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Chapter 3

The Surgical Robot: Applications and Advantages in General Surgery

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Additional information is available at the end of the chapter

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Abstract

The field of General Surgery with its multiple sub-specialties has experienced the progression of minimally invasive procedures performed with the robotic technology since the last decade. The robotic applications are extensive and have contributed to the enrichment of the surgical sub-specialties based on advantages such as increased surgeon control and autonomy, superior instrument dexterity and tissue handling, improved three-dimensional visualization, wristed articulation, all of this despite the lack of haptic feedback. The sub-specialties of Colorectal, Hepatobiliary and Pancreatic, Gastric Oncologic, Bariatric, Foregut, Pediatric, Endocrine, and Hernia Surgery, in addition to General Surgery as the principal specialty, have produced several high-quality randomized controlled trials, meta-analyses, prospective and retrospective series which have established, in many instances, superior results to those of laparoscopy, and at least non-inferior outcomes over the years. From the first pioneer single-surgeon experiences around the world to the most recent large trials, including the first Robotic General Surgery case series in an American community hospital not classified as a tertiary referral center, patients continue to benefit from this technology as surgeons engage in overcoming their learning curve and training their teams, involving their hospital administrators and working with the industry to perfect their techniques for the sake of their patients.

Keywords: surgery, general, robotic, colorectal, hepatobiliary, pancreatic, gastric, oncology, bariatric, foregut, hernia, pediatric, endocrine, learning, curve, technology

1. Origins of a revolution

For general surgeons, it should be easy to define their specialty. For the public, however, the term "General Surgery" may carry the erroneous implication of a lack of specialization, a deficiency in expertise, or even a certain weakness of purpose. To define what General Surgery

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is and stands for, it should be established that it is the mother of all surgical subspecialties, a means to save lives from traumatic experiences, to cure cancer, to offer palliation and improve quality of life, to remove organs that suffer from overwhelming infections, and to reconstruct the body's tissues and organ systems. To restore anatomy and physiology, while life acquires a higher quality, that is the ultimate purpose of General Surgery.

In order to discuss the robotic revolution in General Surgery, it is necessary to establish that this was the last surgical specialty that adopted the robotic technology, first with hesitation. However, to this day, the progress of the robotic technology applications in this field is palpable and replicated by numerous surgeons in the academic and the private practice environment around the world.

The concept of robotics applied to perform an operation has been explored extensively since the end of the twentieth century and the beginning of the twenty-first century, including the development of robotic platforms such as the AESOP/Hermes, the Zeus, and the da Vinci systems [1, 2]. This effort on behalf of multiple companies and research centers, including NASA, led to the development of the telerobotic technology necessary for different specialties to adopt it in order to carry out surgery in a minimally invasive fashion while overcoming some of the obstacles that laparoscopic surgery introduced at the end of the 1980s [3].

However, in spite of the major achievements that robotics in General Surgery has witnessed thanks to its ability to enable minimally invasive surgeons to overcome some of their limitations, even up to a few years ago and to this date there is opposition to the use of robotic surgery. A typical reason that is often quoted is the apparent usefulness of the robot only for certain subspecialties such as colorectal surgery given the limited working space in the pelvis and the challenge posed by traditional laparoscopic instrumentation. This is in addition to the financial burden that the application of robotic surgery carries with it when the conscientious use of only the necessary instruments is not a priority [4].

Despite the reluctance to the widespread adoption of robotics in General Surgery, many surgeons around the world have already been responsible for the advancement of surgery in their fields in all of the disciplines or subspecialties that will be presented in this chapter, such as colorectal, hepatobiliary and pancreatic, gastric oncology, bariatric and antireflux, pediatric, endocrine, and hernia/abdominal wall reconstruction surgery. The purpose of this chapter is to describe these achievements in an objective way, so that the idea that the surgical robot should only be used for colorectal surgery or complex foregut surgery may be challenged and, furthermore, so that this author's passion for robotic surgery may be shared with the international surgical and scientific community for the sake of the patients' well-being.

2. Where engineering meets medicine

Robotic General Surgery has advanced at an accelerated pace since the late 2000s, although early studies as far back as 2004 expressed concerns that the field was in its infancy an lacked the necessary data to substantiate its widespread use and its safe application. Nevertheless,

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even at that early point in the history of robotics in the largest surgical specialty, the multiple advantages of robotic surgery were recognized and described as the ability to have wristed instrumentation with more degrees of motion than the human hand is capable of acquiring, superior visualization with three-dimensional capability and with surgeon control of the camera, the presence of more than two arms to execute tasks, which facilitate the creation of anastomoses with superior dexterity, along with more advanced ergonomics than what can be provided with conventional laparoscopic instruments. On the other hand, the disadvantages were not technical except for the lack of haptic (tactile) feedback for the surgeon. The other disadvantages had to do with systems and processes not related to the technical aspects of an operation, such as the cost of instrumentation, the cost associated with purchasing the technology, the intensive nature of training for the surgeon and the team, and the apparent unproven benefit in all branches of General Surgery, at least as it was seen at that time [5].

Based on expert surgeons' personal experience, however, the most important advantage offered by the surgical platform is the ability to offer them total control of the procedure without the need to depend on someone else to operate the endoscope, or retract, or assist in a manner that would be crucial with conventional laparoscopy. While complex robotic surgery still requires a first assistant, the assistant's role has evolved because the surgeon has total control of three arms at the same time along with the camera, all of which enables the operator to achieve the goals in a manner that is closer to open surgery, at least closer than ever before.

From an engineering perspective, it is essential for surgeons to understand the concept of telerobotics and the categorization of robotics in General Surgery as a short-distance system consisting of a "master" component operated by the surgeon, and a "slave" executor which carries out the tasks performed by the "master" platform in real time. By definition, this is not an autonomous or semiautonomous technology, which is an important point to clarify, since it means that the surgical robot does not have the capacity to operate itself for a reason: it maintains the surgeon's total control of the procedure enabled by a computer interface that facilitates the execution of the operation. This is the definition of a "tele-operator" system (see **Figures 1** and **2**).

As mentioned earlier, the da Vinci system (by Intuitive Surgical, Inc., Sunnyvale, CA, USA) was developed while building upon the lessons learned from its predecessors such as the AESOP and the Zeus platforms. It consists of an ergonomic console unit ("master interface") that includes a display system, the surgeon's user interface and the controller, and a second unit that includes the endo-wristed instruments and the endoscopic camera that execute the tasks as the "slave manipulator." Its application in all fields of General Surgery has been documented extensively, although, initially, it was created to satisfy the minimally invasive needs of cardiothoracic surgeons and urologists, and later on, gynecologists [6].

Even in 2008, at the time when widespread adoption of the robotic interface was beginning to take place among general surgeons, the disadvantage of lack of haptic feedback was studied, with results being consistent with the absence of consensus among the surgical community regarding its essential value to perform an operation. In fact, although the ability to have haptic feedback has been generally considered a useful feature of laparoscopic surgery, its



Figure 1. Surgeon operating at the ergonomic console unit ("master interface"). The user interface allows for "endowrist" articulation of instruments, with seven degrees of freedom for motion.

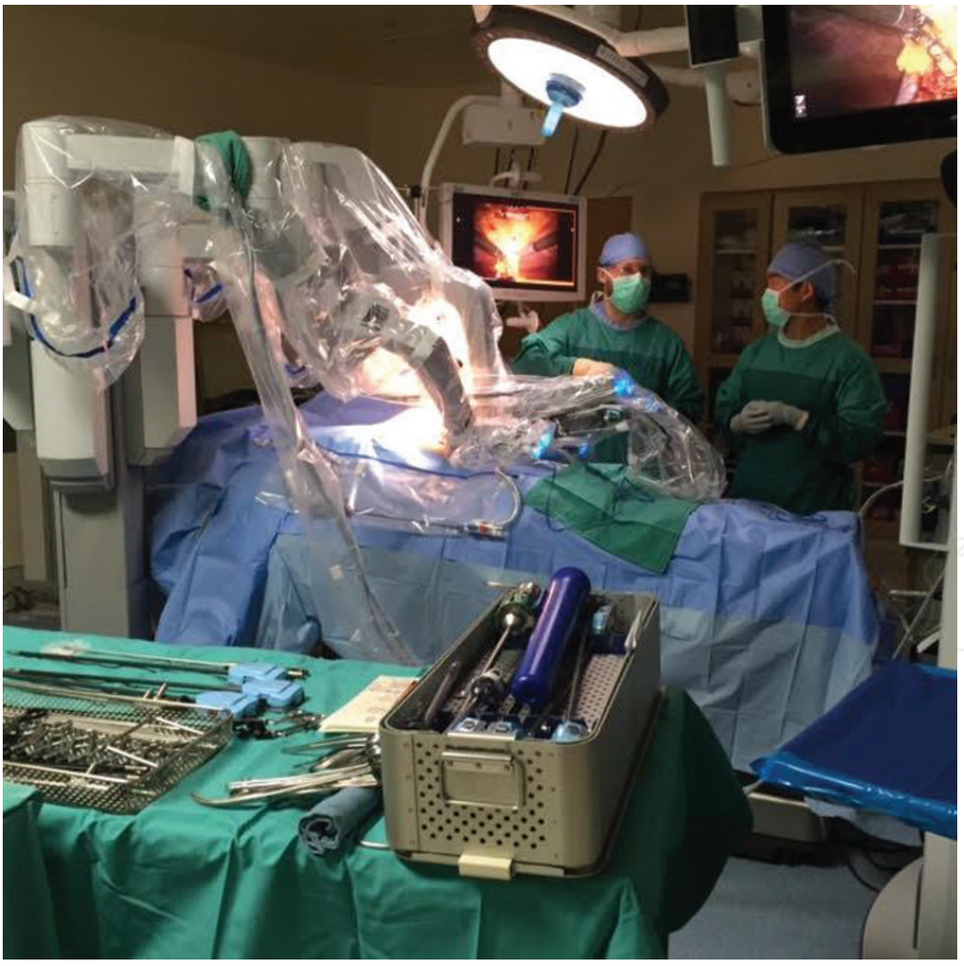


Figure 2. da Vinci system ("slave manipulator") with robotic arms already docked and executing the tasks with the surgeon in control, with the surgical team at the bedside.

absence in robotic surgery can be overcome by the superior visibility offered by the surgeon-controlled three-dimensional endoscope and visual cues when tissue tension is carefully observed [7].

From a technical perspective, the robotic technology enables the surgeon to overcome the challenges that traditional laparoscopic surgery offers, as it has been described. However, an important aspect of this ability to improve the surgeon's skill level can be seen when it is used for practice purposes, both by expert surgeons and by inexperienced surgeons who are trying to develop their skill set to offer the multiple benefits of minimally invasive surgery to their patients. Reductions in errors have been noticed when such practice tasks are undertaken for the purpose of quality and self-improvement [8].

What is impressive, considering the early period when another study was presented at an important surgical society meeting, a successful robotic surgery training program can be implemented, with reproducible and reliable results, as long as the will and determination exist to apply the benefits of robotic surgery and transform them into palpable outcomes with the highest ethical and quality standards in an academic institution [9].

3. Colorectal surgery: the subspecialty that paved the way

The cost of robotic surgery has always been an element of strong criticism used against its adoption in multiple surgical subspecialties, including the pioneer, colorectal surgery. However, even in those well-conducted studies, the benefits of robotic surgery have been noted without a doubt, such as better outcomes in left colectomies, particularly when approaching the rectum when compared to even the most sophisticated 3-D laparoscopic systems [10]. As early as 2013, several manuscripts in the field of robotic colorectal resections were analyzed and the conclusions suggested that robotic surgery would continue to advance and overcome its own weaknesses, with improved outcomes comparable to those of conventional laparoscopy [11].

A more recent review of the colorectal literature, although not in favor of robotic surgery, acknowledges the established advantages over laparoscopic colorectal resections that have been reported by multiple series including decreased blood loss, decreased length of hospitalization, faster return of bowel function and, what is more interesting, a lower rate of conversion to open surgery [12]. Similar conclusions have been drawn from an extensive meta-analysis in 2015 comparing robotic versus laparoscopic colorectal resections, which also pointed out a lower incidence of peri-operative complications and surgical site infections [13].

However, perhaps more significant progress could be achieved once the robotic surgery is not compared to laparoscopic surgery. Conclusions from another manuscript in a prestigious journal have suggested that although it is feasible and safe to perform robotic surgery for sigmoid colon resections for cancer, it offers no real advantage over laparoscopic surgery in terms of oncologic outcomes [14]. Even another publication reported on the feasibility and safety of robotic transverse colon resection for cancer, too [15]. This is an important shifting paradigm from the tradition of comparing once technology against the other, which is sometimes a

reason for many surgeons to hesitate when it comes to deciding to adopt robotics as part of their practice.

More published results from well-done meta-analyses support the superiority of robotic surgery in colorectal resections for oncologic purposes, with the same conclusions already mentioned in terms of blood loss, safety, the length of stay, the return of bowel function, lower estimated blood loss, and conversion rates [16, 17]. On the other hand, the efficiency of the robotic platform can be seen when an oncologic resection is performed, as the number of lymph nodes is comparable to that obtained with laparoscopy by the most experienced surgeons [18] Returning to the issue of cost, robotic segmental colon resections have been associated with increased operative time, perhaps due to the surgeons' learning curve, in addition to overuse of non-essential instrumentation [19].

More specifically on the subject of rectal cancer, robotic surgery has been found highly efficacious and comparable to open surgery, with similar oncologic outcomes, lymph node yields, free margins, disease-free survival, and rate of complications. The length of the operation is greater, but this is something where improvement can be seen with increased volumes [20].

Regarding rectal cancer and the need for total mesorectal excision, which has been a topic of continuous discussion in the literature over the years, the robotic platform has been found to offer superior results for mid and low rectal cancer resections, where the quality of the TME specimen has been documented to be more advanced than its laparoscopic counterpart (see **Figure 3**). Moreover, conversion rates to the open approach have been determined to be lower thanks to the robotic platform advantages explained in detail before [21, 22].

Another aspect of robotic rectal resections for cancer is the facilitation of an oncologic resection with the Firefly™ technology, which has proven very helpful during low ligation of the inferior mesenteric artery pedicle. The ability to perform a precise lymphadenectomy around the IMA is invaluable, all of which is made possible with the robot's multiple benefits when it comes to retroperitoneal and pelvic dissection [23]. The most challenging lymphadenectomy, however, at least in the colorectal surgery arena, corresponds to the total mesorectal excision technique. It is under difficult circumstances of a narrow male pelvis, or a female pelvis that has been previously subjected to radiation therapy, where the fibrosis and desmoplastic reaction from a neoplastic process require the surgeon's maximum level of proficiency for the sake of a safe, efficient oncologic resection. The robotic technology enables the surgeon to achieve excellent results where laparoscopic surgery has failed to deliver in the past [24, 25]. Interestingly, it has been determined that the learning curve for robotic low anterior resection (including total mesorectal excision) is similar and not longer than the learning curve for the laparoscopic technique, which argues against the idea that it would be more difficult to learn to perform such a demanding and challenging procedure with the robot as opposed to doing it laparoscopically. This is not to say that robotic LAR and TME are not highly technical procedures that require a remarkable level of skill to be carried out well, but they can be learned [26–28].

On a separate subject, robotic surgery in the colorectal field has also been extremely useful when it comes to benign disease, which is sometimes more complex than procedures done for neoplastic processes. The perfect example is diverticular pathology with colovesical fistula resection and repair. A study has compared the laparoscopic to the robotic technique. The

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Figure 3. Robotic ultra low anterior resection and total mesorectal excision specimen for rectal adenocarcinoma.

remarkable observation of this series was the fact that the robotic group did not experience any conversions to open surgeries, or any ureteral injuries. The same was not true of the laparoscopic arm [29]. Along the lines of benign disease, rectal prolapse, and robotic rectopexy have been studied and compared to the laparoscopic approach, with the conclusion that both methods to deal with it are effective, although more data are needed to establish any superiority of the robotic technique, such as a randomized controlled trial. Be that as it may, the important aspect of this study is the fact that the surgical robot can be very effective when it comes to benign colorectal disease and its use can be safely expanded to treat conditions that would normally be dealt with open surgery [30, 31].

4. Hepatobiliary and pancreatic surgery: nothing is impossible

Without a doubt, the field of hepatobiliary and pancreatic surgery is highly regarded as one of the most complex and technically demanding subspecialties within General Surgery. In fact, a pancreaticoduodenectomy is considered by most surgeons as the most difficult operation in the world, second perhaps to a liver transplant. What seemed impossible years ago has become a reality with arduous determination and the process of trial and error, where numerous experts have advanced this field to the realm of the minimally invasive and have

turned operations that would typically be unthinkable or impractical with laparoscopy into reproducible robotic procedures whose results will be analyzed here.

In 2013, the largest retrospective series of robotic pancreatic resections was published, which comprised 250 operations ranging from pancreaticoduodenectomies, to central, distal, and total pancreatectomies. This impressive series demonstrated the feasibility of oncologic and benign disease resections with a low conversion rate [32]. A more modest series of 12 patients reported the same year drew similar conclusions while emphasizing the importance of clinical judgment at all times, which serves as a reminder that the robotic technology is just a tool at the service of the surgeon, who is ultimately responsible for the outcome of any operation [33].

A comprehensive literature review the next year also reached these conclusions and warned the surgical community that the series that were examined had their origin in academic centers where the experts in their field performed these procedures, all within hospital systems that had the human and technical capability to deal with the complications that are known to be inherent to pancreatic surgery [34]. When different series are reviewed, the most important advantage from the robotic technology that is strongly applied to pancreatic resections is the resemblance of open surgery that it offers to the surgeon [35]. When discussing its benefits during the performance of a Whipple procedure, on the other hand, the additional advantage of surgeon comfort provided by sitting at the console to control the master interface takes precedence. Just as it has been proven in the colorectal literature, the robotic pancreaticoduodenectomy offers the advantages of a decreased length of stay and fewer wound infections or surgical site occurrences, while the oncologic outcomes are comparable to open surgery [36, 37].

Robotic distal pancreatectomy has been studied, too, with excellent results particularly when it comes to splenic preservation due to the dexterity offered by wristed instrumentation and multi-arm control [38]. On the other hand, robotic distal pancreatectomy is equally effective when a splenectomy is performed at the same time [39]. When a comparison is made between the robotic and the laparoscopic approaches, robotic distal pancreatectomy has been shown to have a lower estimated blood loss, a higher spleen preservation rate, and a shorter hospital stay in spite of a longer operative time [40].

Equally demanding and intensive is minimally invasive hepatic surgery. In fact, although experts have shown that the laparoscopic technique is feasible and reproducible in their hands, the robotic platform has allowed them to have greater control of vascular and biliary structures due to its multiple advantages over laparoscopy which have been extensively reviewed. Comparisons between the two methods have been made in the early 2000s with the same conclusions drawn years later [41]. Although wedge resections and segmentectomies have been reported, the most impressive results have been seen with major hepatectomies when their outcomes and metrics have been analyzed in the literature [42, 43]. A subsequent meta-analysis in 2015 comparing robotic and laparoscopic liver resections reported greater blood loss and longer operative time for the robotic approach. However, most likely the blood loss observation had to do with the technique being used at that time. Nevertheless, both techniques were found to be equally efficient in terms of oncologic outcomes, the length of stay,

and complication rates [44]. In the same fashion, another review of the literature the same year concluded that robotic hepatic surgery is as effective as laparoscopic and open surgery [45]. A review of the literature specifically dealing with the topic of hepatocellular carcinoma reported a similar statement [46].

No matter how many liver resection series were examined, however, although it may seem disappointing to note that robotic hepatic surgery was not found to be superior to its laparoscopic counterpart, what is essential to realize is that the field is evolving and all of the data support the fact that it is safe, comparable to laparoscopy, and with the same oncologic outcomes in spite of the difficulty level associated with this type of operation.

5. Gastric surgical oncology: refinement takes shape

Another complex type of operation requiring a high skill level is gastric surgery, especially when a neoplastic process is at the core of the situation and the requirement for an extensive lymphadenectomy is essential. Where robotic liver surgery has failed to show superiority on multiple fronts when compared to laparoscopy, gastric surgery has compensated and exceeded the expectations, as seen on an impressive series of 200 consecutive gastric resections published in 2013, including decreased operative time, superior lymph node yield, and decreased length of stay [47]. The Asian literature has extensively published case series such as this with impressive results.

The robotic platform allows the surgeon to overcome some of the limitations presented by laparoscopy, above all when performing a D2 lymphadenectomy, where its multiple advantages become more obvious [48]. The usefulness of the surgical robot has been noticed regarding the performance of robotic-sewn anastomoses and challenging dissections near the gastroesophageal junction and the pyloric region, proving helpful during total gastrectomies, for instance [49]. Overall, the robotic technology has established its relevance in the field of gastric surgical oncology for many reasons and will continue to do so in the near future [50, 51].

A meta-analysis from 2013 has actually established that robotic gastric surgery is superior to its laparoscopic counterpart in terms of estimated blood loss and hospital stay, with the only difference being a longer operative time. However, the benefits have been shown and are more definitive than those seen on liver resection [52]. Another meta-analysis has also supported the validity and superiority of robotic gastrectomy for cancer when compared to open surgery [53]. This subject is so important in the surgical oncology community that a worldwide database was created to track the results from gastric resections corresponding to the robotic, laparoscopic, and open modalities [54].

Another aspect that is interesting to note is the fact that robotic gastric resections may facilitate future laparoscopic resections and decrease the operative time for both approaches once the surgeon's learning curve is mastered. This is in addition to the finding of lower estimated blood loss on the robotic group [55]. In fact, as the learning curve for robotic gastric resections is surpassed, the D2 lymphadenectomy yield improves and is superior

to the laparoscopic outcome [56]. These observations made by the experts in this field are a testament to the fact that the robotic technology enables the surgeon to refine the technique to the point that, regardless of the level of difficulty required for this type of procedure, it is possible to continue to improve as the case volume increases. The same conclusion has been drawn from series that include both subtotal and total gastrectomies performed robotically [57].

This refinement of surgical technique is evident when a robotic-sewn anastomosis is created, as mentioned before, which has been found to be reproducible and very convenient in total and subtotal gastrectomies with a Roux en Y, Billroth I, or Billroth II reconstruction, depending on the case [58, 59].

6. Bariatric and antireflux surgery: the youngest field is evolving

In order to discuss the remarkable progress that has been made in the subspecialty of metabolic and bariatric surgery thanks to the robotic technology, it is important to first recognize the surgical robot's applications in antireflux procedures, especially those in which paraesophageal hernia repair is necessary. Such a case is seen with giant paraesophageal hernias, where the complexity of the repair requires a high level of dexterity due to the size of the diaphragmatic defect and the limited space available at the gastroesophageal junction, with vital structures such as the aorta, the inferior vena cava, and the esophagus can be injured, in addition to the spleen and the liver, due to the requirements posed by the tension on the hernia edges. The robotic platform shines in instances such as this, with results that are similar to the laparoscopic rate of complications in expert hands, but with lower hernia recurrence rates [60].

The same observation is true when a redo antireflux operation and hiatal hernia repair are performed robotically. The results are excellent and consistent with the superiority granted by improved dexterity in a field where the normal anatomy has been violated, and where the dissection must resemble what once was expected, structurally speaking [61].

With respect to metabolic and bariatric surgery, robotic surgeons have advanced this continuously evolving field at high speed due to their spirit of innovation and the high level of difficulty caused by their patients' body habitus, which requires them to develop techniques for dissection, exposure, and port placement that would normally not be necessary on patients with a lower body mass index.

A very helpful systematic review has already demonstrated that robotic bariatric surgery is not exclusively favored in redo cases, but is actually being utilized in non-revision operations where a robotic-sewn intracorporeal gastrojejunostomy or jejunojejunostomy anastomosis is constructed during a Roux en Y gastric bypass, or where a challenging gastric resection is necessary during a sleeve gastrectomy. In fact, even if the surgeons choose to staple the anastomoses during Roux en Y gastric bypass, the robotic technology enables them to perform the enterotomy or gastrotomy closure more efficiently [62].

Of course, the relevance of the robotic approach has been exposed in the unusually complex arena of bariatric surgery revisions, where the experts have been able to achieve results with more advanced dexterity and with a more ergonomically feasible method, with excellent visibility and with the advantage offered by the ability to control three arms and the endoscope simultaneously [63, 64].

It is important to note that robotic bariatric surgery has also been found to be relevant in the super obese patients who undergo a sleeve gastrectomy. In these complex cases, with BMI > 50, the robotic technology has proven very useful for the multiple reasons that have been exposed above for bariatric revision operations. This is interesting to realize, since typically most non-bariatric surgeons associate the surgical robot with the Roux en Y gastric bypass and revision surgery. In fact, the robotic approach may increase the surgeon's skill level to then undertake a difficult gastric bypass or a revision procedure while building on the experience offered by robotic sleeve gastrectomy [65].

As expected, when the most technically demanding bariatric operations are performed, the robotic approach takes precedence, as demonstrated by the creation of intracorporeal anastomoses during revision cases where a conversion from a failed sleeve gastrectomy to a duodenoileal bypass is carried out, both in a classic duodenal switch, as well as in a single-anastomosis duodenal switch (SADI), to give an example [66].

7. Pediatric surgery: applications in spite of size

It is remarkable to realize that the robotic platform has been successfully applied to the pediatric population, where the limitations imposed by size have been partially overcome by the robotic system's well-established advantages over conventional laparoscopy.

While the purpose of this chapter is not to discuss robotic surgery applications in the pediatric population in depth, the goal of this section is to document some of the work that has been done in the subspecialty of Pediatric Surgery with the robotic technology, especially with the da Vinci system.

An important pediatric surgery review that was presented at an international conference in 2007, and published in 2008, showed how the most common robotic surgery applications include but are not limited to pyeloplasty, fundoplication, and patent ductus arteriosus ligation. The authors concluded that although the operative time was longer when compared to laparoscopy, they preferred the robotic platform for the same reasons that their non-pediatric surgeon colleagues have described over years. On the other hand, they expressed their concern regarding the need to make this equipment suitable for neonates and to decrease the cost associated with these operations when the technology is used [67].

A more specialized use of the robotic system in pediatric surgery has been described with excellent results comparable to the open approach for choledochal cyst excision and biliary reconstruction [68]. This is just an example of what can be achieved by members of the surgical community who continue to innovate in their fields when they remain open to progress in a responsible manner.

8. Endocrine surgery: robotics in unusual places

Even the subspecialty of Endocrine Surgery has witnessed the advancement of robotics, both in the retroperitoneum with adrenalectomy and in the neck with thyroidectomy. This is a controversial area, especially regarding endocrine surgery of the neck with the surgical robot, yet some experts continue to perform their operations safely. A major criticism for the use of the robot in the neck is the fact that it requires such a high level of skill that it should only be reserved to the experts.

However, with respect to adrenalectomy, the robotic system can be used via the posterior retroperitoneal approach and the lateral transperitoneal approach. The latter is favored for larger tumors. In fact, some authors favor the lateral transperitoneal approach for most tumors regardless of their size and prefer to apply it to pregnant women and children [69].

When compared to laparoscopy, robotic adrenalectomy has been determined to be as effective and to have the same rate of complications, but its major disadvantage is the cost associated with the procedure when the robotic platform is used. Nevertheless, it is a safe technique and the conversion rate to open surgery is very low [70]. In fact, a more recent literature review has shown that robotic adrenalectomy, when performed at high-volume centers, has superior results to the laparoscopic approach, with lower estimated blood loss, shorter hospital stay, and improvement in intra-operative time with a higher case volume [71]. This is an improvement over a prior meta-analysis published 2 years earlier which had concluded that there is no advantage of robotic adrenalectomy over laparoscopic adrenalectomy [72].

On the topic of thyroidectomy, the robotic technique has been found to be very advantageous to the surgeons due to superior ergonomics when compared to the endoscopic approach, in addition to the fact that the learning curve is easier to master with the surgical robot [73]. Another concept was introduced by a group that reported on their initial experience with robotic thyroidectomy in 2011, which was the fact that the robotic technique eliminates the need to have an assistant in spite of an increased procedure time [74].

A recent literature review dedicated to the study of prior series of robotic thyroidectomy for cancer and their comparison to the open approach concluded that the open technique is superior in terms of oncologic outcomes, decreased operative times, and lower cost. However, the robotic approach was comparable to open thyroidectomy for cancer regarding morbidity, short-term recurrence rates, and quality of life outcomes. The authors warn that the technique for this indication should be reserved to the experts at high-volume centers [75]. A few years earlier, a large case series of robotic thyroidectomy for cancer had precisely shown that the robotic approach has decreased operative times and improved lymph node yields compared to the endoscopic technique. Moreover, the robotic learning curve was shorter [76]. A large case series of 100 patients with papillary thyroid microcarcinoma was published and reported on the robotic total thyroidectomy with central node dissection while compared to the open approach. The results were comparable to the open group, with no conversions, and with similar lymph node retrieval [77]. This is just an example of how far some experts have contributed to the advancement of this subspecialty with a minimally invasive technique that has surpassed its endoscopic counterpart.

9. Cholecystectomy: from the traditional to single-site

Robotic cholecystectomy is often one of the first procedures that surgeons learn to perform with the robot in order to overcome their learning curve and build a basic skill set that will allow them to embark on challenging operations in the future [78]. However, it is also true that some cholecystectomies may become complex operations that may lead to complications when meticulous technique and sound surgical judgment are not applied. The initial years of robotics in General Surgery were times when some groups advocated for performing this procedure only for training purposes since there appeared to be no value over the well-established laparoscopic technique, which had been the gold standard for a long time.

A year later, another group presented their data on robotic cholecystectomy by using a different port arrangement in the lower abdominal wall, separate from the traditional approach in laparoscopic cholecystectomy. The results were satisfactory, with safety and efficiency being at the core of their manuscript [79]. Subsequent case series by different centers published the data corresponding to the first robotic single-site cholecystectomies performed at their institution. The common conclusion was, as expected, that this technique was safe and feasible, and that the learning curve is relatively easy to overcome. On the other hand, surgical resident training did not affect the results in a negative way [80, 81].

The technique consists of using a single-site port with four channels created by intuitive Surgical to overcome the limitation that arises from laparoendoscopic single-site (LESS) surgery when the arm movement is the opposite of what the surgeon expects due to the need to pivot the instruments around a central axis. With the robotic single-site technology, however, although there is no wristed articulation of the instruments, the limitation is overcome when the surgeon sits at the console and the arm movement is inverted so that the instrument movement matches the hand movement at the console. This can be very convenient and, indeed, can be applied to perform single-site cholecystectomy in patients with a high BMI most of the time (see **Figures 4**–**7**).

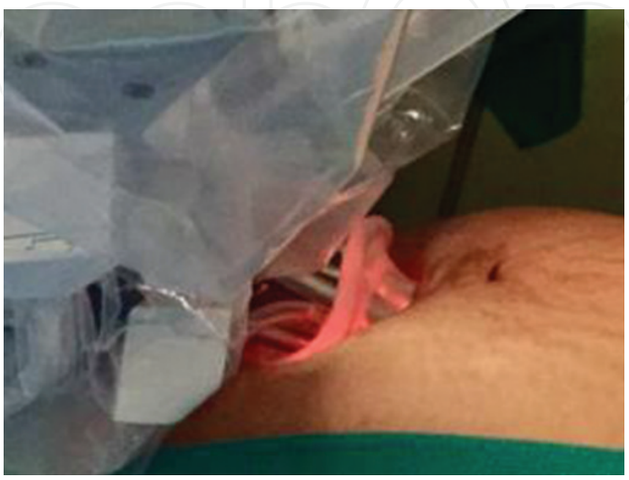


Figure 4. da Vinci single-site port inserted through an infraumbilical 2.5 cm incision.

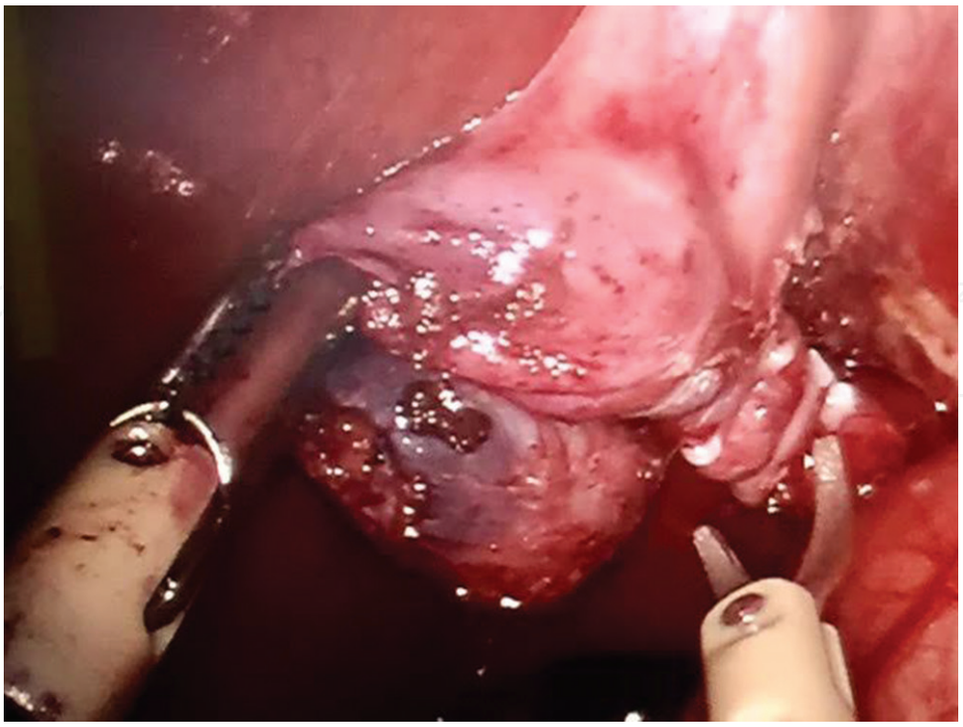


Figure 5. da Vinci single-site instruments in action during a robotic cholecystectomy.



Figure 6. Specimen extracted via the only incision.

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Figure 7. Final cosmetic result. Based on the patient's abdominal wall thickness and BMI, sometimes a vertical skin incision is necessary, although a transverse skin incision is made in most cases. A vertical fascial incision is always favored.

10. Hernia repair: from closing defects to suturing mesh

The field of hernia repair and abdominal wall reconstruction has seen an increasing amount of studies and case series recently published which present new techniques that continue to advance the subspecialty of minimally invasive abdominal wall reconstruction. The results are outstanding and the surgeons witness them to the point that patient satisfaction correlates with less chronic pain and decreased hospital stay. Although laparoscopic hernia repair has been established as an appropriate technique in most cases, its Achilles heel has always been the presence of chronic pain, most likely due to transfascial sutures and to the utilization of tacks for intraperitoneal mesh fixation, whether they are permanent or absorbable.

On the subject of intraperitoneal mesh fixation, a study published in 2012 presented excellent results when the primary ventral hernia defect was closed with intracorporeal sutures placed with the robotic system, and when the mesh was fixed as an underlay with circumferential sutures, without the use of tacks [82]. Just to compare, as early as 2003 another manuscript had already presented a robotic hernia repair, but the idea at that time was to still secure the mesh

with tacks and to not close the primary defect with sutures [83]. As it can be seen, therefore, the field of hernia repair has come a long way by establishing the new concept of primary defect closure for the sake of a more mechanically and physiologically normal abdominal wall, and avoidance of transfascial sutures and tacks to prevent chronic pain. Furthermore, all of the series have determined that the robotic platform offers the opportunity to perform enterolysis more efficiently through the multiple benefits that have been described before [84–86] (see **Figures 8–10**).

Regarding the specific situation of inguinal hernia repair, which has been extensively performed with the laparoscopic total extraperitoneal (TEP) and the transabdominal preperitoneal (TAPP) approaches, the robotic technique offers remarkable advantages in the confined space where it takes place, including the dexterity offered by the wristed instruments and the ability to perform a finer dissection and suture the peritoneal flap in the case of a TAPP. The Urology literature recognizes the relevance of the surgical robot when a TEP is performed at the time of robotic prostatectomy as a combined operation [87]. In the General Surgery literature, where the robotic TAPP approach is favored, the absence of neuralgia after the operation is likely a reflection of all of the advantages offered by the robotic platform in addition to the avoidance of tacks to fix the mesh and close the peritoneal flap, which is similar to the observation made in the ventral hernia series when tacks are avoided as well as transfascial sutures [88]. In addition, the robotic technology has been used to develop new minimally invasive ways to reconstruct the abdominal wall, such as the robotic transversus abdominis release as a posterior component separation with the preperitoneal placement of mesh, but the description of all of these techniques is beyond the scope of this chapter. In reality, such monumental task deserves a separate chapter in a future publication.

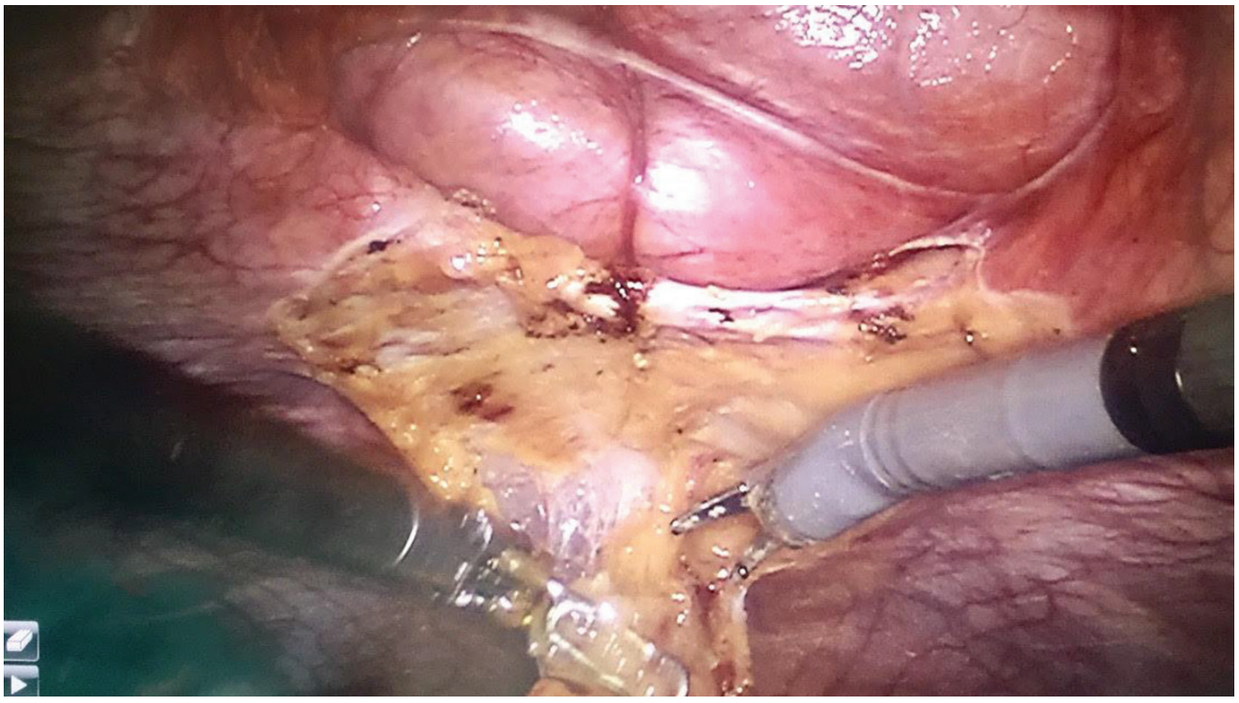


Figure 8. Robotic enterolysis in anticipation of primary closure of an incisional ventral hernia defect, and prior to intraperitoneal mesh implantation with circumferential intracorporeal sutures.

http://dx.doi.org/10.5772/intechopen.68864

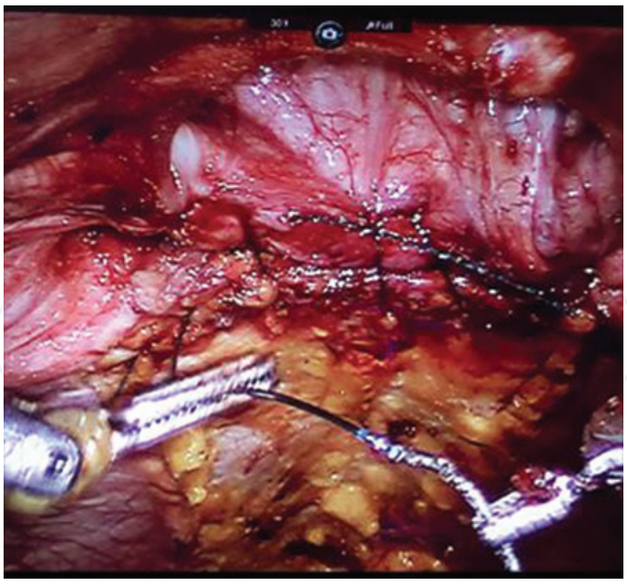


Figure 9. Intracorporeal robotic suturing for closure of incisional ventral hernia defect.

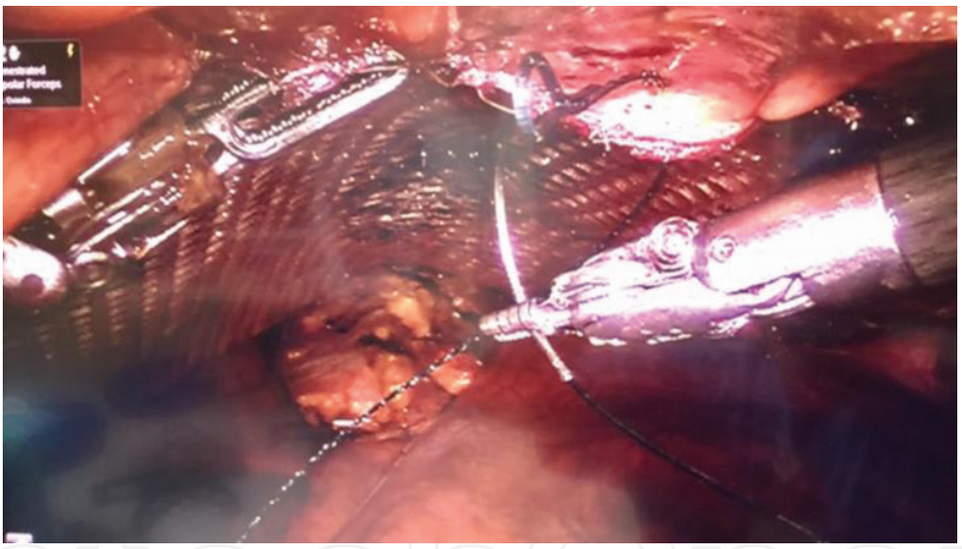


Figure 10. Circumferential intracorporeal suturing of mesh for fixation while avoiding the use of tacks or transfascial sutures.

11. General surgery: robotics applied to all cases

While it is true that much of the progress made in robotic surgery has originated from multiple case series in the surgical subspecialties, as it has been extensively documented in this chapter, a significant degree of advancement has come from true General Surgery programs that have continued to perfect the technique and its applications in a vast range of procedures with success [89]. The perfect example came from an extensive case series of robotic General Surgery cases in a large European community hospital. What is significant about this publication is the fact that it was 2003 and, above all, the relevant observation that the 207 procedures

were performed with the surgical technology in the community hospital environment or, in other words, not in an academic institution associated with a university. Of course, being a large hospital, it was a referral center for other hospitals in the region, but it was a community institution after all [90]. Another European case series of 94 patients was published in 2007 with similar results and conclusions [91].

These studies served as an inspiration for other surgeons who wished to incorporate the robotic surgical approach to their armamentarium and to offer the benefits of robotic surgery to their patients in the General Surgery environment, with most of the series favoring gastrointestinal surgery [92, 93]. Perhaps one of the first publications to lay the foundation for the need to include hospital administrators, medical school and residency program authorities, and the surgical team leadership in the process of creating a successful Robotic General Surgery robotic program was an American manuscript from 2010 [94]. This manuscript opened the gate to a new level of discussion that needed to begin in order to establish the guidelines for a successful, productive, safe, and efficient robotic program to thrive.

12. The last argument: innovation cannot be stopped

In 2016, a comprehensive review of all surgical specialties (such as Urology, Gynecology, and Thoracic Surgery) and General Surgery subspecialties (presented in this chapter) included cases performed from 2000 to 2013. Adverse events were analyzed, and the conclusion was that they were less frequent in those specialties where the surgical robot is used more often. Most of the events were due to equipment malfunction, however, and not to surgeon technique [95]. Nonetheless, once again, surgical judgment takes priority and should always be the driving force in control of the surgical robot.

As long as the advanced technology is utilized to impact our patients in a positive way, there will always be the risk of complications, and no surgeon can deny that, whether the approach is open, laparoscopic, or robotic. In fact, in 2013, a European study expanded on the topic of guidelines and principles that are necessary to guide a successful robotic surgery program. The elements for the ideal organizational model to implement such an efficient program were discussed, but what seems to be different from prior publications by other groups is the fact that the investigators suggested the expansion of the robotic platform to more subspecialties in General Surgery [96]. This is a shifting paradigm from the old idea that the surgical robot should only be reserved to perform highly specialized procedures such as colorectal, complex foregut, or hepatobiliary, pancreatic, and gastric oncology.

Innovation cannot be stopped. When surgeons keep their patients' safety in mind as their top priority, safe innovation becomes a reflection of progress in their specialty. Human beings have always been creative, and their creativity will continue to be applied in their profession regardless of opposition from those who prefer the status quo because it is more comfortable to do so.

The first American case series of robotic General Surgery cases in a community hospital to this date, to this author's knowledge, did not come from a tertiary referral center or fully academic institution. It was inspired by prior European series from the early and mid-2000s that have

already been presented in this chapter. The first American case series, however, came from a very small acute care community hospital of 266 beds affiliated with a university, but lacking a residency program and consisting of a single surgeon experience. The total number of procedures performed was 101, with case #101 being meaningful to the surgeon and his team because of its relevance as the first robotic bariatric operation performed in the city [97].

This publication from 2016 has paved the way for future case series where a higher volume of cases is necessary to achieve statistical significance and inspire others to conduct randomized controlled trials in the future. In fact, a follow-up study is already being prepared for the first 200 robotic General Surgery cases in the same community hospital, this time with statistical significance due to the larger size of the series.

While multiple case series have been reported in the United States, none has included a large variety of cases across most surgical subspecialties including hernia, colorectal, gallbladder, foregut, and bariatric surgery, particularly in a community hospital environment where resources are limited and with the da Vinci S system being used to perform these operations from 2014 to 2015. The manuscript's most important conclusion is twofold: first and foremost, a successful robotic General Surgery program can be implemented in a community hospital by training the surgical team as the surgeon overcomes the learning curve, with improved results seen as the number of cases increases. Secondly, and what may be the most important observation, the study suggests that the surgical robot can be safely and efficiently used both for complex and simple General Surgery procedures, not just for the complex cases.

In conclusion, while hoping to stimulate the international surgical community to appreciate the value of the surgical robot for General Surgery and its multiple subspecialties, this author's ultimate goal is to remind himself and his colleagues around the world that the only way to improve is to continue to learn, both from our own mistakes as well as from the substantial body of knowledge that has been compiled over the years. This is the legacy left for us by a few pioneers who began to open their minds and think outside the dogma that had been established as the infallible truth: that laparoscopy is the least invasive way to perform an operation, and that nothing else can be created that will improve upon its benefits. Innovation, at the core of every surgeon's mind and spirit, will continue to advance in our field to benefit our patients. The best decision we can make today is to prepare ourselves to join others in this magnificent enterprise without being left behind. After all, our patients deserve our best effort to improve and to learn until our last breath.

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