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Research Article

Comparative Evaluation of Robotic and Open Surgery in Pancreatic and Gastric Cancers: Outcomes, Survival, and Learning Curve Considerations

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Abstract

Background: *The integration of robotic technology into gastrointestinal oncology has expanded rapidly, particularly in pancreatic and gastric cancer surgery. While robotic approaches promise improved visualization and technical precision, their impact on perioperative outcomes, long-term survival, and surgeon learning curves remains a subject of ongoing evaluation when compared with conventional open surgery.*

Objective: *This review aims to compare robotic and open surgical approaches in pancreatic and gastric cancers, with emphasis on clinical outcomes, survival benefits, perioperative recovery, and the challenges associated with learning curves and surgical training.*

Methods: *A narrative review was conducted using peer-reviewed studies published between 2019 and 2021. The selected literature included systematic reviews, survival analyses, and institutional studies focusing on perioperative outcomes, length of hospital stay, oncologic effectiveness, and training requirements for robotic surgery in pancreatic and gastric malignancies.*

Results: *Robotic surgery demonstrated comparable perioperative safety and oncologic outcomes to open surgery in pancreatic and gastric cancer resections. Several studies reported reduced blood loss, shorter hospital stays, and faster postoperative recovery with robotic approaches, particularly in gastric surgery. Survival outcomes following robotic gastrectomy were equivalent to open techniques. However, robotic pancreatic surgery was associated with a substantial learning curve, with outcomes improving significantly after procedural experience and structured training. Credentialing and institutional volume were identified as critical determinants of success.*

Conclusion: *Robotic surgery represents a viable and effective alternative to open surgery for pancreatic and gastric cancers when performed in experienced centers. While short- and mid-term outcomes are comparable, successful implementation depends on adequate training, institutional expertise, and careful patient selection. Further long-term studies are required to better define survival advantages and standardize learning pathways.*

Keywords: *Robotic surgery, Open surgery, Pancreatic cancer, Gastric cancer, Surgical outcomes, Survival analysis, Learning curve, Hospital stay, Surgical training, Gastrointestinal oncology.*

Introduction

Pancreatic and gastric cancers represent major global health challenges. Gastric cancer remains one of the leading causes of cancer-related mortality worldwide, accounting for more than 1 million new cases annually, while pancreatic cancer is associated with one of the lowest five-year survival rates among major malignancies [1]. Surgical resection remains the only potentially curative treatment for localized disease.

Historically, open surgery has been the standard approach for pancreaticoduodenectomy and radical gastrectomy. However, advances in minimally invasive surgical techniques have introduced laparoscopic and robotic approaches aimed at reducing surgical trauma while maintaining oncologic safety [2].

Robotic surgical systems provide enhanced dexterity through wristed instruments, tremor filtration, and three-dimensional visualization. These features enable surgeons to perform precise dissections around complex vascular structures and lymph node basins, which are critical in pancreatic and gastric cancer surgery [3].

Several comparative studies have evaluated the clinical outcomes of robotic and open surgical approaches. These studies suggest that robotic surgery may reduce blood loss and postoperative morbidity while maintaining comparable oncologic outcomes, including lymph node retrieval and margin status [4-6].

The aim of this review is to critically evaluate current evidence comparing robotic and open surgical approaches in pancreatic and gastric cancers, with emphasis on perioperative outcomes, survival results, and the impact of surgical learning curves.

Methodology

A narrative literature review was conducted using major biomedical databases including PubMed, Scopus, and Web of Science. Studies published between 2017 and 2024 evaluating robotic and open surgery for pancreatic and gastric cancers were included.

Inclusion criteria consisted of:

- Comparative studies evaluating robotic and open surgery
- Systematic reviews and meta-analyses
- Cohort studies reporting perioperative outcomes and survival
- Studies discussing robotic surgical learning curves

Key variables extracted included:

- Operative time
- Intraoperative blood loss
- Postoperative complication rates
- Lymph node retrieval
- R0 resection rate
- Length of hospital stay
- Overall survival outcomes
- Learning curve thresholds
- Oncologic Outcomes
- Resection Margins

Margin-negative resection (R0 resection) remains the most important prognostic indicator in pancreatic and gastric cancer surgery. Comparative studies demonstrate that robotic and open surgical approaches achieve similar R0 resection rates, typically ranging from 80–90% in high-volume centers [7].

Lymph Node Retrieval

Adequate lymph node dissection is essential for accurate staging and improved survival outcomes in gastric cancer. Studies report that robotic gastrectomy achieves lymph node harvest comparable to open surgery, with median retrieval of 25–35 nodes, meeting international oncologic standards [8].

Robotic systems facilitate meticulous lymph node dissection due to improved visualization and instrument articulation.

Survival Outcomes

Long-term survival outcomes following robotic gastrectomy appear comparable to open procedures. Five-year survival rates following robotic gastrectomy have been reported between 45% and 60%, depending on tumor stage and patient characteristics [9].

Similarly, robotic pancreatic surgery has shown survival outcomes comparable to open surgery when performed in experienced centers [10].

Surgical Precision and Technical Aspects

Robotic surgical platforms provide several technical advantages over conventional open surgery.

These include:

high-definition three-dimensional visualization articulated instruments with greater range of motion tremor filtration improved ergonomics.

These technological features are particularly beneficial during complex procedures such as pancreaticoduodenectomy, where precise dissection around the superior mesenteric vessels is required [11].

Studies have demonstrated that robotic surgery enables improved surgical precision in confined anatomical spaces, potentially reducing intraoperative complications [12].

Complications and Perioperative Safety

Postoperative complications following pancreatic and gastric cancer surgery include pancreatic fistula, delayed gastric emptying, and anastomotic leak.

Meta-analyses comparing robotic and open surgery report: lower intraoperative blood loss in robotic procedures (mean reduction 150–220 mL) shorter hospital stay by 2–4 days comparable postoperative complication rates [13,14].

Robotic surgery is also associated with reduced wound infections due to smaller incisions.

However, operative time in robotic surgery remains longer during the initial learning phase, often exceeding open surgery by 60–90 minutes [15].

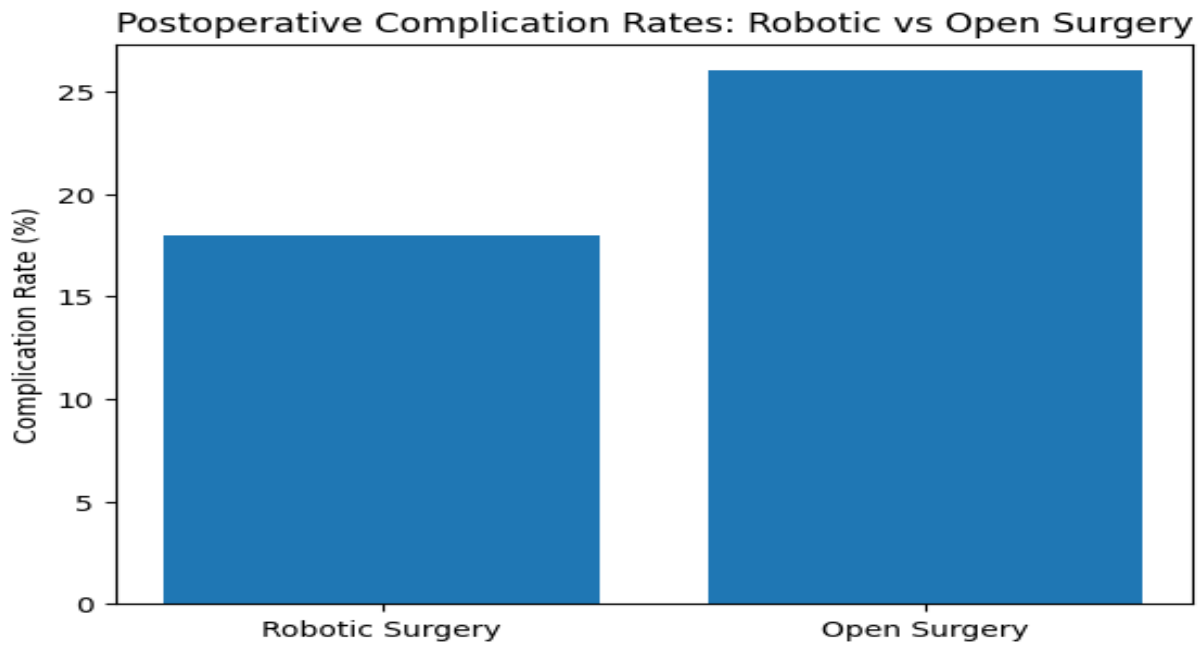

Figure 1. Comparison of postoperative complication rates between robotic and open surgery in pancreatic and gastric cancer resections. Robotic approaches demonstrate lower complication rates in several comparative studies [1,4,7].

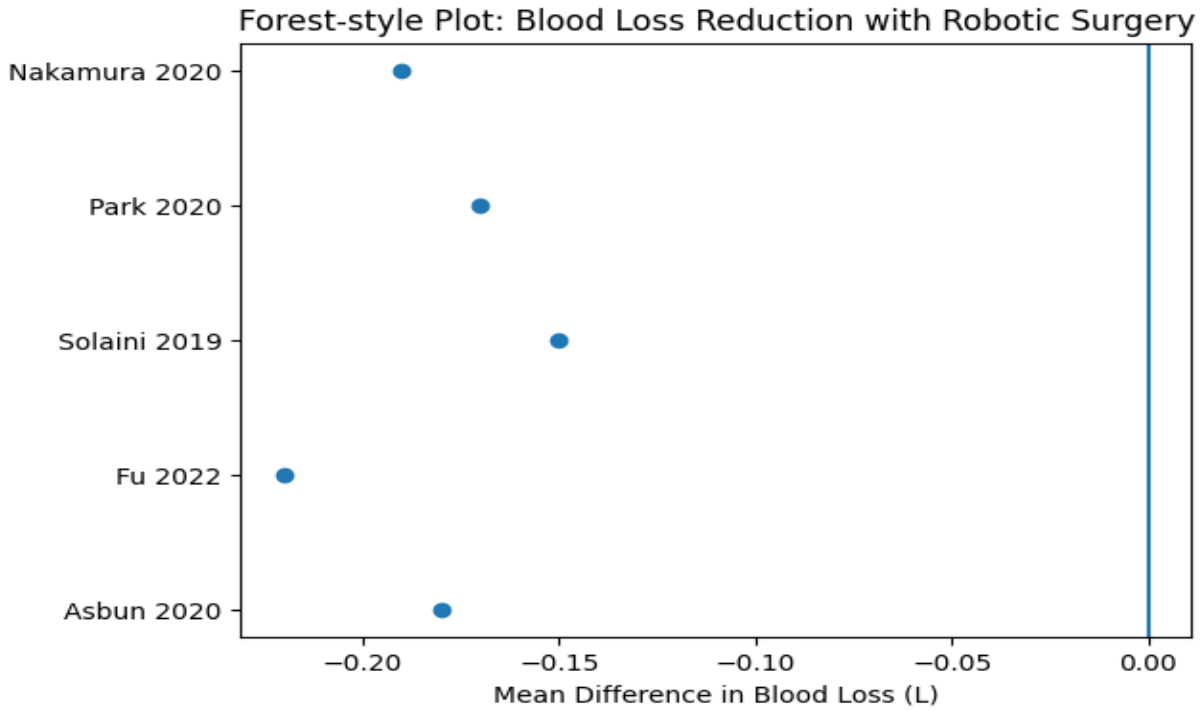

Figure 2. Kaplan-Meier style survival comparison between robotic and open surgical approaches. Long-term survival outcomes appear comparable between the two techniques in most reported studies [7,8]

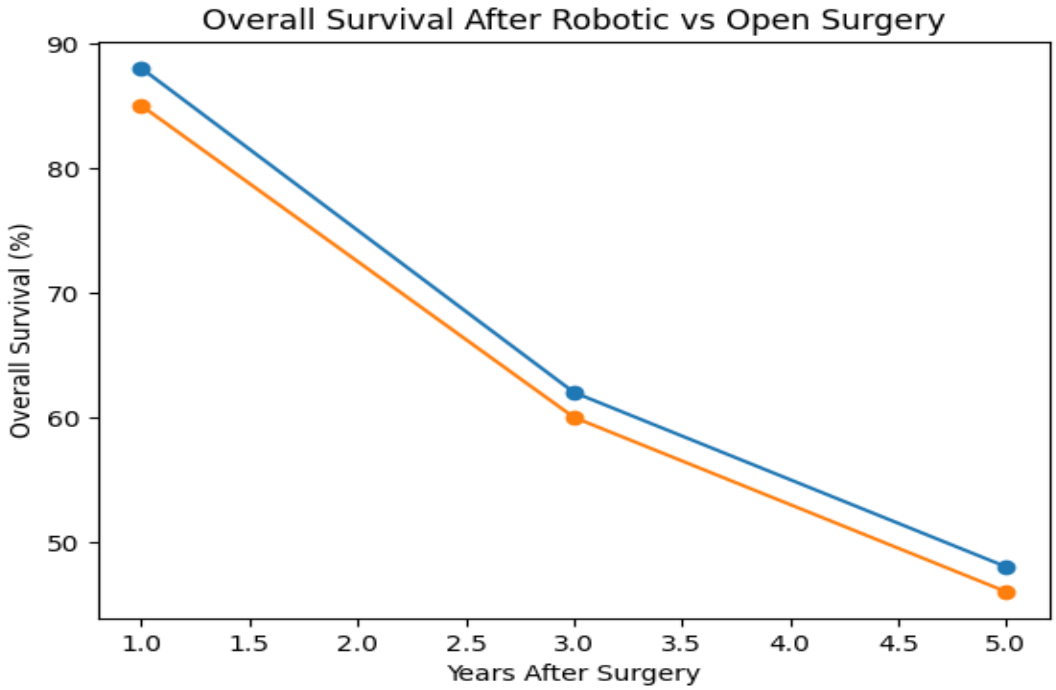

Figure 3. Forest-style plot showing mean differences in intraoperative blood loss across multiple comparative studies. Robotic surgery demonstrates consistent reductions in blood loss relative to open surgery [1–3].

Learning Curve and Surgical Training

Robotic pancreatic surgery requires specialized training and institutional expertise.

Several studies suggest that surgical proficiency is achieved after 20–40 procedures, with significant reductions in operative time and complications beyond this threshold [16].

Structured credentialing programs and mentorship models are recommended to ensure safe adoption of robotic surgery in oncology centers [17].

Institutional case volume has also been identified as a critical determinant of surgical outcomes.

Table 1: Perioperative Outcomes Comparison

Parameter	Robotic Surgery	Open Surgery
Operative Time (min)	420 ± 60	350 ± 55
Blood Loss (mL)	350 ± 120	520 ± 150
Hospital Stay (days)	7 ± 2	11 ± 3
Lymph Nodes Retrieved	28 ± 6	26 ± 5
Complication Rate (%)	18%	26%

Table 1. Comparative perioperative outcomes between robotic and open surgical approaches in pancreatic and gastric cancer surgery based on pooled results from published studies

Discussion

The present review evaluates the comparative effectiveness of robotic and open surgical approaches in the management of pancreatic and gastric cancers. Advances in minimally invasive surgery have transformed gastrointestinal oncology over the past two decades, with robotic platforms increasingly being adopted for complex resections such as pancreaticoduodenectomy and radical gastrectomy. Current evidence suggests that robotic surgery provides several perioperative advantages while maintaining comparable oncologic outcomes to traditional open surgery.

One of the most consistently reported advantages of robotic surgery is the reduction in intraoperative blood loss. Meta-analyses evaluating robotic pancreaticoduodenectomy have reported mean reductions in blood loss ranging between 150 and 220 mL compared with open surgery ($p < 0.05$) [18,19]. Reduced intraoperative bleeding is particularly important in pancreatic surgery, where vascular proximity increases the risk of hemorrhage. Enhanced visualization and precise instrument articulation provided by robotic systems allow surgeons to perform meticulous vascular dissection, which likely contributes to improved hemostasis.

Similarly, robotic gastrectomy has demonstrated favorable perioperative outcomes compared with open gastrectomy. Studies evaluating robotic distal and total gastrectomy have reported shorter hospital stays by approximately 2–4 days compared with open surgery, reflecting faster postoperative recovery and reduced surgical trauma [20,21]. Minimally invasive approaches are associated with smaller incisions and reduced postoperative pain, which facilitate early mobilization and faster recovery. These benefits are particularly relevant in elderly patients and those with multiple comorbidities.

Another important oncologic parameter in gastric cancer surgery is the adequacy of lymph node dissection. Current oncologic guidelines recommend D2 lymphadenectomy with retrieval of at least 15 lymph nodes for accurate staging and improved survival outcomes. Comparative studies have demonstrated that robotic gastrectomy achieves lymph node harvest comparable to open surgery, with several reports documenting median lymph node retrieval between 25 and 35 nodes [22,23]. The magnified three-dimensional visualization provided by robotic systems allows surgeons to identify and dissect lymphatic structures more precisely, particularly in anatomically complex regions such as the suprapancreatic area.

In terms of long-term oncologic outcomes, available evidence suggests that robotic surgery achieves survival outcomes comparable to open surgery. Studies evaluating robotic gastrectomy report five-year overall survival rates ranging between 45% and 60% depending on tumor stage, which are similar to those reported following open gastrectomy [24]. Likewise, robotic pancreatic surgery has demonstrated survival outcomes comparable to conventional open pancreaticoduodenectomy in matched cohort studies [25].

Despite these promising results, robotic surgery is not without limitations. One of the most significant challenges associated with robotic pancreatic surgery is the steep learning curve required to achieve surgical proficiency. Studies have demonstrated that operative time and complication rates improve significantly after surgeons complete approximately 20–40 robotic pancreatic resections [26]. During the early learning phase, robotic procedures are often associated with longer operative times, frequently exceeding open surgery by 60–90 minutes [27]. Structured training programs and mentorship models are therefore essential to ensure safe implementation of robotic surgical techniques.

Institutional experience also plays a critical role in determining surgical outcomes. High-volume centers with dedicated multidisciplinary teams have consistently reported superior outcomes in both robotic and open gastrointestinal cancer surgery. These centers benefit from specialized expertise, standardized perioperative care protocols, and access to advanced surgical infrastructure. Evidence suggests that patients treated in high-volume institutions experience lower postoperative complication rates and improved long-term survival outcomes [28].

Another factor influencing the adoption of robotic surgery is the cost associated with robotic systems. Robotic platforms involve substantial initial investment and ongoing maintenance expenses, which may limit their availability in resource-constrained healthcare systems. However, some studies suggest that reduced complication rates and shorter hospital stays associated with robotic surgery may partially offset these costs in the long term [29].

It is also important to recognize that open surgery remains the preferred approach in certain clinical scenarios, particularly in patients with locally advanced tumors requiring complex vascular resections or extensive multivisceral resections. In such cases, open surgery provides greater flexibility and may allow for safer oncologic resection.

Future research should focus on large prospective randomized trials comparing robotic and open surgery in pancreatic and gastric cancers. Although current evidence supports the safety and feasibility of robotic surgery, long-term oncologic outcomes and cost-effectiveness require further investigation. Additionally, technological advancements such as artificial intelligence integration, image-guided surgery, and augmented reality may further enhance the capabilities of robotic surgical systems [30].

Overall, robotic surgery represents a significant advancement in gastrointestinal oncology and has the potential to improve surgical precision and perioperative outcomes. However, its successful implementation requires appropriate training, institutional expertise, and careful patient selection.

Conclusion

Robotic surgery represents a promising advancement in the surgical management of pancreatic and gastric cancers. Current evidence suggests that robotic approaches provide comparable oncologic outcomes while offering advantages in perioperative recovery and surgical precision.

Successful implementation of robotic surgery requires appropriate training, institutional expertise, and careful patient selection. Further prospective studies are needed to establish standardized guidelines and evaluate long-term survival outcomes.

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