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A brief overview of the development of robot-assisted radical prostatectomy



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Learning curve

ABBREVIATIONS

L, laparoscopic;
RA, robot-assisted;
RP, radical prostatectomy

Abstract Robot-assisted radical prostatectomy (RP) has gained remarkable world-wide distribution and has become a standard procedure for localised prostate cancer, indeed a new ‘gold standard’. There are proven advantages in reduced blood loss and shorter recovery time. Whilst case series publications often report improved functional outcomes, systematic hospital and healthcare data analyses mostly do not support these findings. Robotic surgery remains more costly. Its use has also increased knowledge about the anatomy of RP.

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Introduction

In an early review of robot-assisted surgery in urology, Binder et al. [1] in 2004 wrote that ‘to date, robots have not lived up to the dreams of the pioneers in the 1960s

and 70s, but there is little doubt by specialists that human intelligence will soon be surpassed by machine intelligence’. This has not happened yet, 14 years later. Robot-assisted surgery has come a long way and has developed into a technique used worldwide. However, it has not become ‘robotic surgery’ in the true sense of the term; there is no machine intelligence doing surgery on its own and this is certainly not in sight. It is not human-operated telesurgery either. Minimal delays in long-distance transmission have made it impossible to implement true telesurgery either.

Instead, robot-assisted surgery is refined laparoscopic surgery with the robotic system providing better vision,

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better instrument control, more refined dissection, and better ergonomics for the surgeon.

The revolution started with the development of the silicone chip and its origins are in Silicon Valley in the USA. Robot-assisted devices for use in surgery were first developed and marketed by two Silicon Valley-based companies [2]. Computer Motion Inc., which developed the Automated Endoscopic System for Optimal Positioning (AESOP) robotic device, a voice-controlled camera arm for laparoscopic surgery, enhanced a few years later by the telemanipulator system named 'ZEUS'. After Computer Motion's advance into the field, Intuitive Surgical Inc. marketed its da Vinci® Surgical System, which became highly successful and carried the day. The da Vinci system's development had been heavily funded by the USA Department of Defense and there are many built-in patents. This sophisticated remote-controlled telemanipulator system, developed specifically for use in surgery, soon became the new standard for radical prostatectomy (RP). In 2003, the two companies merged under the name Intuitive Surgical Inc., which solved legal problems over patent rights.

The standard of RP until then had been open 'anatomic' RP as described by Walsh et al. [3]. He described his technique of RP in the late 1980s. His detailed anatomical descriptions and research allowed RP to become an accepted and widely used treatment for localised prostate cancer. The technique allowed for early control of Santorini's plexus, thus reducing intraoperative blood loss, and of sparing of the neurovascular bundles, facilitating functional recovery with better preservation of sphincter and erectile function in younger men. A steep increase in the number of RPs performed followed.

This standard was then challenged by laparoscopic RP (LRP), which was developed as a 'minimally-invasive' alternative in the early 1990s. The first report dates back to 1992 [4], but LRP only developed further after it was embraced and refined in France, where Guillonnet and Vallancien and others described the standardised Montsouris technique [2,3]. LRP proved to obtain similar oncological and functional results as open RP, although this was initially hotly disputed.

However, LRP carries a rather long learning curve. For this reason, its adoption was not universal and many urologists stuck to the still 'gold standard' of open RP.

With the advent of robot-assisted RP (RARP) this was different. Robotic surgery does have a shorter learning curve, it can be adopted by surgeons without laparoscopic experience, and its control of the instruments is less tiring and easier than laparoscopy [5]. This allowed many experienced open surgeons to switch to robotic surgery much more easily than the transition to laparoscopic surgery had been. Probably for this reason, robotic surgery made its advance into urological surgery much more quickly and easily than laparoscopy ever

did. Since its clinical introduction in Europe in 1999, the da Vinci system has opened up a new era in minimally invasive surgery. It allows refined microsurgical preparation and suturing, easier and better than laparoscopy ever did, and provides excellent endoscopic vision, also better than in laparoscopy.

The first RARPs were performed at the Department of Urology of Frankfurt University in Germany in 2000 [6]. The interest in the USA remained low, until excellent results were first reported at the AUA annual conference in 2001. In 2002, Menon et al. [7] published the first prospective trial comparing the results of RARP with those of open retropubic RP and reported that the robotic technique was safer, with reduced blood loss.

After that the technique was taken up by several centres in the USA and developed further [8,9]. Shrivastava et al. [10] and Menon et al. [11] developed the standardised Vattikuti technique of RARP and reported excellent outcomes, both oncologically and functionally. This led to an enormous surge in the application of RARPs worldwide, first in the USA, then in Europe, and later elsewhere around the world. Refinements in the mostly transabdominal technique, improvements in nerve-preservation ('Veil of Aphrodite'), technical developments (fourth arm), and the development of the extraperitoneal approach, brought more complexity but also improved results and reduced complications with RARP. There remains an unresolved controversy whether the extraperitoneal approach has advantages over the intraperitoneal approach to RARP [12].

Again, the comparison with the still 'gold standard' open technique was hotly debated over some years [13]. But with increasing case numbers and longer follow-up it soon became clear that the oncological and functional results of RARP performed by expert console surgeons were as good as if not better than those of expert open surgeons. The debate of whether RARP is equivalent to open surgery is definitively over today. Open surgery remains 'a' gold standard in that it is required in difficult locally advanced cases and those with numerous positive lymph nodes, although highly experienced robotic surgeons would contest this as well. Definitely, RARP has become the new 'gold standard' for localised prostate cancer, where good functional results are of paramount importance and it has definite advantages both over open and LRP [14]. It can even be argued with some evidence that robotic surgery, with its different techniques of dissection and better visualisation, has led to increased knowledge of the anatomy of RP [15].

However, in extensive analysis of hospital data, the differences between the different techniques of RP often appear somewhat different. Analysis of hospital data confirms reduced hospital stay and reduced blood loss but no definite oncological, functional or quality-of-life advantages for RARP [16].

RARP differs from its predecessor, the laparoscopic technique, in a few important points. The robotic surgeon is in full control of all instruments and the camera. The role of the (still needed) table-side assistant is limited to changing instruments, retraction, and suction. Port placement is different from normal laparoscopy and placement of the assistant's additional ports is critical, as external and internal collisions with the robot arms are a common problem.

What are the proven advantages of the new 'gold standard'? Due to the laparoscopic feature of gas insufflation and increased intra-abdominal pressure there is less bleeding and hence less need for blood transfusions. Recovery time is shorter and many studies show that postoperative analgesic requirements are reduced. Hospital stay can be shortened although the extra-short hospital stays reported from the USA have to be taken with a 'grain of salt'. The USA-American system caters for extremely intensive post-hospital care, which in many cases is not very different from postoperative in-house care administered in Europe, where hospital stays are traditionally longer than in the USA.

The spectrum of robotic procedures over the years has been extended to include partial and radical nephrectomy, pyeloplasty, and radical cystectomy including intracorporeal urinary diversion and, most recently, renal transplantation. All these robotic procedures are characterised by the principal advantages of robot-assisted surgery – reduced blood loss, less pain, and shorter recovery time. As for laparoscopy, there is scientific evidence that post-aggression metabolism is reduced in RARP in comparison to open RP [17]. Complications of robotic surgery are related to surgeon and hospital volume, as is to be expected [18].

The costs of the robotic system remain an issue. Investment costs are extremely high, as are those of the surgical instruments, whose use is limited to 10 applications by the company. The costs per case vary and depend on several factors, not only case load of the hospital but also the number of instruments used per case [19]. The difference in costs also depends on the reimbursement system; for example, in Canada, RARP is more than \$6000 more expensive per procedure compared to the open technique [16]. Costs need to be compared to other modern techniques of treatment such as modern radiotherapy [20].

Since the introduction of the da Vinci robotic system there has been comparatively little development in the field, although Intuitive Surgical has been constantly refining its system and has developed several more instruments for robotic use. Also, the original three-arm system has been virtually replaced by the four-arm system [21] and the newest generation, the Xi system, has advantages for upper quadrant surgery. However, despite constant rumours, there have been no competitors who actually have marketed an alternative robotic system.

Undoubtedly there will be developments in the telerobotic field over the next 10 years. If and when a new system becomes available, it is to be hoped that costs will be reduced considerably. Further developments may be robotic surgery with fewer ports or the integrated use of three-dimensional reconstructions of prostate MRI during surgery. It is certain, that robotic surgery is here to stay, that its role will further expand, that it will be refined, and that it will become more and more expensive.

Conflict of interest

None.

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