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ORIGINAL ARTICLE

Robotic Pancreatic Resections: Feasibility and Advantages

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Abstract The robot is an innovative tool to perform complex pancreatic resections. It upgrades conventional laparoscopy by adding specific ergonomic technical details (e.g., EndoWrist). Robotic complex pancreatic operations such as pancreaticoduodenectomy can be carried out safe with equal oncological results, morbidity, and mortality compared to open procedures. The patients benefit from less blood loss, decreased hospitalization, and all other benefits of minimally invasive surgery. Nevertheless, the robot has some limitations like missing haptic feedback and the high costs. It has to find its indications beneath conventional laparoscopic procedures, which is currently extensively discussed. But the available technology is certainly convincing, and a further improvement can be expected which will increase its widespread in the future.

Keywords Pancreaticoduodenectomy · Pancreas · Robotic surgery · Whipple procedure · Minimally invasive surgery

Background

The pancreas is located in the retroperitoneal space, surrounded by various vessels, and it produces several digestive enzymes. These parameters make this organ still challenging for surgical procedures. Tumors that are located in the body or tail of the pancreas can be removed by distal pancreatectomy, which can be performed with or without spleen preservation depending on the respective indication. These operations can be performed by laparoscopic procedures that add all benefits of minimally invasive procedures to the patient like less blood loss and shorter hospitalization. Even overall complication rate is less in laparoscopic distal pancreatectomy compared to open procedures (33.9 vs. 44.2 %) [1]. Therefore, this type of surgery is widely accepted and frequently performed for indications regarding the distal area of the pancreas. For tumors which are located in the pancreatic head and uncinate process, especially for adenocarcinomas, the Kausch-Whipple procedure or pancreaticoduodenectomy (PD) is the standard of care. This operation requires mobilization of the pancreas from the adherent vessels, lymph node dissection, and safe suturing during reconstruction. Otherwise, pancreatic fistula may occur, which has decreased over the decades by improved techniques but remains an issue in pancreatic surgery. Behind these facts, laparoscopic PD did not raise in the same way than laparoscopic distal pancreatectomy. Several surgeons prefer hand-assisted or hybrid procedures for PD which still contain aspects of open techniques. Only few surgeons perform complete laparoscopic PD. There remains an extended learning curve and several technical challenges which blocked the wide distribution of laparoscopic PD so far. Currently, robotic-assisted procedures spread out in various fields of surgery. Even in surgical oncology, the robot is used for several indications, and it seems that it can bring an upgrade in some technical aspects compared to conventional laparoscopy. For pancreatic surgery and especially minimally invasive PD, the robot is extremely helpful to overcome technical challenges of this complex operation.

Technical Aspects of Robotic Pancreatic Resections

To compete with open techniques, minimally invasive techniques must enable the surgeon to produce comparable results

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to standard open operations. Especially in surgical oncology, this is an issue to add all benefits of surgery to the patient and not to delay adjuvant treatment. The key for PD during resection is the mobilization of the adjacent vessels. Especially in advanced tumors or after radiation, this can be challenging and may need sometimes a partial vessel resection and reconstruction to get adequate oncological results. The da Vinci robotic system (Intuitive Surgical, Inc., California, USA) is currently widely spread in use and provides an excellent 3-D, amplified visualization of anatomic structures. The very agile instruments are very precise at the tip enabling the surgeon to perform advanced maneuvers. One clear improvement compared to standard laparoscopic instruments is the so-called EndoWrist; a technical innovation that provides in combination with circumferential tip articulation mobility in a third dimension and is therefore very helpful during tissue mobilization. Own experience indicates that vessels, even especially small vessels, can be dissected very precisely using these tools. Several surgeons even undertake vascular resection and reconstruct them by a patch or graft interposition during robotic PD. The Pittsburgh group is highly experienced in robotic PD and provides a distinguished technique for these procedures [2]. They published on 250 robotic pancreatic procedures recently and removed advanced pancreatic tumors including cases after neoadjuvant chemoradiation with robotic assistance [3]. A further crucial issue is lymph node dissection since the lymph node ratio was identified as a main prognostic indicator in pancreatic cancer [4]. Considering the described technical advances of robotic surgery, it is evident that lymph node dissection can be carried out sufficiently by the robot. The published data indicate a mean amount of 13–32 harvested lymph nodes during robotic PD [5, 6]. The reconstruction by the surgeon and here especially the pancreaticojejunostomy are further key players for successful PD. Handling a needle and sewing is very good and manageable with the robot. The described "EndoWrist" function has certainly improved minimally invasive sewing a lot. But there is currently one limitation making sewing sometimes challenging especially in a soft pancreas. The missing haptic feedback can lead to pancreatic tissue injuries/tear caused by too much tension during knotting or the thread can break easily. The published fistula rates after robotic PD are between 6.6–35 % [6].

Advantages and Concerns of Robotic Pancreatic Resections

Based on the current published experience, it is evident that robotic pancreatic surgery and especially PD can be performed safely and is appropriate in experienced hands [5, 6]. The technical innovation with its ergonomic benefits has improved minimally invasive surgery a lot and is especially useful in complex operations such as PD. Robotic PD leads to a decreased blood loss (153–394 ml) as it is described in Table 1. Hospitalization (9.8–16.4 days), morbidity (26–50 %), and mortality (0–3 %) do not change between open and robotic procedures in some series (Table 1) [5, 6]. However, several studies reported a significantly shorter length of hospital stay when compared to open PD (9.79 vs. 13.26 days, $P=0.043$) and noted a significantly lower postoperative complication rate following robotic PD (25 vs. 75 %, $P=0.05$) [5]. Oncologic surgical-related outcomes appear to be equivalent comparing robotic to open PD. The number of harvested lymph nodes and resection margin negative rates (88–100 %) show no significant differences in the published series (Table 1) [5]. It is important to mention that in one series an improvement in the mean lymph node retrieval rate was evaluated with robotic-assisted PD as compared to open PD (16.8 vs. 11, $P=0.02$) [5].

Nevertheless, some limitations may decelerate the widespread of robotic-assisted minimally invasive procedures. To overcome the learning curve, some authors suggest a minimum of 50 robotic PDs. This can become a problem in smaller centers with less volume. The mean operation time is elongated for PD by the robot (421–780 min) [6]. Even setting the robot prior and after the operation needs time and prolongs the procedure. These facts and the high investment for the robot and the running costs strain the hospital budget and have to be

Table 1 Surgery-related indicators of recently published series of robotic pancreaticoduodenectomy [5, 6]

Author	Year	Number of patients	Mean operative time (min)	EBL (ml)	Margin negative rate (%)	No. of lymph nodes harvested (mean)	Morbidity (%)	Mortality (%)	Length of hospital stay (days)
Gulianotti et al.	2010	60	421	394	92	14	26	2.2	12.5
Buchs et al.	2011	41	431.5	389	n.r.	16	39	2.4	12.7
Zeh et al.	2012	50	568	350	89	18	Clavien II,II: 25 Clavien III/IV: 30	2	10
Zureikat et al.	2013	132	527	n.r.	n.r.	n.r.	Clavien II,II: 41 Clavien III/IV: 22	2	10
Baker et al.	2014	27	527	467	74	n.r.	11	0	10

EBL estimated blood loss, *n.r.* not reported

considered when settling a robot program. Finally, the missing haptic feedback needs improvement to enable surgeons doing challenging procedures more efficiently and faster in the future.

Conclusions

In summary, the robot is one of the highest innovations for minimally invasive pancreatic surgery. The clinical need and its value are currently controversially discussed. But it is evident that it adds an upgrade to conventional minimally invasive procedures. The main limitations are currently the high costs. But keep in mind that it is just the beginning of an era with high potential for future developments. The technical feasibilities exist, and they will not disappear.

Compliance with Ethical Standards

Conflict of Interest None

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