The Emerging Role of Robotics and Laparoscopy in Stone Disease

Mitchell R. Humphreys, MD

KEYWORDS

• Laparoscopy • Robot-assisted surgery • Ureterolithotomy • Pyelolithotomy • Urolithiasis • Calculi

KEY POINTS

- The prevalence of open surgical procedures has decreased dramatically with the advent of minimally invasive and endourologic procedures in the United States and world wide.
- When endourologic procedures fail, laparoscopic or robot-assisted techniques offer patients significant benefits over open surgery.
- In certain clinical circumstances such as abnormal anatomy, the need for concomitant reconstruction efforts, the unavailability of endoscopic equipment or experience, robotic or laparoscopic approaches may be considered as initial treatment options for patients.

INTRODUCTION

The surgical management for urolithiasis has undergone a dramatic clinical evolution during the past 3 decades. Advances in endoscopic equipment and procedures have relegated the practice of open stone surgery nearly to one of historical interest. The defining developments of percutaneous nephrolithotomy (PNL), ureteroscopy (URS), extracorporeal shock-wave lithotripsy (SWL), laparoscopy, and robot-assisted surgery have diminished the role of open surgery in the modern day urologist's armamentarium. The European Association of Urologists (EAU) and American Urologic Association (AUA) have released guidelines that attempt to define the roles of various surgical procedures and techniques in the spectrum of surgical stone intervention. The in-depth rationale, benefits, and morbidities associated specifically with laparoscopic and robot-assisted approaches have yet to be fully adjudicated as urologists become more facile with these procedures. The following report will discuss the historical changes from open to minimally invasive treatment options and review the literature and indications of laparoscopic and robot-assisted approaches for the management of urolithiasis.

HISTORICAL PERSPECTIVE

Urolithiasis has plagued mankind since before recorded history; in 1901 a stone was extracted from an Egyptian mummy dating to 4800 BC.[1] During Hippocrates' era, specific surgical interventions, although crude by modern standards, were described to relieve the symptoms of stone disease.[2] The reports of successful stone surgery were rare in the subsequent millennia, with most procedures resulting in death and significant morbidities. In 1879, Heinke described the first pyelotomy incision with subsequent stone extraction.[2] During the next several decades, because of the complications associated with early attempts of nephrolithotomy, pyelolithotomy became standard therapy with the adjuvanted use of blood coagulum, fibrin and fibrinogen, or cryoprecipitate to assist with the removal of calyceal stones and

There are no financial relationships to disclose as it pertains to this article.
Department of Urology, Mayo Clinic, 5777 East Mayo Boulevard, Phoenix, AZ 85054, USA
E-mail address: Humphreys.mitchell@mayo.edu

Urol Clin N Am 40 (2013) 115–128
http://dx.doi.org/10.1016/j.ucl.2012.09.005
0094-0143/13/$ – see front matter

fragments.[3,4] Smith and Boyce then described the first anatrophic nephrolithotomy for staghorn calculi in 1968, which redefined the approach to large complex kidney stones.[5] This was predicated by the technical description by Josef Hyrtl (1882) and Max Brödel (1902) of the avascular plane of the kidney that allowed bloodless access to the renal collecting system.[6]

The recognition of ureteral calculi and their particular surgical management mirrored that of nephrolithiasis. Thomas Emmet of New York published his account in 1879 of 3 women with distally impacted ureteral stones that were treated by open ureterolithotomy, including one through a transvaginal approach.[7] Then, in 1910, Gibson described the extraperitoneal approach to the distal ureter that remained in practice during the next century.[7]

The role of open surgical consideration has given way to a collection of techniques and technology that have minimized the subsequent mortality and morbidity for most patients requiring stone surgery. Arthur Smith labeled the new frontier of minimally invasive surgical management: endourology, or the closed controlled manipulation within the urinary tract.[8] This shift in the treatment paradigm was established by several important developments that will only be briefly described in the context of the relevant surgical evolution. Fernström and Johansson described the first percutaneous removal of a kidney stone in 1976,[9] which was preceded by the initial description of percutaneous nephrostomy tube placement for hydronephrosis in 1955.[10] The subsequent development of an intracorporeal lithotripter in 1977[11] permitted PNL to become the mainstay of intervention for large renal stones. In a survey of disease codes, the annual use of PNL in the United Stated increased from 1.2 per 100,000 to 2.5 per 100,000 between 1988 and 2002.[12] Other surgical means of accessing the kidney and ureter for stone disease involved the development of retrograde approaches via URS.

URS was initially developed in the late 1970s to diagnosis and treat conditions of the distal ureter.[13] The introduction of rigid, semirigid, and flexible URS has allowed the usefulness of URS to increase dramatically during the past several decades.[14] This is predominantly a result of the vast technological advances made for URS stone management including miniaturization, new instruments, and lasers, in addition to the improved endoscopic skills of the urologist.

Further diminishing the role of open surgery was the development of SWL, first described by Chaussy and colleagues[15] in 1980 and approved by the US Food and Drug Administration in 1984. It has become the most commonly used therapeutic intervention for patients with upper tract stones.[16] The advantages of SWL include high patient tolerance because of the infrequent need for invasive surgical procedures and minimal morbidity.

The emergence of these technologies and procedures were followed by the development of minimally invasive surgery such as laparoscopy. Clayman and colleagues[17] reported the first transperitoneal laparoscopic nephrectomy in 1991, drawing attention to the capabilities of such a novel technique. Laparoscopy became an alternative to open surgery with decreased complications, less morbidity, and high stone-free rates and fostered the imagination of innovators to push the surgical envelope even further. The advanced engineering capabilities and desire to pursue remote surgery by the military gave rise to the modern day da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA).[18] During the past, decade the US health care system has seen an explosion of robot-assisted surgical procedures. In June 2010, Jin and colleagues[19] randomly surveyed 400 US hospital Web sites and found that 41% of all hospitals described robotic surgery and statements of clinical superiority were made on 86% of these Web sites. The exponential growth of robot-assisted laparoscopic techniques has provided a critical enabling technology to the surgical armamentarium, making laparoscopy possible for those not proficient in 2-dimensional spatial relationships or lacking the dexterity for precise laparoscopic maneuvers.

PATIENT CONSIDERATIONS

The prevalence of open surgical procedures has decreased significantly with the advent of minimally invasive and endourologic procedures. In the United States in 2000, only 2% of Medicare patients were treated with open surgery when they required a stone operation.[20] Internationally, when alternative equipment and expertise are available, open surgery is done in only 1% to 5.4% of all patients requiring stone surgery.[20–27] Even in developing countries, the prevalence of open surgery has decreased from 26% to 3.5% of patients requiring stone surgery.[28,29] As such, even though the prevalence of open surgery has collapsed, there remain certain clinical scenarios when it may be indicated (**Table 1**). The maturity of laparoscopic proficiency, equipment, and robotic experience has shown the ability to duplicate nearly any open surgical procedure.[26] The advent of robot-assisted and laparoscopic approaches, when the resources and expertise