepresence in surgery and it has been elegantly developed and demonstrated by the group of Dr Kavoussi from Johns Hopkins (16). Their vision and persistence has resulted in the realization of telesurgery in urology, as demonstrated in the 18th World Congress of Endourology – 2000, and again elsewhere, with Dr. Kavoussi in Baltimore, teaching surgeons in Thailand, how to accomplish a laparoscopic procedure. Working from Baltimore over 3 ISDN at 384 kilobits per second, Dr. Kavoussi has control of the camera through an AESOP robot as well as control of the keying of the electrosurgical unit. Aside from two way voice and visual contact, using a telestrater, he can actually draw on the screen and indicate anatomical structures and lines of incision.

Certainly technology such as this is a boon to the military or to remote areas in need of surgical expertise, but it is also a great step forward in the concept of teaching and spreading new surgical procedures. It is one thing to go to a course and hear about a new procedure, perhaps see it performed live and transmitted to an auditorium, and perhaps even perform it yourself in an animal model or cadaver ... but this remains a far cry from actually being mentored through your first clinical experiences with this new surgery such that your learning curve is flattened thereby assuring your comfort with the procedure and your success. This to my mind is the true potential to be realized from telesurgery ... improved surgeon education and with it better patient care.

NEEDLE INVASIVE

Until now, I have only dwelled on shrinking the wound from a single long incision to several, 3 – 12 mm incisions. But even this is changing. In the near future, for ablative surgery, perhaps the largest incision will be that to accommodate a 14-gauge needle. Initial animal work was completed on the use of cryotherapy to freeze small renal lesions (17,18). At the Cleveland Clinic, Gill & Novick (19,20) have completed the largest clinical study in this realm and have shown reasonable efficacy for this technique with follow-up out to 2 years. Presently, the probe is most commonly placed using a laparoscopic approach but already Shingleton & Sewell colleagues (20) at the University of Mississippi have reported successful application of cryotherapy to renal lesions using a 2 mm cyroprobe positioned using an open MRI scanner. Of similar interest are the developments in the field of radiofrequency ablation, interstitial laser therapy, and interstitial photon radiation in which again needle sized probes are used to deliver various forms of energy to a renal lesion in an effort to completely necrose it. Future directions will deal with determining the best method for achieving rapid complete necrosis in the kidney. Once this is determined, it may be only a short period of time before all renal lesions in the < 5 cm range are treated percutaneous.

NONINVASIVE

It has been said that "Minor surgery is anything done to someone else". What is better than minor surgery ... no surgery at all, or if you will noninvasive surgery. In no specialty has this evolution from maximally invasive to minimally invasive to noninvasive surgery been better demonstrated than in our field of Urology. The advent of the extracorporeal shockwave lithotriptor has meant that over 80% of patients with surgical urolithiasis could be spared any invasive procedures at all while still enjoying an effective cure of their stone. If one can ablate a 1.5 cm stone in the renal pelvis without making any incisions, then why do we not have technology that can perform in a similar manner for a 1.5 cm tumor in the lower pole of the kidney or for that matter, "horrors of horrors" to even ablate the entire prostate noninvasively?

Urologists, such as Vallacien et al. (22), were on this path, several years ago when then the Technomed company produced a piezoelectric source for destruction of superficial bladder tumors. Termed the Pyrotech, it was able to heat ultrasonically targeted tissue in a 10 x 2 x 2 mm focal area to 108 degrees centigrade at a focal length of up to 32 cm. Subsequently additional work has been done with another extracorporeal energy source, high intensity focused ultrasound (23). Early results have appeared to be promising as Gelet et al. (24) reported using this technology to treat prostate cancer and Kohrmann et al. (25) also reported here its application to renal lesions. Using the same technology, Chan, Kavoussi and co-workers (25,26) reported at the 18th World Congress of Endourology - 2000, the development of a hand held HIFU unit, which successfully obliterated the vas deferens in their canine model; the potential clinical impact of this device on population control is indeed, significant. However, all of this noninvasive technology is expensive to develop and deploy. Nonetheless, can there be any doubt that within the next 10 years, machines of this nature will appear on the scene? The application to a large variety of cancerous lesions is obvious, but even more so one wonders whether this would provide for a major shift in our philosophy of therapy such that we might begin to treat individuals at high risk for a disease before the disease developed. Certainly if the treatment were of little to nil morbidity, what man over the age of 50 with a strong family history of prostate cancer would not consider, perhaps even seek out, a noninvasive prostatectomy and eliminate completely his risk for developing prostate cancer, or for that matter even BPH?

This then brings me to the final point of this presentation which is the entire shift of the medical-surgical industrial complex from its current emphasis on health care, replete with hospitals and patients, in which all efforts are aimed at ministering to disease manifest, to another perhaps higher level, of emphasizing health maintenance, which is home and person based in which all efforts are expended in the prevention of disease or early detection and treatment before it has a chance to debilitate. This then may well be the final fruit of all of our technological advances, an affordable, higher quality, of health through prevention, early detection and preemptive treatment.

So I leave you with a sense of our progress and a sense of our need for exploration ... in both areas the goal remains the same ... to heal ... to provide for those who seek our counsel and our skill with a resolution of their maladies in the most humane, least disruptive manner ... for it is the quality of this moment and the one immediately to follow that truly matters most to each and everyone of us ... so I will finish with a different quote ... a more hopeful statement than that with which I began this presentation, for it was Sir William Osler who observed: “Diseases that harm require therapies that harm less”. I would hope that in the future, our therapies will heal absolutely and harm not al all ... and so let us continue to move, from knife to cannula to needle to nothing…

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