Robotic Pediatric Surgery

68

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The first reported pediatric case of robotic minimally invasive surgery was a Nissen fundoplication in 2000, performed on a 10-year-old girl in Germany.

68.1 Introduction

Minimally invasive surgery (MIS), such as laparoscopic and endoscopic surgery, revolutionized practice in the 1980s by making it possible to operate through small incisions, which reduced patient recovery times and associated morbidity. In the last two decades, another field of MIS has flourished: robotic-assisted surgery.

Endoscopic and laparoscopic surgery can limit the surgeon's dexterity, degree of freedom of movement, and quality of visualization compared with the traditional "open" approach. Consequently, robotic platforms have been developed to overcome these limitations.

Following the approval of the first robotic surgical system, *the da Vinci™ system* (Intuitive Surgical Inc., Sunnyvale, CA) in 2000, robotic surgery has been used in a wide variety of surgical specialties for adults, for example in cardiac, thoracic, colorectal, head and neck, gynecology and urology surgery.

Robotic surgery within pediatrics presents some unique challenges, such as working within a small operative field with tools built for adults and costliness for hospitals, hence initial adoption of the technology has been slow.

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The best example of success with robotic-assisted surgery within pediatrics has been in robotic-assisted *laparoscopic pyeloplasty (RALP).* Some studies have shown reduced operating times and length of postoperative stay compared to other approaches.

68.2 The Da Vinci™ System and Other Robots

- The da Vinci system is now in its 4th generation
- "Master–slave" system:
  - Lacks any autonomy
  - Function is dependent entirely on the operating surgeon.
- The system comprises three main components:
  - "Patient cart"—houses the instruments above the patient
  - "Vision cart"—processing and energy hub of the system
  - "Surgeon console"—surgeon control of the camera and instruments
- Camera
  - (Currently) 12 mm and 8 mm sizes
  - Articulated (termed EndoWrist) instruments

    Available in 8 mm and 5 mm sizes. However, the articulation system of the 5 mm instruments requires a greater intra-corporeal working space than that of the 8 mm and so counter-intuitively the larger instruments are more appropriate for most pediatric procedures.
  - Conventional or smaller minimally invasive surgery in young children (Fig. 68.1)

    3 mm size conventional instruments are commonly used in the da Vinci Surgical System for children, but more precise smaller instruments with endoWrist (e.g., KidsArm) would be a vital addition in this field.
- Other Platforms
  - Following the 2003 merger with Computer Motion, Intuitive Surgical Inc. holds a monopoly in the market.
  - Alternative platforms are now at various stages of development and regulatory approval. There are competitors such as *Senhance™ Surgical Robotic System* by TransEnterix and *KidsArm™* (being developed by the Hospital for Sick Children in Southern Ontario), that are developing robotic technology designed specifically for minimally invasive pediatric surgery.

68.3 Advantages

- Similar to endoscopic/laparoscopic surgery
  - Faster recovery time, reduced levels of pain and blood loss, and improved cosmetic results
- The da Vinci system
  - High definition and high optical (10×) magnification stereoscopic ('3D') field of view.

Fig. 68.1 Non-robotic 3 mm instrument and robotic 8 mm instrument and infant. Reprinted with permission from Cundy, T.P., Marcus, H.J., Hughes-Hallett, A. et al. Robotic surgery in children: adopt now, await, or dismiss? Pediatr Surg Int 31, 1119–1125 (2015). https://doi.org/10.1007/s00383-015-3800-2

  – Remotely operated instruments that produce precise wrist-like articulation with 7 degrees of freedom of movement, which resembles the motions of performing open surgery much more closely than conventional endoscopic surgery does.
  – Possible performance of more complex surgical cases
    For example, Delicate reconstructive surgery and anastomoses, via a minimally invasive approach that traditionally was not achievable by conventional endoscopic techniques.
    Depth perception allows a shorter learning curve for challenging intracorporeal work is reduced compared with that of conventional MIS.
    Overall reported conversion-to-open-procedure rate is low, around 2.5%, which is comparable to conventional laparoscopic surgery.

68.4 Disadvantages

- Large financial burden of a robotic program in most healthcare economies given the initial cost of the robot in addition to ongoing costs of maintenance and supplies.
  – This cost is difficult to offset because of the invariably low volume of pediatric cases.

Table 68.1 Advantages and disadvantages of robotic-assisted surgery

Advantages	Disadvantages
Enhanced dexterity and mobility	Platform designed for adult use
Similar to the motions of performing "open" surgery, ↓learning curve for transitioning to robotic operating	Too expensive High initial cost in addition to ongoing costs of maintenance and supplies
HD optics and high magnification (10×)	Low-volume caseload
Stereoscopic ("3D") field of view allows for better depth perception	Lack of strong empirical evidence for improved outcomes for the patient
Micromovements and precise wrist-like articulation allows for reconstructive procedures (advanced suturing skills)	Not cost-effective for a restricted healthcare budget
Tremor elimination	Technology only accessible to a small number of tertiary institutions in the developed world
Better ergonomics and comfort for the surgeon	Unsustainable—models become outdated every 5–10 years and manufacturers threaten to stop maintenance support for older models
Reduced complication rates (in certain operations)	Lacks the haptics (perception of touch) of open surgery

- Current systems are designed primarily for adult-sized abdomens.
  - Ports are required to be at least 6 cm apart (8–10 cm in older generations), which is not realistic in practice when operating in a space smaller than 40 mm^3.
  - Physical constraints limit the use of the robot to mostly older or larger children with suitable abdominal or thoracic domains.
  - Because of the lack of comparative research in this field, there is little evidence to show that overall robotic-assisted surgery offers any additional benefits over the laparoscopic approach (Ref. Table 68.1).

68.5 Indications

68.5.1 Urological Surgery

- *Robotic-assisted laparoscopic pyeloplasty (RALP)*
- Best example of the technology's capabilities in pediatric practice.
  - Using the conventional laparoscopic technique, the anastomosis during a pyeloplasty demands considerable technical skill and is associated with a significant learning curve.
  - Evidence suggests that because of the robotic assistance, RALP has significantly reduced operating time, length of postoperative stay and medication use, and improved scar cosmesis compared with the conventional approach.
- Urological surgery must often access deep structures of the pelvis in a narrow surgical field, which may be better suited to a robotic approach. Other urological procedures that have been successfully undertaken robotically include:
  - Robotic-assisted laparoscopic ureteric reimplantation (RALUR)

- Robotic-assisted Nephrectomy (RAN)/hemi-nephrectomy (RAHN)/laparoscopic nephroureterectomy (RALNU)
- Robotic-assisted pyelolithotomy
- Robotic-assisted uterocalicostomy and ureteroureterostomy
- Robotic-assisted augmentation cystoplasty
- Robotic-assisted creation of catheterizable conduits (appendicovesicostomy and antegrade continence enema)
- Robotic-assisted bladder neck reconstruction
- Robotic-assisted excision of bladder diverticulum, urachal cyst excision, excision of posterior urethral diverticulae, prostatic utricles, seminal vesicle cyst, and varicocele

68.5.2 General Surgery

- Fundoplication.
  - Little evidence for significant benefit over conventional laparoscopy
- Others include:
  - Robotic-assisted cholecystectomy and splenectomies
  - Robotic-assisted Heller's myotomy
  - Robotic-assisted diaphragmatic hernia repair
  - Robotic-assisted duodeno-duodenostomy/duodenojejunostomy
  - Robotic-assisted pull-through
  - Robotic-assisted excision of choledochal malformation/cysts
  - Robotic-assisted ovarian cystectomy
  - Robotic-assisted salpingo-oophorectomy

68.5.3 Cardiothoracic Surgery

- Robotic-assisted thoracoscopic surgery (RATS) for a patent ductus arteriosus (PDA)
  - However, when compared with the conventional approach, video-assisted thoracoscopic surgery (VATS), the evidence shows no advantage of RATS over VATS.

68.5.4 Oncological Surgery

In adults, minimally invasive surgery is commonly used for oncological surgery, but with pediatric solid tumors, "open" surgery is the typical approach. There is a lack of comparative trials within oncology between MIS and robotic-assisted surgery in children. Nevertheless, the robotic platform has the potential to be useful for lymph node dissection because of enhanced optics and precision of movement.

- Most of the published studies are individual case reports, including:
  - Robotic-assisted excision of juvenile cystic adenomyoma
  - Robotic-assisted radical cystoprostatectomy
  - Robotic-assisted retroperitoneal lymph node dissection
  - Robotic-assisted partial adrenalectomy for pheochromocytoma

68.6 The Future

As the market grows, the emergence of strong competitors will likely drive down costs and spur further innovation. The current technology will likely be further developed to become more compatible with the constrained working space of neonatal abdomens and thoraxes. This would make a robotic approach possible for a wide variety of new procedures.

- Artificial intelligence and machine learning may make partially autonomous surgical robots a reality in the future, for example as previously mentioned KidsArm, being developed by the Hospital for Sick Children in Southern Ontario.
- Application of haptics to the robot console, which would provide the operator with proprioceptive feedback comparable to conventional open surgery, therefore reducing the learning curve associated with the transition to robotic operating.
- *Some of the newer devices are*:
  - *da Vinci SP* (single port) system.

    This system enables control for three fully-wristed, elbowed instruments, and the first fully-wristed da Vinci endoscope through a single 2.5 cm cannula.
  - *Autonomous Mini Robot (AMiRo)*

    This system is a modular and extensible mini robot platform. Currently, it is designed for scientific research and education. It offers remote controlling as well as an implementation of an artificial neural network running on the platform. Being the size of a tennis ball, this robot can be of great help for children in future.
  - *Microrobots*

    These robots exhibit special characteristics of size, function, and material choice. Recent evidence have encouraged fabrication techniques, locomotion at microscale environment, and targeted drug delivery. Due to their tiny size, they can travel through the body to perform tasks that no conventional robot could do. Microrobots can be made as small as bacteria. It can be injected via a small needle into the viterous performing eye surgery using nanotechnology or can swim in small arteries, and detect diseases in humans.

– *Humanoid robot*

Designed to evolve among humans. These robots are safe and pleasant to interact. These robots are a promising platform to explore robotics surgeries, especially in children as they interact very well with children too.

Further Reading

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