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Role of Robotics in urology

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Introduction:

Leonardo da Vinci is credited for the first drawn 'humanoid robot', known as Leonardo's Robot in 1495. This robot could do a number of activities and it was operated by pulleys and cables [(1)]. The term 'robot' comes from the Czech word 'robota', which translates as 'forced work'. It was introduced in 1920 by the Czech playwright; novelist and journalist Karel Capek in his hit play Rossum's Universal Robots [(2)].

The first digitally programmed robot, the Unimate, was installed in New Jersey, in 1961 which worked on a General motor assembly line. Since then, Robots have been used in various industries such as manufacturing, packing, transport, space programs, laboratory research, surgery etc. By definition, a surgical robot has an artificial sensing that is manipulated and controlled by computer which can be reprogrammed to carry out a wide range of surgical tasks.

The field of urology has become progressively innovation driven and in this way has been on the cutting edge of careful advanced mechanics [(3)]. Modern robotic surgical systems can be categorized as master-slave systems, precise-path systems, or intern-replacement systems. On-line robotic systems, also known as Master slave systems, the most recognizable sort, were created from starting examinations in "telepresence" medical procedure financed by the US Department of Defence. Urology has grasped the utilization of robotic surgical systems in a developing number of clinical applications, which were intended to recreate the surgeon's movements continuously inside the operated field [(4)]. Year 1985 has witnessed the first recorded use of a robot-assisted surgical procedure when the PUMA 560 robotic surgical arm was used in a neurosurgical biopsy [(5)]. Since then, the most commonly utilized robotic gadget is the da Vinci which was release in 1997 and approved by Food and Drug Administration (FDA) in July 2000. This robot comprises of three or four arms, one of which is utilized to hold and control the laparoscopic camera while the others are utilized to control specific laparoscopic instruments with endo-wrist innovation that permits 7 degrees of movement [(6)].

Since its introduction into surgical practice, Robot has become an integral part of urological practice. Subsequently, Robotics has been used to perform various urologic procedures including radical prostatectomies, cystectomies, nephrectomies, adrenalectomies and pelvic floor procedures. Like all advances there is a trade-off between the advantages and downsides. General drawbacks include the high costs and lack of haptic feedback.
On the other hand, most eminent benefits are the manual dexterity of the instruments alongside movement scaling and tremor-filtering ability. The robotic systems have better ergonomic control with less surgeon fatigue and strain along with stereo-optic vision and a three-dimensional image and are undeniably appropriate for surgeries in constrained spaces, for example, prostatectomies [(1-6)].

Paediatric urologic surgeries and female urology have also noticed an increased adoption of robotic applications. In this article, we will endeavour to cover robotic surgical applications in urology and ongoing advances in these strategies.

Robotic platforms:

(A) Da Vinci Robotic system:

It is the most popular commercial robotic system. It has three components namely surgeon console, patient cart with robotic arms and vision cart. The first da Vinci system was launched in 1999. A fourth instrument arm was added in 2003. In 2006, the da Vinci S version, offering the high-definition vision to surgeons, was released. The da Vinci Si model was introduced in 2009 with an isocyanine green fluorescence (Fire-FlyTM technology) and finger-based clutch mechanism [(7)]. Dual console of the da Vinci Si representing an ideal training platform during surgery [(8,9)]. A new model of da Vinci named Xi was brought to market in 2014 with a peculiar feature of 8 mm camera that can be used at any of the four ports (camera hopping). Along with this table motion technology (surgical table can be moved without undocking the robotic arms) is also a part of this new robotic version [(9)].

(B) CMR

CMR Surgical is a Cambridge based British medical technology company that produces a robotic surgery system called Versius. It was known as Cambridge Medical Robotics but changed its name to CMR Surgical in March 2018 [(10)]. On 30 september 2020, CMR Surgical has announced the introduction of Versius, at the Frimley Health, first hospital of UK to use Versius in Urology, as well as in Colorectal surgery [(11)]. CMR Surgical claims Versius to be more flexible and versatile, having independent modular arms which are "quick and easy to set up" [(12)]. However, well designed randomised trials are still needed to compare this robotic system with the gold standard da Vinci system.

(C) Medtronics
Medtronics Hugo RAS (Robotic assisted surgery) is still awaited to be launched in market. Key features claimed by Medtronics about this system are flexibility and universal use for both key hole and open surgeries [13]; apart from this an open console with the autofocusing monitor. The robotic arms are comparable to human arms having of seven joints with serial kinematics. Robotic arms are driven by micro-motors, with option of tactile feedback via potentiometers [9]

Radical prostatectomy

This is a well-known procedure for the treatment of localised prostate cancer and the number of surgical procedures is increasing because of increasing diagnosis of prostate cancer thanks to improved awareness and widespread availability of screening tests. Although, laparoscopic procedures have overcome the morbidity associated with the open procedures, the primary limitation was the limited spaces in pelvis which leads to difficulties in performing vesico-urethral anastomosis. Introduction of robotics has overcome the problems associated with restricted manoeuvrability.

With 3D perception and jointed laparoscopic instruments giving 7 degrees of articulation, the da Vinci framework gave the ideal combination of the magnified advantages and minimally invasive feature of laparoscopy with the dexterity of an open surgery [14]. The robotic radical prostatectomy is now a widely accepted and well established surgical procedure of choice and emerging as a frontrunner for radical prostatectomy in well-resourced nations [15, 16]. Undeniably, the main benefit is a shorter learning curve compared with laparoscopy is a boon to surgeons [17].

The technique of robotic prostatectomy has undergone significant improvisation to accomplish superior oncological and functional results with a better understanding of the neurovascular anatomy [18]. Various studies have shown the benefits of preservation of neurovascular bundle on improved post-operative erectile and orgasmic function [19]. Gulfano et al has proposed the new technique of robotic radical prostatectomy approach named as Retzius-sparing robotic radical prostatectomy which has recently gained popularity [20]. In the Retzius (posterior) approach, continence and erectile function can be recovered early; however, higher positive surgical margin is the main concern with the posterior approach [20, 21].

Apart from this, several other modifications has been proposed for robotic prostatectomy to achieve early continence which have been eased by robotic system namely- bladder neck preservation/reconstruction, preservation of urethral length, peri-urethral suspension and reconstruction, pubo-prostatic ligaments preservation and limited endopelvic-fasica dissection [22]. Despite this, Level 1 evidence comparing robotics surgery and laparoscopic/ open surgeries has been limited. Asimakopoulos etal has compared laparoscopic and robotic prostatectomy and reported significantly better erectile function recovery in the robotic arm but no difference in perioperative and continence outcomes [23].

Follow-up studies also shown similar results in these arms with some superiority of robotic arm, however, still a robust randomised study is required for level 1 evidences [24, 25].
Although controversial, some studies claim that risk of positive surgical margin is less after robotic assisted radical prostatectomy as compared to laparoscopic or open approach [26]

Partial nephrectomy

Partial nephrectomy is the surgical modality of choice for small renal masses [27]. This procedure involves renal artery clamping; hence, time is a crucial factor in the procedure to minimise the warm ischemia time. Traditional open approach is more morbid because of large incision and can have longer hospital stays and delayed recovery and problem with the laparoscopic approach is longer warm ischemia. Robotic surgery is an ideal answer to mitigate these challenges with a shorter artery clamping time and early recovery [28, 29]. In fact, the learning curve for the robotic approach is significantly lower than its counterpart (15–25 cases compared with 100–150 for laparoscopic) [30].

Several modifications have been proposed for robotic partial nephrectomy such as safely omitting cortical renorrhaphy [31]. Similarly, a new technique using a dye named Indocyanine green (ICG) is a potential aid to robotic partial nephrectomy as it helps in real-time identification of renal mass, renal vasculature and tumour margin [32]. By this it can help in minimizing the ischemia time by allowing selective clamping. Some provided evidence that it can be beneficial in improved perioperative and oncological outcomes [33]. It can be an adjunct especially in difficult cases with impaired renal function or challenging vascularization [34].

Interestingly, the increased cost of the robotic approach is counter-balanced by the reduced hospitalisation and complication rates [35].

Radical cystectomy

Radical cystectomy and urinary diversion with pelvic lymph node dissection is the standard of care for muscle-invasive and high-risk superficial bladder cancer. Traditionally, open surgeries remains a highly morbid procedure with a delayed recovery. Menon et al reported the initial series of nerve spare robotic radical cystectomy in 2003 [36]. Since then, there are a number of studies have been published on robotic cystectomy but still level 1 evidence confirming the superiority over conventional approach remains unproven [37,38,39]. The current evidence states that although the robotic approach achieves better results in terms of blood loss and hospital stay, oncological outcomes and good quality lymphadenectomy are equivalent only as compared to open counterpart [40]

Although in the initial series of robotic approach, extracorporeal approach was used for the urinary diversion, modern surgeries involve the intra-corporeal approach with an equivalent outcome [36, 41].

Robot-assisted pyeloplasty

The open dismembered pyeloplasty has been the standard of care for pelvi-ureteric junction obstruction, with a high success rate (>90 %) [42]. Minimally invasive alternatives have been tried to reduce the morbidity associated with open approach such as balloon dilatation and endopyelotomy but success rates of only 60-70% [43]. Laparoscopic pyeloplasy has been proven as a standard treatment for pelvi-ureteric junction obstruction with less morbidity and good outcome. Robotic technique has also been tried for that but the outcomes were statistically similar as with the laparoscopic approach although the learning curve is much shorter with the robotic technique [44].

Robot-assisted radical nephrectomy and nephroureterectomy

Gold standard treatment for large and locally advanced renal tumours is radical nephrectomy. Although number of radical nephrectomies done by robot-assisted is increasing, it still failed to prove benefits over its laparoscopic counterpart. Compared to open surgeries shorter hospitalization and reduced morbidity can be benefits but this can be achieved by laparoscopic approach as well. Randomized clinical studies with long-term follow-up are needed to obtain more definitive level 1 evidences. [45]. Similar theory applies for nephron-ureterectomy patients and available studies are enough to prove superiority of robotic approach [46].

Female Urology

Application of robotic system in female uro-genital system is also emerging and predominantly used for repair of stress urinary incontinence and lower urinary tract fistula namely vesico-vaginal, vesico-uterine and utero-vaginal fistula [47, 48]. Robot assisted colpo-suspension and bladder neck AMS-800 artificial urinary sphincter implantation has been increasingly used to treat female stess urinary incontinence [48, 49]. However, Robotics in female urology is still in its primitive stage and robust trials are needed for its widespread use.

Other robotic procedures

Although not routinely performed, ureteric reimplantation, stone surgery, cystoplasty, andrology such as varicocelectomy, testicular sperm extraction, vasectomy reversal and spermatic cord denervation [50, 51, 52]. Some centres, routinely do robotic donor nephrectomy in renal transplantation [53]. Simple prostatectomy is also being done by this approach although HoLEP has superseded it and is being increasing used for larger glands; however randomised trials are still needed for definitive evidence [54].

Conclusion

Robotic surgeries have become an integral part of urology practice. Although, prostatectomy and partial nephrectomy has shown some clear advantages in randomised studies, rest of the robotic procedures still fail to show clear superiority in the randomised studies. The main prohibiting factor for extending the robotic surgery to all applications and surgical specialities is cost. The expansion of the platforms has been very slow, given there is a degree on monopoly in the industry. But in recent times, it is encouraging to see more alternatives coming in to the market. This competition will drive innovation and reduce the cost. The future generation will undoubtedly be benefitted by this and it is incumbent upon the current generation to allow the expansion of this technology.

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