

The evolution of robotics in urology: the dawn of a new era

Robotic urology has evolved from concept to cornerstone, paving the way for AI and autonomous surgery.



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As a specialty, urology has changed enormously over the past three decades. The innovative advances in minimally invasive surgery have led to decreasing utilisation of the age-old gold standard: the open approach. Robot-assisted laparoscopic urological surgery (RALUS) is one such advancement that has been embraced by surgeons and patients alike.

HISTORICAL FOUNDATIONS

Urology's inaugural robotic application occurred in 1989 in London when the late Mr John Wickham and colleagues employed the Probot system, preceded by the development of the Puma robot, in an attempt at robotic transurethral prostatic resection.^{1,2} This was the first pure robotic surgery in the field of urology.

The development of AESOP (Automated Endoscopic System for Optimal Positioning) by Computer Motion (Goleta, CA, US) marked the first robotic instrument that could be controlled by voice, hand or pedal. Approved by the US Food and Drug Administration (FDA) in 1994, it was utilised initially for urological laparoscopic procedures.³

Subsequently, several surgeons in other specialties adopted AESOP for performing laparoscopic surgery as it is challenging for the assistant to manipulate the camera in coordination with the primary surgeon's movements in a narrow operative space during lengthy procedures. Later modifications resulted in the ZEUS robotic platform (Computer Motion). Concurrently, an early version of the da Vinci® system was released by Intuitive Surgical (Sunnyvale, CA, US). In 2000, da Vinci® became the first robotic platform to be approved by the FDA for general laparoscopic surgery.

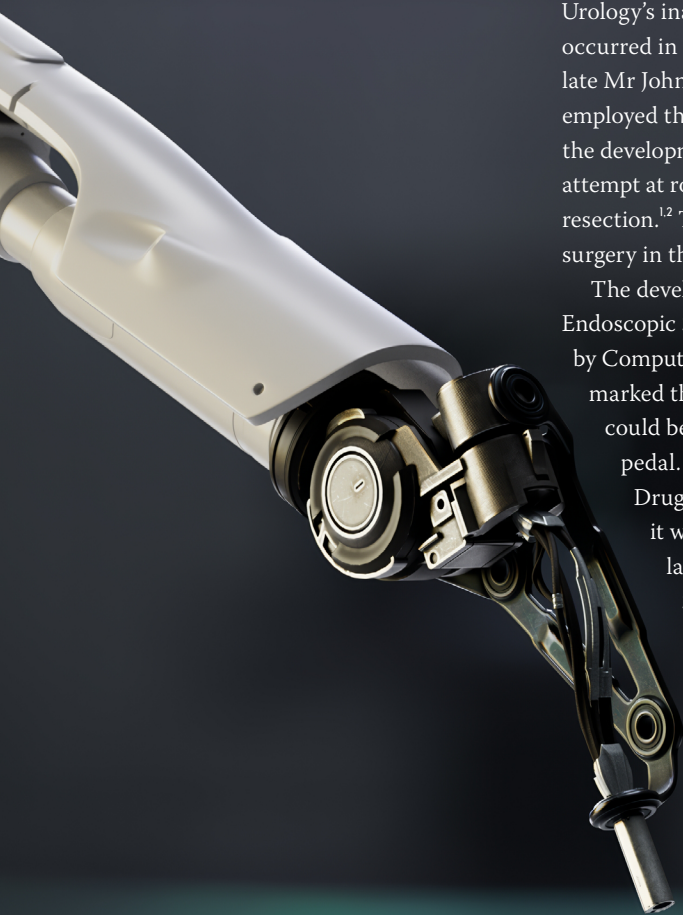
The ZEUS system was phased out in favour of the da Vinci® robot when Computer Motion and Intuitive Surgical combined operations in 2003.⁴ The da Vinci® platform

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has emerged as the most widespread across numerous surgical disciplines. Intuitive Surgical has expanded the da Vinci® system through multiple generations, from the original standard model in 2000 to the da Vinci® 5 robot in 2024, which includes a new console as well as some other upgrades.

THE GLOBAL COMPETITIVE LANDSCAPE

Although a single company has pretty much dominated the interest across all surgical fields, the substantial costs of the initial machine, instruments and maintenance have encouraged global competition. There are now at least ten new robotic platforms designed for different urological procedures. Outside the US, commonly utilised alternative systems include Hugo™ (Medtronic, Minneapolis, MN, US), Versius® (CMR Surgical, Cambridge, UK), Revo-i (Meerecompany, Seoul, South Korea), Hinotori™ (Medicaroid, Kobe, Japan) and SSi Mantra (SS Innovations, Delhi, India). Similarly, in China, domestically developed robotic platforms are being successfully employed in clinical practice (e.g. the



SHURUI® single-port system [Surgerii, Beijing, China]).

Contemporary urological surgical robots operate as master–slave systems, in which surgeons manipulate robotic arms by controlling a remote console. This configuration highlights that they are not autonomous robots but rather telepresence devices, making the term ‘surgeon-controlled robot-assisted surgery’ a more precise descriptor.⁵ Explaining this distinction to patients can reassure them that a surgeon (and not a machine) is performing the operation. The development of various robotic systems worldwide will help reduce costs and democratise access to surgeon-controlled robotic surgery globally.

CLINICAL EVOLUTION AND ADOPTION

At the turn of the millennium, there was tremendous integration of technology in medicine, coinciding with robot-assisted laparoscopic surgery entering the field of urology. Abbou and colleagues performed the first robotic radical prostatectomy, reporting the results in the *Journal of Urology*.⁶ Although other surgeons also undertook similar procedures, these were not reported at that time. These efforts catalysed the growth of robotic surgery in Europe.^{7,8} In

the US, Menon was the first to implement a structured programme for robotic radical prostatectomy worldwide and this model was adopted globally.⁹ This stimulated the field, resulting in the expansion of RALUS for different indications in uro-oncology and other branches of urology. Building on the learning and experience gained from robot-assisted radical prostatectomy, the first series of robotic radical cystectomy with hybrid intracorporeal urinary diversion, partial nephrectomy, radical nephrectomy and renal transplantation were reported.^{10–12}

With regard to my own experience in RALUS, after my initial learning curve, the conversion from laparoscopy to robotics proved an extremely smooth transition and led to my journey in assisting several centres in setting up robotic programmes.^{13,14} One of the first robotic urology symposiums was organised at Guy’s Hospital, London, in February 2004, reflecting the burgeoning enthusiasm among urologists. In June 2004, Mr Dasgupta and I, along with other team members, performed the first four cases (prostatectomy, cystectomy, colposuspension and anterior pelvic exenteration), and established a structured robotic urology programme at Guy’s Hospital.¹⁵ In April 2005, I also performed the first robotic

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radical prostatectomy in India (Figure 1).¹⁶ Subsequently, I aided several other centres around the world in setting up their robotic programmes, and also demonstrated live robotic surgery in Asia and Europe.

Figure 1 First robotic urological procedure performed on 29 April 2005 at All India Institute of Medical Sciences



TELESURGERY AND FUTURE DIRECTIONS

The first transatlantic robot-assisted procedure provided the impetus for telerobotic surgery.¹⁷ This brought about the emergence of intercontinental telerobotic surgery, making history beyond domestic and nearby regional applications. Such operations have been carried out with homegrown robots in India, China and Japan. These systems offer modular designs, cloud connectivity and affordability, challenging the market dominance of the da Vinci® platform.

Open and laparoscopic surgeons have adapted to RALUS techniques over the past 25 years, and it has now become a cornerstone of modern surgical practice, representing a true paradigm

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shift. Augmented reality, fluorescence imaging and 3D anatomical modelling for intraoperative navigation are being utilised at select institutions. Teleconferencing and consultation, telerobotics and teleproctoring are current clinical realities.

The future will witness further integration of digital technologies, artificial intelligence (AI)-guided procedures and telerobotic surgery into mainstream practice. Image guidance, prostate-specific membrane antigen fluorescent imaging, molecular imaging, AI-guided automated assessment and computer vision are currently being evaluated to provide intraoperative surgical assistance. AI has already penetrated numerous aspects of medicine, from diagnosis to treatment planning, and is making significant advances in the robotic field, which will prove invaluable for autonomous surgery.

The amalgamation of knowledge and technology will lead to the development of fully autonomous robotic surgery – a reality that may not be too far off. Although the future appears bright for these areas, concerns remain regarding cost, legal implications and ethical considerations.

CONCLUSIONS

Our fundamental mission centres on managing patient pathology effectively. When multiple surgical approaches exist

for a given condition, we must prioritise methods that optimise safety, efficacy and cost effectiveness while minimising recurrence or progression risk. For this reason, we should consider all of these factors when performing surgery, whether for open, laparoscopic, minimally invasive or robotic procedures.

When adopting newer technology to perform surgical intervention, the balance of safety, efficacy and cost needs to be assessed from a global perspective in order to be available for most of the patients. We must of course continue striving to make surgery safer, more effective and more economical but we must also critically evaluate our progress in surgical science. The latest technology is not always the optimal approach for treating a patient. The patient's pathology, body habitus and medical comorbidities, besides availability of tools and technology, should dictate the surgical technique.

As we continue to develop newer techniques with advanced instrumentation and machines, which can prove challenging for both surgeons and patients to navigate, hence it is important to remember that this is how progress and change come about. Despite 25 years of advances in RALUS, it remains surgeon-controlled robotic surgery. Nevertheless, autonomous robot-assisted urological surgery is gaining traction. We must remain open to embracing and guiding such change if it has the potential

to meaningfully benefit our patients and society.

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