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Review Article

An Advanced Robotic System for Robot-Assisted Surgery in Gynaecology

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Abstract

Minimally invasive surgery (MIS) in gynecology aims to achieve the same surgical objectives as traditional open surgery while minimizing trauma, reducing pain, accelerating recovery, and improving patient outcomes. Robotic-assisted surgeries (RAS) have become the standard for many gynecological procedures, with the Dexter Robotic System™ (Distalmotion, Switzerland) being a new surgical system that facilitates the transition from laparoscopy expertise to RAS. The adoption of robotic technology in gynecological surgery has increased globally, particularly in the last five years. Further technical development in RAS and surgical platforms integrating artificial intelligence will flatten the learning curve of robotic surgeons by enhancing intuitive controls, improving real-time feedback and visualization, and providing comprehensive virtual training environments for skill acquisition. This will facilitate an easier and earlier transition to RAS for surgeons of all experience levels. The continued exponential growth in RAS use for gynecological procedures is anticipated in the coming years.

Keywords: *Gynaecology, Surgery, Laparoscopy, Dexter Robotic System.*

Introduction

Laparoscopic surgery (LAP) has evolved over the past century, with its advantages compared to open surgery being well established. LAP minimizes damage to surrounding tissues, resulting in reduced pain, decreased blood loss, fewer postoperative complications, shorter hospital stays, faster recovery, and lower morbidity when compared to traditional open surgery. Robotic-Assisted Surgery (RAS) has provided further advantages to surgeons over laparoscopic techniques, with applications expanding significantly since the first FDA approval in 2000. However, the adoption of RAS still shows discrepancies across various surgical fields, particularly in urology, where the shift from open surgery to minimally invasive surgery (MIS) has faced challenges due to the steep learning curve associated with LAP.

Research has shown that residents rated more nervousness and anxiety for laparoscopy compared to robotic-assisted surgery, but their technical performance was actually superior in robotic drills compared to laparoscopic drills. On the other hand, the adoption of RAS in gynecological surgery is progressing at a slower pace, with RAS performed in numerous benign and malignant conditions such as hysterectomy, oophorectomy, salpingectomy, myomectomy, ovarian cystectomy, lymphadenectomy, endometriosis surgery, sacrocolpopexy, and pelvic exenteration. Hysterectomies, as the most frequently performed major gynecological surgical procedures, have been transitioning to the RAS approach at a relatively rapid pace.

The benefits of MIS have led to a notable trend shift in gynecological surgery, as evidenced by studies reporting significant reductions in open surgery rates. Numerous published reviews on robotics in gynecological surgery highlight a strong interest within the surgical community to develop awareness and accelerate the adoption of more advanced technologies. However, some factors continue to hinder the complete replacement of traditional open surgery with MIS. Gynecologist surgeons can perform almost all surgeries using conventional laparoscopic instruments and don't seem to require further development of advanced technological systems. Convincing them to increase the practice of RAS remains difficult among the community.

The advantages of robotic assistance for surgeons are clearly documented, with robotic instruments offering a greater range of motion compared to traditional laparoscopic instruments, which is particularly advantageous in intricated surgical steps such as suturing, fine dissection, or delicate tissue manipulation. Robotic instruments can also replicate movements of a human wrist, enabling greater flexibility in maneuvering with confined spaces. Additionally, robotic systems filter out hand tremors, providing steady and precise movements, especially useful for tasks requiring high precision.

Surgeons operate robotic systems from a comfortable console, reducing physical strain and fatigue during long procedures, leading to improved surgical precision. A recent systematic review and meta-analysis revealed that 82% of gynecological surgeons performing laparoscopic procedures experience musculoskeletal symptoms, and there is less occurrence of work-related musculoskeletal disorders in robotic surgeons due to the seated, ergonomic position. In some instances, the use of robotics may confer certain advantages, such as autonomy when limited or no assistance is available, with improved or similar perioperative outcomes compared with other surgical approaches.

While the advantages that robotic assistance bring to the surgeon are undisputed, the impact on the surgical performance and benefits for patients remains a topic of debate in the literature. While data to support the feasibility for various gynecological procedures exist, there is a limited number of reliable, high-quality comparative studies demonstrating the superiority of RAS over LAP. Prospective studies are also rare, and larger retrospective meta-analyses can provide insights into the available evidence, but they are also prone to selection bias and information bias.

Fig1: Dexter Surgical robot

The operating time (OT) in robotic surgery (RAS) is often observed to be unchanged between the two approaches, with some studies reporting longer OT for RAS. However, there is evidence to the contrary, as well. To ensure patient safety and the appropriate use of technology, appropriate training on robotic devices is necessary. The learning curve can be steep, and not all surgeons have access to adequate training opportunities. The American College of Obstetricians and Gynecologists (ACOG) and the American Association of Gynecologic Laparoscopists (AAGL) have released statements recommending rigorous training and credentialing standards, minimum case numbers, proctoring, and peer case review.

One important factor in reaching optimal surgical performance is the learning curve. Advanced endoscopic operations are not easy to learn and master, and even with years of experience, LAP introduces inherent drawbacks that can affect the surgeon's performance. These drawbacks lie in the loss of depth perception when using a 2D endoscope, an unstatable video camera when held manually, limited dexterity, counterintuitive and limited movement of LAP surgical instruments (due to the enforced fixation by the trocars and no deflection at the tip), the fulcrum effect, and very poor ergonomics for the surgeon and their assistants over extensive operation time. Innovation in endoscopic systems such as high-resolution 3D cameras has recently further improved surgical performance during LAP.

The linear regression of operation times shows a significant reduction after the first 30 cases of robotically assisted hysterectomies. However, they do not always compensate for the lack of haptic feedback, which some surgeons rely on for precise adjustment and judgement during their laparoscopic procedures. This transition requires specific training and neuro-adaptation skills acquisition. Finally, regular practice and the use of robotic systems are necessary to maintain surgical skills. Surgeons who use the system infrequently might struggle to maintain proficiency. Additionally, nursing staff must also be trained in the use of the robot system. MIS training and the LAP experience of medical personnel already help in smoothing the learning curve for RAS.

The implementation of a robotic surgery program, while offering numerous benefits, can be limited by certain practical factors, such as the large footprint of the robot and the sterilization processes involved. Robotic surgical systems such as the da Vinci Surgical System typically occupy a significant amount of space within the operating room, which can limit the flexibility of arranging surgical equipment and personnel at the bedside during procedures to avoid collisions. Smaller operating rooms may find it challenging to accommodate large robots, potentially leading to logistical issues and reduced maneuverability for the OR team. The robot’s size can obstruct access to the patient or surgical site in some cases. Retrofitting an operating room to accommodate a robotic system may require additional investments in infrastructure, including modifications to the OR layout, electrical system, and space allocation.

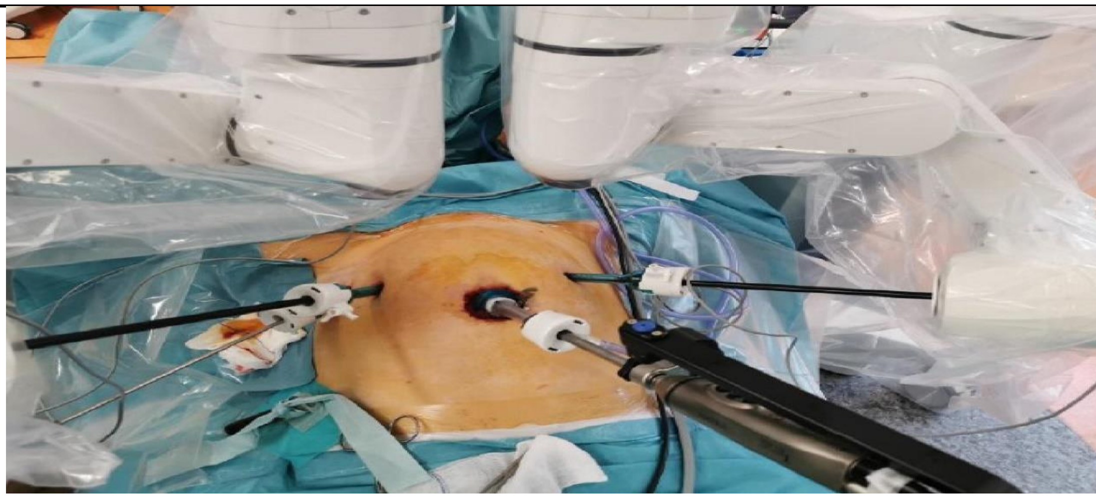

Fig2: Operating room during a Dexter robotic system surgery

While robotic systems offer enhanced dexterity and precision, their complexity can lead to technical challenges during surgery. Malfunctions or technical issues can disrupt procedures. Robotic systems permit the surgeon to perform endoscopic surgery only if the ports are positioned appropriately and no arm collides with other arms. The workspace reached by the robot instrumentation may limit the freedom of port placement and require multiple trocar placements, leading to more incision scars than in LAP. Some patient morphology or anatomy may hinder the possibility of performing RAS due to challenging port placement or robot docking.

Proper cleaning and reprocessing of robotic instruments that are not single-use require dedicated resources and processes to ensure patient safety. Reprocessing robotic instruments is generally more complex and can involve higher consumable costs, specialized training, and maintenance requirements compared to laparoscopic instruments.

Hospitals may establish their own policies and criteria for granting privileges to use robotic systems, considering factors such as surgeon training, experience, case volumes, and patients' outcomes. Robotic platforms are typically shared across multiple disciplines within institutions, with hospital administration and payers assessing procedures costs and associated reimbursements to allocate robotic access among different specialties. Gynecology procedures, especially benign cases, often receive lower reimbursement coverage when compared to urological or complex general surgery interventions, resulting in limited access to the robot. LAP procedures are well established and cost-efficient.

On the public side, a 2016 study showed that patients undergoing surgery in a competitive regional market were more likely to undergo a robotically assisted procedure. Patients often see the adoption of new technology as an indicator of high-quality care, and advanced technology acquisition may help hospitals recruit surgeons interested in using robotic surgical systems. Hospital decisions to purchase robotic machines are mainly driven by this market pressure.

Given the inherent costs of RAS, the majority of robotic cases in gynecology were initially performed for malignant indications. Today, benign conditions are treated robotically as well, so RAS approaches have been described for numerous procedures, including hysterectomy, myomectomy, sacrocolpopexy, endometriosis surgery, and a few others. RAS surgery was found to be associated with increased incremental disposable costs per case and total hospital charges when compared to LAP. Costs are indirectly influenced by the OR team workflow, postoperative processes to expedite discharge, and converting surgery to the ambulatory setting.

The expansion of the competition landscape in RAS is driving the technological evolution of robots, which hold the promise of delivering innovative solutions for indications that were previously unaccounted for, reducing costs, and expanding the range of gynecological procedures suitable for RAS. The Dexter Robotic System™ (Distalmotion SA, Epalinges, Switzerland) represents an alternative to traditional robotic systems, offering a mobile design, minimal weight, and compact form factor that allows for easy storage and freeing up space.

One of Dexter's innovative features is its ability to facilitate a smooth transition from LAP surgery to RAS. The system is designed for swift modality changes between RAS and LAP, with its unique feature, the LAP mode, enabling each robot arm to be folded away from the surgical field within less than 30 seconds with a simple button push, all without the need to undock them. This flexibility should facilitate speed, ease of maneuvering, confidence in the approach, and the use of well-established surgical instruments that the surgeon has mastered and that are readily available in the hospital's inventory.

The Dexter open console in the operating room allows for immediate communication and interaction between the surgeon and his team. The compact setup of the robotic arms allows for a wide operating space at the patient's bedside for the assisting surgical team. This sterile environment allows for easy observation, training, and support between the surgeon and trainees, both at the patient's bedside and at the surgeon console.

In emergency situations, the surgeon's sterility remains uncompromised throughout the operation, enabling swift response at the patient's bedside. This not only ensures a safer procedure but also reduces the mental workload on the surgical assistant. However, certain procedural steps in gynecological surgeries require a well-trained surgical assistant or active participation of the surgeon, which can lead to delays and require the surgical team to adapt.

The LAP mode feature of the Dexter System grants the main operating surgeon complete open access to swiftly perform critical steps, enabling the surgeon to seamlessly transition to laparoscopic mode. This facilitates on-demand robotically assisted surgery for the efficient and precise execution of crucial surgical maneuvers such as uterus manipulation and morcellation in the bag with the power morcellator.

The Dexter system has gained practical experience through an ongoing post-market trial sponsored by the manufacturer, with ethical approval obtained and patients participating in ongoing hysterectomies.

Conclusion

Robotic surgery (RAS) is increasingly being used in gynecological surgery, particularly in malignant and benign scenarios. This trend has been increasing in the last five years. Technological advancements like artificial intelligence are expected to flatten the learning curve for robotic surgeons by improving intuitive controls, real-time feedback, and virtual training environments. This will facilitate an easier transition for surgeons of all experience levels. The use of RAS in compx gynecological surgeries will continue to grow, with accelerated research in AI driving the implementation of cutting-edge technological advances.

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