A short history of robotic surgery

A concise review of the use of robotic technology to enhance surgery

Tim Lane Consultant Urologist and Robotic Surgeon, Lister Hospital, Stevenage

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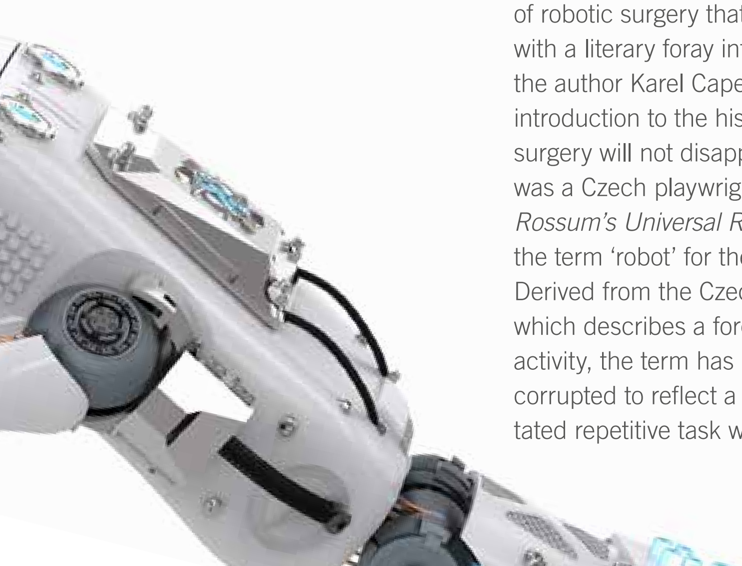
The extent to which robotic surgery has been embraced by the surgical fraternity has been unparalleled. It has been driven in part by rapid developments in technology and in part by the ease with which adaptations have been made to existing laparoscopic procedures and techniques. Robotic procedures are rapidly becoming the new standard of care. As with a number of other technological advances in medicine and surgery, these developments have seldom been introduced as a result of randomised prospective studies.

There is not a review of the history of robotic surgery that does not start with a literary foray into the world of the author Karel Capek and this brief introduction to the history of robotic surgery will not disappoint. Capek was a Czech playwright. His play *Rossum's Universal Robots* defined the term 'robot' for the first time. Derived from the Czech word *robota*, which describes a forced labour or activity, the term has rapidly become corrupted to reflect a machine-orientated repetitive task with little – if any – artificial intelligence. In the play the robots that once undertook mundane tasks for their human masters later attempt to throw off their subservient roles and take control of their own destinies. Although the current use of robots – machines that can undertake ultra-precise, repetitive and pre-programmed procedures – is commonplace in industry, they have only relatively recently been adopted by the medical sector to enhance the delivery of care.

There are three main types of robotic systems currently in use in the surgical arena. Active, semi-active and master–slave systems. *Active* systems essentially work autonomously (while remaining under the control of the operative surgeon) and undertake pre-programmed tasks. The PROBOT and ROBODOC platforms described later are good examples of this. *Semi-active* systems allow for a surgeon-driven element to complement the pre-programmed element of these robot systems. Formal *master–slave* systems (of which the da Vinci® and ZEUS platforms were the forerunners) lack any of the pre-programmed or



autonomous elements of other systems. They are entirely dependent on surgeon activity. Surgeon hand movements are transmitted to laparoscopic surgical instruments, which faithfully reproduce surgeon hand activity – but intracorporeally.

Authors often differ in their definition of the first robotic procedure of the modern era. For most, the honours are awarded to Kwoh *et al*[1], who used the PUMA 560 robotic system to undertake neurosurgical biopsies with greater accuracy – in effect, stereotactic brain surgery. The same system was subsequently used by Davies *et al*[2] to undertake a transurethral resection of the prostate (TURP) – a precursor of what would ultimately be termed the PROBOT. It was designed specifically to undertake a TURP and was developed by Integrated Surgical Supplies Ltd. In essence, the PROBOT represented a framework to direct a rotating blade to complete the process of prostatic resection. Although the PROBOT failed to gain wider clinical appeal, a similar concept was simultaneously being explored elsewhere. In this respect, parallel developments were being undertaken to develop the ROBODOC system (the first of the *active* robotic systems to achieve a formal FDA approval) and a machine designed to improve the precision of hip replacement surgery. It was adopted almost immediately in Europe (and subsequently in the US), with the first procedures being undertaken in 1992. A further system (PAKY) employed a similar percutaneous approach to access the kidney for stone surgery. None of these systems, however, were designed to embrace or augment a laparoscopic procedure.

Although the early *active* robotic systems clearly demonstrated the potential of mechanical devices to enhance surgical interventions, the driving force for developments that were ultimately to enhance laparoscopic procedures were based on the concept of telepresence, which in turn was derived from a collaboration between the Ames Research Centre at NASA and researchers from Stanford. The US military, recognising the potential significance of linking surgeons (distant from the battlefield) to patients via a robotic platform, saw a potential to reduce the mortality and morbidity from service personnel serving in fields of conflict. Researchers (many of whom were originally involved with this military interest group) went on to develop their ideas commercially in the public and commercial sectors.[3,4] Direct funding was provided to Computer Motion to develop the Automated Endoscopic System for Optimal Positioning (AESOP) robotic platform. This system essentially enabled surgeons to voice control the positioning of a laparoscopic camera system. Later modifications resulted in the system being re-launched as the ZEUS operating system. An alternative option was the EndoAssist (a slightly bulkier but considerably cheaper alternative), which relied on infrared signals directed from a headset worn by the operating surgeon. At about that time, the forerunner to what was eventually to become Intuitive Surgical released the SRI Green Telepresence system, which was later to undergo a radical overhaul before morphing into an early version of the current da Vinci® system.

These two rival systems, ZEUS and da Vinci, went on to dominate the field of robotic surgery for a decade – trading world-firsts and pushing back the frontiers of minimally invasive surgery. The three-armed ZEUS platform continued to make use of the voice-activated AESOP camera system. One of its three arms held the camera and a further two arms were used to hold surgical instruments. The da Vinci® platform represented a three-to-four-armed system, with a central arm holding a binocular lens (for 3D vision). Perhaps more significant, however, was the fact that the surgical instruments used via the remaining arms on the cart were articulated at the wrist to seven degrees of freedom. It represented a unique selling point and an innovation that ultimately proved crucial in the subsequent dominance of the da Vinci® platform.

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The da Vinci® platform was the first to be used to undertake a cholecystectomy (Belgium 1997). The following year Carpentier *et al* (also using the da Vinci® platform) undertook a mitral valve replacement – significantly taking advantage of the innovative 'wristed' instruments for the first time. Subsequently, a re-anastomosis of a Fallopian tube was performed using the ZEUS system in 1998. The following year the first closed-chest beating-heart cardiac bypass procedure was undertaken by Douglas Boyd and colleagues at the London Health Sciences Centre in Ontario. The same team later went on to undertake a cardiac revascularisation procedure, also using the ZEUS platform. In 2001 a transatlantic cholecystectomy was undertaken using the ZEUS system (the operative surgeon undertaking the procedure in New York while the patient was physically in Strasbourg, France). The ZEUS and da Vinci® systems were effectively unified when Computer Motion and Intuitive Surgical merged in 2003. As a result, further innovations and improvements were centred on the da Vinci® platform, which has subsequently dominated the world of robotic surgery for almost a decade.[5–8] It has only been in the past few years that newer technology companies have emerged and introduced a significant element of competition and choice to this rapidly evolving field.

The reviews presented here in this supplement to the *Annals of the Royal College of Surgeons* explore the current extent to which robotic surgery is now enhancing surgical practice and consider future developments in the field as a new generation of companies enter this rapidly changing arena.

References

1. Kwoh YS, Hou J, Jonckheere EA *et al*. A robot with improved absolute positioning accuracy for CT guided stereotactic brain surgery. *IEEE Trans Biomed Eng* 1988; **35:** 153–161.
2. Davies BL, Hibberd RD, Ng WS *et al*. The development of a surgeon robot for prostatectomies. *Proc Inst Mech Eng [H]* 1991; **205:** 35–38.
3. Satava RM. Surgical robotics: the early chronicles: a personal historical perspective. *Surg Laparosc Endosc Percutan Tech* 2002; **12:** 6–16.
4. Felger JE, Nifong L. The evolution of and early experience with robot assisted mitral valve surgery. *Surg Laparosc Endosc Percutan Tech* 2002; **12:** 58–63.
5. Eichel L, Ahlering TE, Clayman RV. Role of robotics in laparoscopic urologic surgery. *Urol Clin North Am* 2004; **31:** 781–792.
6. Eadie LH, Seifalian AM, Davidson BR. Telemedicine in surgery. *Br J Surg* 2003; **90:** 647–658.
7. Sung GT, Gill IS. Robotic laparoscopic surgery: a comparison of the da Vinci and Zeus systems. *J Urol* 2001; **58:** 893–898.
8. Challacombe B, Khan S, Murphy D *et al*. The history of robotics in urology. *World J Urol* 2006; **24:** 120.