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REVIEW ARTICLE

What defines the "value" of robotic surgery for patients with gastrointestinal cancers? Perspectives from a U.S. Cancer Center

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Abstract

The use of robotic surgery has experienced rapid growth across diverse medical conditions, with a notable emphasis on gastrointestinal cancers. The advanced technologies incorporated into robotic surgery platforms have played a pivotal role in enabling the safe performance of complex procedures, including gastrectomy and pancreatectomy, through a minimally invasive approach. However, there exists a noteworthy gap in high-level evidence demonstrating that robotic surgery for gastric and pancreatic cancers has substantial benefits compared to traditional open or laparoscopic methods. The primary impediment hindering the broader implementation of robotic surgery is its cost. The escalating healthcare expenses in the United States have prompted healthcare providers and payors to explore patient-centered, value-based healthcare models and reimbursement systems that embrace cost-effectiveness. Thus, it is important to determine what defines the value of robotic surgery. It must either maintain or enhance oncological quality and improve complication rates compared to open procedures. Moreover, its true value should be apparent in patients' expedited recovery and improved quality of life. Another essential aspect of robotic surgery's value lies in minimizing or even eliminating opioid use, even after major operations, offering considerable benefits to the broader public health landscape. A quicker return to oncological therapy has the potential to improve overall oncological outcomes, while a speedier return to work not only alleviates individual financial distress but also positively impacts societal productivity. In this article, we comprehensively review and summarize the current landscape of health economics and value-based care, with a focus on robotic surgery for gastrointestinal cancers.

KEYWORDS
gastric cancer, pancreatic cancer, quality of life, robotic surgery, value-based health care

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1 | INTRODUCTION

The use of robotic surgery has experienced rapid growth across diverse medical conditions, with a notable emphasis on gastrointestinal cancers. Robotic surgery has played a pivotal role in enabling the safe performance of complex procedures, including gastrectomy and pancreatectomy, through a minimally invasive approach. However, there is an absence of high-level evidence demonstrating that it has substantial benefits compared to traditional open or laparoscopic methods.

The primary impediment hindering the broader implementation of robotic surgery is its cost. The escalating healthcare expenses in the United States have prompted healthcare providers and payors to explore patient-centered, value-based healthcare models and reimbursement systems that embrace cost-effectiveness. Thus, it is important to determine what defines the value of robotic surgery. It must either maintain or enhance oncological quality and improve complication rates compared to open procedures. Moreover, its true value should be apparent in patients' expedited recovery and improved quality of life (QoL). Another essential aspect of robotic surgery's value lies in minimizing or even eliminating opioid use, even after major operations, offering considerable benefits to the broader public health landscape. A quicker return to oncological therapy has the potential to improve overall oncological outcomes, while a speedier return to work not only alleviates individual financial distress but also positively impacts societal productivity.

In this article, we comprehensively review and summarize the current landscape of health economics and value-based care, with a focus on robotic surgery for gastrointestinal cancers.

2 | MEDICAL EXPENDITURE IN THE UNITED STATES AND COST OF CANCER TREATMENT

In the global landscape of healthcare, the escalating costs associated with an aging population, coupled with the development and utilization of expensive new drugs and cutting-edge biomedical technologies, pose formidable challenges for every healthcare system.[1,2] The United States, in particular, grapples with a substantial surge in medical expenditures, spending by far the most on healthcare, equivalent to 16.6% of its gross domestic product (compared with 12.7% in Germany, 11.5% in Japan, 9.7% in Korea, and 2.9% in India), on the basis of the 2023 OECD report.[1] Since 2000, the price of medical care, including services provided as well as insurance, drugs, and medical equipment, has increased by 114%.[3] Labor, pharmaceutical, and administrative costs appeared to be the major drivers of the difference in overall cost between the United States and other high-income countries.[4–8] With such escalating costs, payers are redistributing the weight of these burgeoning costs onto patients through mechanisms such as high premium, high-deductible health plans, co-payments, and out-of-pocket expenses.[9] Financial burden has contributed to a concerning statistic, indicating that a substantial percentage of the U.S. population lacks adequate medical insurance coverage, despite the government's efforts, including the Affordable Care Act.[10] More concerningly, the relative increase in expenditures has not resulted in reciprocal improvements in overall health in the United States.[11,12]

The financial implications of cancer care are profound and rapidly rising.[13] The introduction of novel cancer drugs undoubtedly enhances patient outcomes, but it concurrently propels the overall cost of care to unprecedented levels.[14] While the value of human lives is immeasurable, the financial resources available for medical expenditures are not infinite. In this landscape of the dynamic evolution in cancer treatment, characterized by rapidly escalating costs and an increasing incidence of cancer diagnoses among the aging population, a critical juncture has been reached. There is a societal consensus that healthcare should be more thoughtfully assessed on the basis of "value,"[15] and the United States is seeking a transition to a value-incentivized healthcare model.[16] It is imperative that we allocate our financial resources judiciously, with an overarching goal of delivering the most effective cancer care to the largest possible segment of the population as a collective national and international effort.

3 | CONCEPT OF VALUE-BASED HEALTHCARE IN CANCER TREATMENT

Value-based healthcare is a healthcare delivery model that prioritizes value, defined as quality of health outcomes per dollar expended in providing those outcomes.[15] The focus is on achieving the best possible health outcomes for patients at a reasonable cost. All of the work and costs that do not improve quality outcomes are considered "waste." However, value is a complex and multifaceted concept, particularly in cancer care (Figure 1), that is poorly represented by a single number of any kind.

The challenge of the wider implementation of value-based healthcare is that most metrics that are important to quantify value are not commonly measured. Although several domains (length of

$$\text{Value} = \frac{\mathit{Quality}}{\mathit{Cost}}$$

Quality:
Oncological outcomes: Survival, recurrence
Oncological quality metrics: Negative margin, yield of LNs
Surgical safety: Complication, mortality
Quality of life: Symptoms/pain, functional recovery
Return to adjuvant therapy

Cost:
Medical cost (patients, payors, hospitals)
Non-medical direct cost (e.g. travel)
Indirect/opportunity cost (e.g. loss of income)
Society cost (loss of productivity)

FIGURE 1 Value equation of surgical oncology care.

hospital stay, incidence of complications, readmission, and survival) are more routinely captured and reported using existing systems in many centers, many other metrics, particularly patient-reported outcomes (PROs) that can quantify patients' QoL and functional interference, are rarely available. In addition, the direct and indirect costs required to deliver the individual as well as the full cycle of care for each patient are difficult to estimate and require dedicated and thoughtful costing methodologies. Furthermore, how we weight each value metric has not been fully determined and should be individualized.

4 | ROBOTIC SURGERY FOR CANCER

There is a growing interest in minimally invasive surgery (MIS) across various medical procedures, including in complex cancer operations. The robotic surgery platform offers high-quality 3-D vision and augmented accuracy in surgical skills with articulated instruments, enabling more complex cancer operations in a minimally invasive fashion. Although there has been a rapid increase in the use of robotic surgery for complex oncological procedures,[17–19] there is still a notable absence of high-level data supporting the benefits of this costly approach. In 2019, the U.S. Food and Drug Administration cautioned patients and healthcare providers about the expanded use of robotic approaches in cancer surgery, stating that “the relative benefits and risks of surgery using robotically-assisted surgical devices compared to conventional surgical approaches in cancer treatment have not been established.”[20]

Aside from safety concerns during surgeons' learning phase of robotic surgery,[21–23] the primary obstacle hindering broader implementation is the associated cost. Priced at over 1 million USD,[2,19,24] and with an estimated overall cost of 3000–6000 USD per surgical procedure,[2,24–26] the value for money in robotic surgery has been questioned, necessitating further exploration. The fundamental concept in evaluating healthcare value is patient-centricity.[15] A comprehensive assessment of value should consider individual and social impacts, both direct and indirect, on short- and long-term health outcomes, as well as the costs of and costs potentially saved by robotic surgery.

4.1 | Determining the value of robotic surgery using surveys

To encompass the multidimensional and holistic value of cancer treatment, various comprehensive value frameworks have been proposed. The American Society of Clinical Oncology's Net Health Benefit score[27] and the National Comprehensive Cancer Network's Evidence Blocks[28] offer systematic guidance for physicians to assess the relative value of cancer therapies, considering factors such as benefits, toxicities, and affordability. The University of Texas MD Anderson Cancer Center promotes a broad definition of the value of cancer treatment, incorporating traditional measures such as quality, safety, and patient experience, along with considerations of costs to both payers and patients.[29–31] Value charts have also been introduced by researchers to quantify and visually represent these crucial value domains.[29,32,33]

While progress has been made in recognizing and measuring important value metrics, determining the relative importance of each metric within these frameworks remains unknown. Individualization appears to be crucial to facilitate truly patient-centric cancer care delivery. Recognizing that each patient's values and priorities may differ, tailoring the assessment of treatment value to individual needs becomes imperative. This acknowledges the uniqueness of each patient's circumstances and preferences, reinforcing the importance of a personalized approach in evaluating the comprehensive value of cancer treatment.

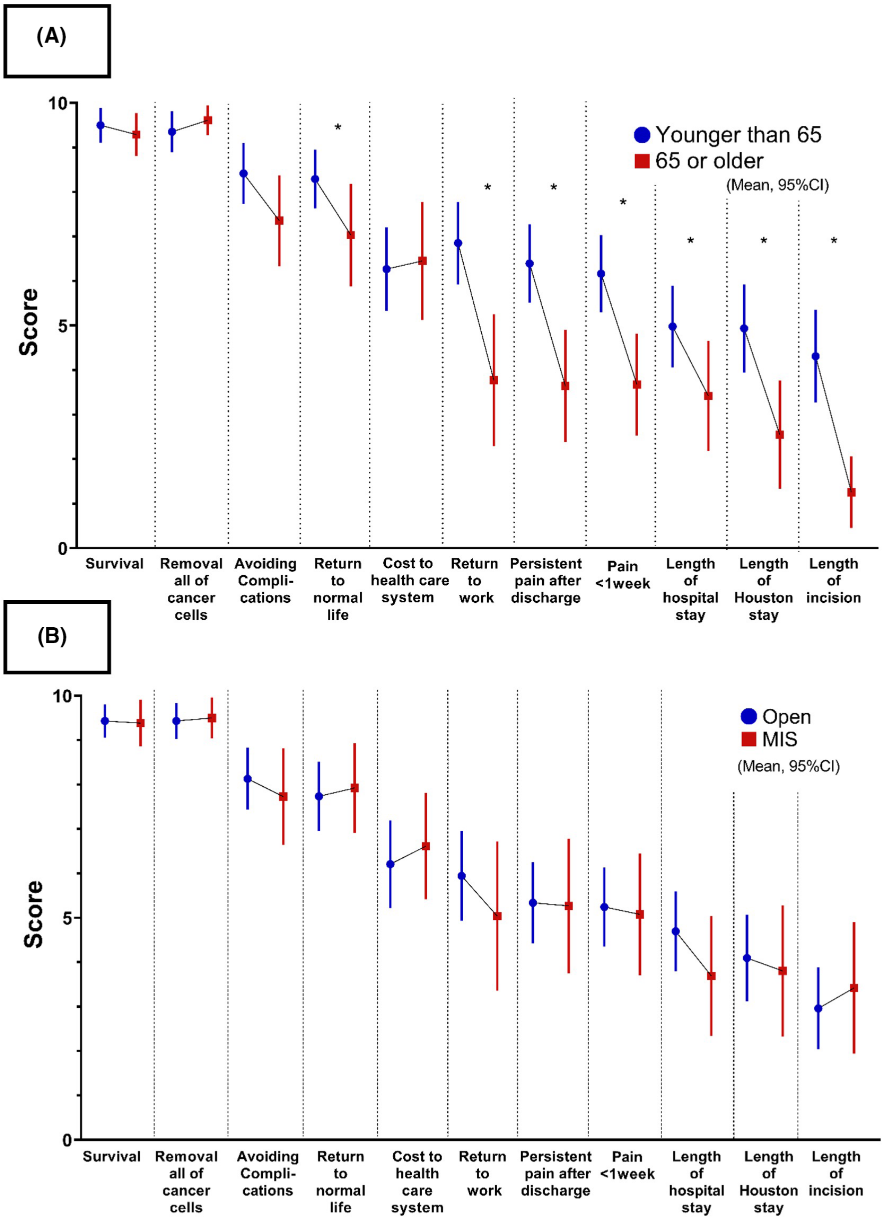
What constitutes the “value” of robotic surgery for patients undergoing complex gastrointestinal cancer surgery? To gain insights into patients' perspectives on the value of surgery for complex upper gastrointestinal cancer operations, we conducted a survey study among patients who had undergone major pancreatectomy or gastrectomy for cancer diagnoses from January 2019 to December 2021. The results were noteworthy (see Figure 2).[34] Metrics such as survival and the complete removal of cancer cells consistently received the highest scores across different age groups. Subsequently, the avoidance of complications and a return to normal life were consistently deemed important. Conversely, factors such as the length of incision, followed by the length of hospital stay and the length of stay in Houston, garnered the lowest mean scores.

The findings of our survey study have implications for our goals with robotic surgery in cancer patients: First, the oncological quality of the operation must be maintained or improved compared to that of the conventional open approach. Additionally, MIS particularly with robotic surgery platform should achieve outcomes that align better with metrics that are highly valued by patients, such as QoL and functional recovery (i.e., return to normal life and return to work), rather than focusing on the length of hospital stay or incisions. It is crucial to acknowledge that patients' perspectives on the value of surgery vary by age and are likely influenced by financial and social situations. In essence, the benefits of robotic surgery must extend beyond merely smaller incisions.

4.2 | Safety and oncological outcome—Is “not-inferior” enough to justify robotic surgery cost?

Patients with cancer are in search of high-quality oncological operations that are capable of completely removing all cancer cells without increasing complication rates, irrespective of the surgical approach. In the field of surgical oncology, researchers' focus has been to demonstrate “non-inferiority” in overall survival when comparing open and minimally invasive approaches. Multiple randomized control trials (RCTs), predominantly from Eastern Asia, have compared open versus laparoscopic gastrectomy in gastric cancer and have consistently demonstrated non-inferiority

FIGURE 2 Value ratings (descending order) of each metric and the differences between groups. (A) Ratings stratified by age (younger than 65 years vs. 65 years or older). (B) Ratings stratified by surgical approach (open vs. minimally invasive surgery [MIS]). *$p < 0.05$.



in survival outcomes and improved complication rates after laparoscopic gastrectomy compared to after open procedures.[35–41] In the context of pancreatic cancer, the DIPLOMA RCT compared MIS versus open distal pancreatectomy, reporting equivalent overall survival rates as well as comparable R0 resection rates, LN yield, complication rates, and time to functional recovery.[42] In contrast, the safety and oncological quality of MIS pancreatoduodenectomy remain areas of uncertainty.[43]

In general, MIS approaches have demonstrated feasibility and safety, reducing complication rates and achieving equivalent oncological outcomes compared to the open approach in surgical oncology operations, and the robotic approach shows signs of improved short-term outcomes as well as conversion rates compared to the laparoscopic approach, when performed by experts at experienced centers.[44–52] Evidence suggests that MIS approaches may lead to a quicker return to intended oncologic treatment (RIOT),[53] which could serve as an important landmark representing the functional recovery of patients. Nevertheless, there is no evidence showing improved survival with MIS compared to the open approach in any cancer types.

Regarding short-term outcomes, the length of hospital stay appears to be influenced by cultural and preferential factors as well as hospital protocols, and the MIS approach may have limited impact in this regard.[46,54] The reported benefits of MIS including robotic surgery in complex surgical oncology may be limited to a reduction of non-major complications (without reducing major complications such as anastomotic leak and pancreatic fistula), blood loss (with uncertain impact on recovery or transfusion needs), and incision length (which may not be a primary concern for patients) for the cost of a longer operation.[36,37,40,44] Considering the substantial increase in financial cost associated with robotic surgery, the current evidence suggests that these benefits do not justify the additional expense.

One notable gap in the existing literature is the lack of data demonstrating the benefits of robotic surgery in terms of patients' QoL after surgery. While MIS surgeons believe that patients may feel "better" after MIS surgery than open surgery, this perception is not supported by robust data, leaving a significant gap in demonstrating the overall value of robotic surgery in enhancing patients' postoperative QoL.

4.3 | QoL measurement in robotic surgery using patient-reported outcomes

While interest in utilizing PROs in cancer surgery grows, providing a direct measure of patients' perceptions of their physical and mental health status, challenges persist.[55,56] Collecting PRO data is time-consuming, labor-intensive, and expensive, with limitations in the information's applicability to specific cancers and surgical procedures. Recognizing these challenges, targeted research efforts are needed in the field of PROs in surgery, including exploring ways to incorporate PROs into decision-making and reimbursement systems, seamlessly integrate them into electronic health records, and develop a comprehensive measure of surgical quality encompassing PROs.[57] Addressing these gaps will contribute to a more comprehensive and patient-centered approach to cancer care, extending the evaluation of treatment outcomes beyond traditional clinical measures to encompass the holistic well-being of individuals undergoing cancer treatment, in a more cost-effective fashion.

Many validated PRO questionnaires are available.[58–65] For PRO questionnaires to be valuable, they must contain clinically meaningful question items that have been formally developed and validated in a specific patient population.[66] Questionnaires should be thorough yet concise, avoiding overlapping or irrelevant questions specific to the patient population, and respect the time patients need to complete the survey. It is crucial for PRO questionnaires to be written in easy-to-understand layman's language, allowing patients to directly report their symptoms without the need for a physician's assistance or interpretation. Studies have shown that patients often report greater severity of symptoms than do their clinicians, and a self-reporting system empowers patients to notify their clinicians of their symptoms.[67]

The most commonly used Patient-Reported Outcome Measures (PROMs) in studies assessing PROs after upper gastrointestinal cancer operations include the EuroQol-5D[58] and the European Organization for Research and Treatment of Cancer (EORTC) QLQ-30.[62] The EuroQol-5D, which is designed for the general population, consists of only five questions that evaluate mobility, self-care, activity, pain, and mood. It is widely used for the validated calculation of quality-adjusted life years for cost-efficiency analyses in many countries.[68–73] The EORTC QLQ-30 is the most extensively used cancer-specific questionnaire, comprising 30 question items. It incorporates functional and symptom scales, along with a global health and QoL scale. Additionally, it is often used in conjunction with supplemental cancer type-specific domains, such as those for the esophagus (OES18 and 24),[63] stomach (STO22),[64] and pancreas (PAN26).[65]

The MD Anderson Symptom Inventory (MDASI) is a concise measure that assesses the severity of cancer-related symptoms. Its key advantage lies in its succinct design, comprising only 13 symptom items and six measurements of interference with daily functioning.[74] MDASI is written in simple language, prompting patients to report symptom severity and activity interference on a scale of 0–10 for the past 24 h, unlike many other questionnaires that utilize a 7-day or 4-week recall period.[62,75,76] MDASI's simplicity is a notable strength, as it is written in easy-to-understand language, and a lower score consistently represents better QoL, enabling patients to swiftly report outcomes in less than 3 min, while other PROMs generally require >10 min to complete.[76] This enables frequent repetition, showcasing dynamic changes in QoL and recovery after surgery. Moreover, MDASI has expanded versions tailored to specific populations on the basis of cancer types and treatment regimens.[77] Currently, we are in the process of developing a novel version, MDASI-UGI-Surg, that is specifically designed for surgical patients with upper gastrointestinal cancers (esophageal, gastric, and pancreatic) undergoing major operations.

Due to the limitations inherent in cross-sectional studies, such as non-response bias and variability in the timing of reporting after surgery, there is a crucial need for studies that prospectively collect PROs at predefined intervals. Ideally, such studies should be incorporated into well-designed RCTs, but unfortunately, this is rare.

The Laparoscopic versus Open Gastrectomy for Gastric Cancer (LOGICA) study[54] in the Netherlands conducted an RCT comparing open versus laparoscopic gastrectomy for gastric cancer. The primary outcome assessed was the length of hospital stay, and PROs were collected using EORTC QLQ-30 and STO22, both before and at multiple time points after surgery, starting at 6 weeks up to 1 year. The results demonstrated equivalent safety, similar lengths of hospital stay (median, 7 days in both cohorts), R0 resection rates, lymph node yields, 1-year overall survival rates, and equivalent QoL measures, including functional and symptom scales at all time points. This study confirmed the equivalent safety of MIS gastrectomy in a Western population, although it failed to show the superiority of the MIS approach over open gastrectomy. With the established use of Enhanced Recovery After Surgery (ERAS) protocols, which have significantly shortened the length of stay in recent years, patients and physicians may not prioritize lengths of stay less than 1 week after major gastrectomy, regardless of the potential quicker recovery with MIS. The PRO benefits of MIS may manifest during a postoperative period shorter than 6 weeks.

The Leopard RCT compared open versus MIS (mostly laparoscopic) distal pancreatectomy.[44] In addition to short-term safety analyses, the trial reported QoL changes and comparisons during the 90-day period as well as at the 1-year follow-up.[78,79] The Leopard trial revealed a lower complication rate (Clavien–Dindo grade ≥III; 25% vs. 38%), a lower delayed gastric emptying rate (6% vs. 20%), a quicker functional recovery (defined as achieving independence in mobility and sufficient pain control with oral medication, maintaining more than 50% of daily required calorie intake, the absence of intravenous fluid, and no signs of infection; 4 vs. 6 days), and a shorter length of hospital stay (6 vs. 8 days) in the MIS group. However, the grade B/C pancreatic fistula rate was higher in the MIS group (39% vs. 23%), although the rates of those needing intervention were similar (22% vs. 20%). Patients reported using EQ-5D and EORTC QLQ-C30 before surgery and at 1, 3, 5, 14, 30, 90, and 365 days after the operation. A comparison of reported QoL between the MIS and open cohorts showed better scores in the MIS group during the first 30 days after surgery. However, there was no significant difference in QoL at 90 days and 1 year after surgery.

Considering the QoL data that result from prospective RCTs, it appears that the QoL benefits driven by quicker recovery after MIS approaches are likely limited to the early phase within 2–3 months after surgery. Further studies are needed to quantify the dynamic changes of QoL after surgery in both MIS and open cancer operations. Prospective studies investigating the benefits of oncological robotic cancer operations are lacking and needed and require frequent measurement of QoL to demonstrate an area under the curve visualization for the cumulative benefit of the MIS approach.

4.4 | Opioid epidemic in the United States and opioid reduction by robotic surgery

The opioid crisis in the United States has become a devastating public health issue, characterized by the widespread misuse of and addiction to opioid drugs. The crisis gained significant attention in the late 1990s and has since escalated into a major epidemic, with severe social and economic consequences; more than 1 million people in the United States have died since 1999 from a drug overdose.[80] There has been a significant and continued increase in synthetic opioid-involved overdose death rates, nearly 23 times from 2013 to 2021; these deaths accounted for 88% of all opioid-involved deaths in 2021, among which 21% were a result of medically prescribed opioids.[80,81] A post-surgical prescription is often patients' initial exposure to opioids,[82] and up to 10%–15% of opioid-naïve patients use opioids past the postoperative period.[83] The diversion of prescription drugs from legal sources to the illicit marketplace has been a widespread issue. In this context, minimizing opioid exposure and eliminating opioid prescriptions has substantial value to society beyond the benefits to patients after surgery.

ERAS is a multidisciplinary, evidence-based approach to perioperative care that aims to optimize the entire surgical process to enhance patients' recovery and reduce complications. The ERAS protocol has gained widespread acceptance in various surgical specialties over the past few decades. The integration of ERAS protocols into various surgical specialties has shown promising results in terms of improving patient outcomes, reducing hospital stays, and minimizing complications. Additionally, the emphasis on opioid reduction by promoting alternative multimodal pain management, aligns with broader efforts to address the opioid crisis by advocating for responsible and evidence-based pain management practices in healthcare settings. MD Anderson has led the evolution of ERAS in various surgical services for the past decade.[84–86] In addition to improved short-term outcomes and costs, we have reported significant opioid reduction after pancreatectomy and gastrectomy: the majority of patients do not require an opioid prescription at the time of discharge.[85,87]

MIS has consistently demonstrated a reduction in opioid use across various operations compared to open approaches, as reported in several studies.[88–91] However, limited data exist regarding opioid use after oncologic gastrectomy or pancreatectomy. Furthermore, with the widespread adoption of ERAS protocols in surgical oncology, which have already significantly improved short-term outcomes, including reduced hospital stays and opioid usage, a pertinent question arises: can MIS, particularly utilizing robotic approaches, further enhance these outcomes in complex surgical oncology operations? To address this, we investigated data from our robotic surgical oncology program during its implementation phase from 2018 to 2021, comparing outcomes after robotic and open gastrectomy and pancreatectomy. The results revealed minimized opioid use following robotic procedures, with a significant reduction compared to open approaches from postoperative day 1. Remarkably, a majority of patients undergoing robotic pancreatectomy and gastrectomy did not require opioid prescriptions at the time of discharge, despite having a shorter length of stay than did their open cohort counterparts.[92–94] These findings, observed at an institution where ERAS is fully integrated and postoperative care is meticulously managed with a focus on opioid reduction, underscore the potential value of robotic surgery in reducing post-gastrectomy and pancreatectomy opioid usage in these patient cohorts, and for society.

4.5 | Importance of precise cost estimation and reimbursement system considerations in determining the value of robotic surgery

One barrier to value-based care implementation is the difficulty of accurately estimating the costs of delivering patient care.[95,96] Conventional cost analyses in the United States using Medicare Cost Reports have substantial limitations. Such data are based on highly aggregate data for estimating costs and are flawed by the assumption that every billable event in a department has the same profit margin, burying the costs of valuable but non-billable events. Cost estimation for the Medicare Cost Report uses relative value units to represent a professional fee (including labor, practice expenses, and malpractice expenses) as part of operative costs, for which there are no relative value units (RVUs) assigned for robotic procedures. Moreover, RVUs were derived from specialty panels and national surveys of physicians, who stand to gain from overestimating the time and complexity of their work, which are not systematically measured or confirmed in practice settings.[96] The inability to properly measure cost is a fundamental issue that limits reliable cost-efficiency analyses and appropriate reimbursement and the effective building of strategies for healthcare cost reduction. In reality, the cost of resources, particularly the labor costs, depends on how much time is used, not on the charge or reimbursement for the service. Thus, we have been using time-driven activity-based costing for cost estimation at MD Anderson,[97,98] which estimates labor costs on the basis of the time used to provide care and an individual's salary. It calculates the individual resources used for the activity, a process that is carefully conducted by our institution's financial division using detailed costing data.

We conducted comprehensive cost analyses comparing robotic and open operations using time-driven cost allocation in pancreatectomy and gastrectomy. The primary outcome assessed was the total perioperative cost, representing the estimated amount the hospital paid for services during both the index hospitalization and the 30 days of postoperative care. Our analysis included the costs of the operation, postoperative inpatient care, and outpatient care, including readmission within 30 days from surgery. As expected, the operational cost increased significantly with the adoption of robotic surgery, consistent with previous reports.[24–26] This increase was attributed to the expenses related to acquiring and maintaining the robotic platform and longer operation times, leading to higher anesthesia, labor costs, and room charges. However, postoperative inpatient costs were notably lower in the robotic cohort, driven by shorter hospital stays and reduced ICU utilization, while outpatient care costs remained similar. Consequently, the total perioperative costs were comparable between the robotic and open surgery cohorts.

In the gastrectomy study, Bayesian generalized linear regression models estimated a 76.5% likelihood of an overall cost reduction with the robotic approach [Hirata Y, Lyu H, Azimuddin A, et al. *Ann Surg Open*. 5(1): p e396, 2024] In pancreatectomy, propensity score-matched analyses revealed a 16% reduction in total perioperative costs with the robotic approach, despite higher operating room costs [Manuscript under review]. This observation may be attributed to the high inpatient costs, particularly ICU costs, in the United States[99]; the increased costs of the operation with robotic surgery can be offset by a reduction of approximately 2 days in hospital stay length. Further studies are warranted for cost estimation in complex robotic surgical oncology operations in the United States and other countries with different costing proportions. These studies should include meticulous labor costing. Robotic surgery enables a reduction in the number of surgical assistants required, and effective use of robotic surgery systems reduces the robotic cost per use. Continued efforts should be made to minimize costs, maximizing the value of robotic surgery in each healthcare system.

4.5.1 | Value-based reimbursement models

The prevailing reimbursement system in the United States relies on the fee-for-service model, wherein healthcare providers receive compensation for each service or procedure performed. This model incentivizes providers on the basis of volume rather than the quality or efficiency of care.

Since its inception in 1983,[100] the diagnosis-related group (DRG)-based payment model has been widely adopted in many countries, such as the diagnosis procedure combination (DPC) model in Japan.[101] In the DRG model, providers receive reimbursement for the case-complexity-adjusted costs associated with providing medical care for a specific condition.[102] DRG payments do not hinge on achieving positive outcomes and may overlook vital support services that are crucial to overall value.[103]

In contrast, value-based reimbursement aims to incentivize high-quality care[16] and typically involves two primary payment models: capitation and bundled payments.[103,104] Capitation entails a fixed annual payment per covered life to healthcare organizations, obliging them to address the comprehensive needs of a diverse patient population. The bundled payment system compensates providers for managing a patient's medical condition across the entire care continuum, encompassing all services, procedures, tests, medications, and devices involved in the treatment of specific conditions, such as lower extremity joint replacement. Lower extremity joint replacement bundle payment programs have demonstrated reduced episodic spending and resulted in maintained or improved quality of care in patients.[105,106]

4.5.2 | Reimbursement models for robotic surgery

Reimbursement for robotic surgery varies significantly among countries. In South Korea, the government does not reimburse the use of robotic surgery platforms; however, healthcare providers are permitted to charge patients or private insurance systems directly for the additional cost.[107] In Canada, the public healthcare system does not fund robotic surgery, leading to patient access only when supported by research or philanthropic funds. This has resulted in delays in the implementation of robotic surgery in Canada.[108,109] In Japan, in contrast, the government has not only approved the use of robotics in various cancer operations for insurance coverage but also provides additional reimbursement. For instance, reimbursement for robotic or laparoscopic pancreatoduodenectomy is nearly double that for open surgery, and robotic gastrectomy receives additional reimbursement compared to the laparoscopic approach. However, the use of robotic approaches in complex surgical oncology procedures is tightly restricted to qualified institutions by academic societies.[110,111]

In the United States, Medicare and most U.S. private insurers currently do not pay separate or additional fees for the use of surgical robots.[2] The cost of robotic surgery is absorbed by hospitals, likely influenced by surgeons' strong preferences, patient demand, and competition among hospitals for market share.[112–114] A study utilizing insurance claim databases in the United States compared patient out-of-pocket costs and total payments by payers for robotic and open cancer operations (hysterectomy, nephrectomy, prostatectomy, and colectomy). The analysis included data from 15 893 patients, revealing a substantial reduction in out-of-pocket costs and total payments for all studied cancer operations with robotic surgery (e.g., −$728 out-of-pocket cost and −$38 151 total payment for partial colectomy).[114]

The optimal reimbursement model for robotic surgery remains uncertain. However, in the U.S. payment model, which lacks specific robotic cost reimbursement, robotic surgery has flourished amid value-based competition. While profitability remains a significant driver for the rapid adoption of robotic surgery,[115] studies have indicated that institutions that use surgical robots have experienced a notable surge in surgical volume, facilitating the desired centralization of surgical procedures.[18,116,117] The more frequent use of the robotic surgery platform can mitigate acquisition costs, and the increased volume enhances the net profit of the hospital. Robotic surgery has been reported to be cost-effective for high-volume centers and surgeons.[118,119] Additionally, particularly for procedures that had previously been performed as open surgery, such as complex pancreatectomy and gastrectomy, costs can be offset by reductions in postoperative hospital costs and by productivity gains if patients recover more rapidly and have shorter hospital stays, as the DRG-based payment system pays a fixed amount for inpatient care, regardless of the length of hospital stay.

4.6 | Financial toxicity in cancer patients and potential benefits of robotic surgery

In cancer treatment, the term financial toxicity (FT) describes the negative impact of rising healthcare costs on the overall well-being of patients.[120] FT encompasses a range of financial challenges, including medical and non-medical (such as travel to receive care at a specialized cancer center) out-of-pocket expenses, lost wages due to treatment-related work disruptions, and the overall financial strain experienced by patients and their families. The resulting financial burden often leads to increased debt, depletion of savings, and challenges in meeting daily living expenses. Research has indicated that bankruptcy rates among cancer survivors are 2.5 times higher than those among peers without a history of cancer.[121] FT is known to influence decision-making among cancer patients and may be associated with poor treatment adherence.[122,123]

FT among cancer patients is typically evaluated through survey studies utilizing the Comprehensive Score for Financial Toxicity (COST) questionnaire.[124,125] This tool encompasses questions covering various aspects of financial hardship, including out-of-pocket expenses, income changes, and distress related to financial concerns. The scoring ranges from 0 to 44, where lower values indicate higher levels of treatment-induced financial distress. FT is often defined by a COST score below 26.[125] The incidence of FT has been shown to be correlated with overall QoL.[126–128] After major gastrointestinal operations such as gastrectomy and pancreatectomy, patients often experience long-term gastrointestinal dysfunction and reduced QoL.[129,130] Patients' perception of their financial status can be significantly influenced by impaired QoL and mental health.

In our survey study assessing patients who underwent pancreatectomy and gastrectomy for cancer at MD Anderson, an unexpected 48% of respondents reported experiencing FT. Those with FT were more likely to be under 50 years old, non-Hispanic White, working for payment before surgery, and have household incomes below $75 000 or credit scores below 740 or unknown than were those without FT. Furthermore, a longer hospital stay and extended time off from work for patients or their caregivers were associated with FT. On multivariable analysis, being under 50 years old and having a credit score below 740 or unknown were linked to a higher risk of FT, while the use of robotic surgery was found to be protective against FT [ref: unpublished]. Robotic surgery has the potential to alleviate FT among cancer patients undergoing surgery by reducing out-of-pocket medical costs.[114] Quicker recovery facilitates a faster return to work and increased productivity,[131] particularly in comparison to open surgery. The protective effect of robotic surgery against FT may be more pronounced among younger, working patients.

5 | FUTURE STUDIES OF ROBOTIC SURGICAL ONCOLOGY IN VALUE-BASED CARE

Recent reports have consistently highlighted the enhanced oncological quality of robotic operations compared to laparoscopic approaches, indicating improvements in R0 resection rates and lymph node yield, and leading to the widespread adoption of robotic surgery for minimally invasive complex gastrointestinal cancer operations. However, there have been no extensive large-scale randomized trials examining robot-assisted surgery's effectiveness in gastrectomy or pancreatectomy for cancer diagnosis. The available observational evidence is limited and does not conclusively demonstrate that the long-term outcomes of robot-assisted surgery surpass those achieved through conventional open procedures.[2] To delineate the value of robotic surgery in complex cancer operations, upcoming studies should prioritize outcomes from the patients' perspective, surpassing the focus on “non-inferiority” in survival.

Surgeons, driven by individual and societal efforts,[132] continually enhance the oncological quality of operations, including those robotic operations.[133] Furthermore, prospective studies, ideally incorporating an RCT design and data collection that has been seamlessly integrated into routine surgical oncology practice, should persist in investigating the postoperative QoL benefits of robotic surgery. As per the aforementioned study results, the QoL advantage of robotic surgery over the open approach may be confined to the initial 2–3 months after surgery. Therefore, frequent PRO assessments after surgery are imperative to quantify cumulative benefits by visualizing dynamic changes in QoL over time. While the benefits may be short-term, the accelerated recovery in QoL, synergizing with advanced ERAS protocols, facilitates a quicker return to work. This not only mitigates FT for working patients but also ensures a more consistent, quicker RIOT. RIOT, reflecting adequate QoL recovery after surgery, presents a robust oncological benefit, particularly in cancer types with established advantages of adjuvant therapy, such as pancreatic and gastric cancers.

The comparison of value between laparoscopic and robotic approaches for cancer operations is indeed an intriguing topic. Currently available data from index studies often combines outcomes of both laparoscopic and robotic approaches, making it impractical to define value separately. When laparoscopic surgery is safely performed by experts with trained assistants to achieve high-quality oncological operations, the use of a robotic platform may not necessarily add additional value. However, the technical advantages provided by advanced surgical robots likely enable a higher number of surgeons to achieve similar quality operations, potentially with a shorter learning curve period. In the United States, including our center, the current practice has largely shifted towards robotic approaches. Many surgeons "skip" laparoscopic experience and its associated learning curve period before implementing robotic approach to complex gastrointestinal cancer operations. The relative value of robotic surgery compared to laparoscopic approaches is also influenced by factors such as the relative cost of the robot compared to other aspects of surgical care, such as personnel salaries and hospital stay expenses per day. The cost of surgical robots is also expected to change as more industries venture into this field. Future global studies investigating the values of laparoscopic and robotic operations across different countries and medical expense backgrounds are warranted.

Ongoing efforts will persist in enhancing the centralization of complex cancer treatment, including surgery. Public reporting of hospital performance evaluations, such as U.S. News Ranking and Vizient,[134–136] naturally drives patients to seek healthcare at top-rated hospitals with reported better outcomes. The volume-outcomes relationship continues to exist, especially for highly specialized operations such as robotic surgical oncology.[137] A high volume of such specialized cases not only improves outcomes but also enhances the efficiency of robotic operations and postoperative care, thereby reducing the cost per case. Cost analyses remain critical as part of the value evaluation of robotic surgical oncology. These analyses should encompass hospital costs, insurer's payments, as well as patients' medical and non-medical out-of-pocket costs. Additionally, societal impact, including patients' and families' return to work, associated productivity, and the reduction of opioid prescriptions, should be considered. The implementation of a value-based reimbursement model in surgical oncology, aligning financial incentives with the delivery of high-quality, cost-effective care, may further facilitate the future utilization of robotic surgery. This approach is geared towards providing patient-centered healthcare, enhancing the decision-making process, and tailoring care plans to individual patient needs and preferences.

6 | INNOVATION AS A VALUE

Innovation itself holds intrinsic value, particularly in technological advancements that pave the way for further innovations. Robotic surgery platforms, marked by their console design, stable vision in controlled environments, and the ability to track surgeons' motions, serve as a foundation for integrating various future technologies. An illustrative example is the built-in fluorescent imaging technology, such as FireFly in the DaVinci Xi platform by Intuitive Surgical. With a simple click, this technology activates fluorescent imaging, facilitating guided surgery for enhanced anatomical localization and sentinel lymph node mapping. The widespread adoption of fluorescent imaging systems stimulates the development of molecularly targeted fluorescent agents, contributing to improved tumor localization.[138,139]

A significant leap in future generations of robotic surgery platforms will undoubtedly involve artificial intelligence (AI) technology, ultimately aiming for automated surgery. Technologies for analyzing surgical videos are emerging that may guide surgeons in oncological dissections to enhance surgery quality and reduce complications.[140–143] Techniques such as 3D reconstruction of preoperative CT scans provide surgeons with valuable guidance for preoperative planning,[144] and integrating these images into the robotic surgery console's view is a foreseeable advancement. In the future, we may witness the incorporation of these images into the actual surgical field, utilizing augmented reality or overlay imaging. AI-driven tracking and quantification of a surgeon's movements can evaluate technical efficiency, aiding in surgical skills assessment, scoring, and potential feedback.

Such AI-driven skills evaluation and feedback technologies have the potential to standardize surgical techniques, equalize operative quality, certify surgical proficiency, minimize learning curves, and educate future generations. Preliminary studies have already demonstrated that AI outperforms humans in simple procedures such as suturing.[145] The accumulation and maturation of these technologies may enable intraoperative guidance and partial or complete automation of procedures in cancer operations. Last, there is a growing trend and interest in robotic surgery among young surgeons across various fields. The value of having a robotic surgery program is immense, particularly in academic hospitals with residency/fellowship training programs,[146,147] as they play a pivotal role in shaping the future of robotic surgery.

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ETHICS STATEMENT

Approval of the research protocol: N/A.

Informed Consent: N/A.

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