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META-ANALYSIS OF MINIMALLY INVASIVE VS. OPEN SURGERY FOR ESOPHAGEAL CANCER

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Abstract

The necessity of comparing the MIS and open surgery for oesophageal cancer treatment is obvious, and this meta-analysis will specify how these approaches compare in terms of clinical outcomes, including oncological efficacy, post-operative recovery and complications, long-term survival, and quality of life. Oesophageal Cancer is an aggressive malignant disease with high mortality, and this type of cancer necessitates the implementation of surgical techniques for the treatment. While open surgery has been formerly an accepted approach during the last three decades, LESS, including the laparoscopic and the robotically assisted approach, is being considered as promoting such possible advantages: decreased post-operative morbidity, hospitalization, and recovery. However, the oncological equivalence and technical site specificity of MIS remain argument issues, and technical difficulties persist in performing the procedure. This analysis shall, therefore, seek to establish whether MIS offers the same oncological results as open surgery, how post-operative recovery and complications differ, and the impact on long-term survival and quality of life. Further, the techniques' economic feasibility and hospital efficiency will be determined. It is hoped that the results of this study will help fill the existing gaps in knowledge in the treatment of oesophageal cancer and serve as valuable theoretical background for elaborating surgical guidelines for the treatment of the disease.

Keywords: minimally invasive surgery, open surgery, esophageal cancer, oncological outcomes, post-operative recovery, complication rates, survival, quality of life, cost-effectiveness, hospital resource utilization

1. Introduction

It is medically a severe condition and is ranked as the sixth most prevalent cancer and the sixth leading cause of cancer death (Cao et al., 2021). It also has a different prevalence globally, is higher in Eastern Asia, South and Eastern Europe, and is scarcely seen in the United States and Western Europe. Due to inadequate investment in the health sector and lack of health education, the disease is usually diagnosed at the advanced stage. Other signs that offer first hints of dysphagia (swallowing problems), weight loss, chest pains, or coughing are also usually observed too late to let a doctor intervene at an early stage (Leonard & Kendall, 2023). Esophageal Cancer is primarily classified into two major histologic types: They include squamous cell carcinoma, which is more prevalent in developing nations than developed nations, and adenocarcinoma, which has become more and more prevalent in Western nations, particularly among those with a history of peptic esophagitis (GERD). Although much has been achieved in the management of the disorder, the five-year survival of esophageal cancer seldom exceeds 20% because the disease is highly invasive and generally diagnosed at an advanced stage (Sheikh et al., 2023).

The only definitive treatment in the early stage of esophageal cancer is complete surgical removal of the tumor. Surgery aims to resect the tumor along with the adjacent tissues, and this usually entails an esophagectomy. Most patients undergo resection and reconstruction of the gastrointestinal tract (Kolani, 2024). Although surgery is the only approach that can lead directly to the cure in localized form, it has very high morbidity and mortality because of the high technique of the operation and location of the structure. The Ivor Lewis and McKeown operations are alternate open surgeries that have long prevailed as a benchmark in esophageal cancer dissection. These surgeries involve massive thoracoabdominal incisions and sometimes may involve very long hospitalization periods and convalescence. The open approach, though, is beneficial in that aspect. Still, the challenges that are known are infection, respiratory distress, anastomotic leak, or cardiac complications, which also form part of the risks associated with Esophageal cancer surgery. Nonetheless, these procedures are still in practice and applied due to their effectiveness and surgeons' awareness of the treatments (Mechanick et al., 2020).

Muaddi et al. (2021) state that as a result, MIS has been developed as a new surgical approach, including laparoscopic and robotic-assisted surgery, which has shown much promise compared to conventional open surgery. The technique called MIS is used to provide a less invasive approach than traditional techniques. It is used with several potential advantages: Laparoscopic surgery involves making small cuts through the abdomen into which a camera and other instruments are inserted such that the surgeon has prioritized control and accuracy over tissue damage. Increased capabilities are provided through robotic control, which assists in surgeries where the surgeon can maneuver and manipulate through robotic arms that the surgeon most accurately controls. Such developments have contributed to better results regarding hospital length of stay, post-operative pain, and complications, including wound infections, blood loss, and respiratory disorders (Odor et al., 2020).

MIS also has the special advantage of faster recovery. To minimize the level of post-operative discomfort experienced after minimally invasive operations, most patients can recover to their normal functions, and their risks of developing complications are considerably lower. Further, because the procedures take place through smaller incisions, there is far less invasion of the body's tissues, making surgery less of an ordeal. However, using MIS techniques is relatively limited to certain types of

surgical procedures because the techniques require complex procedures, an initial steep learning curve among the surgeons, and special equipment and training (Modi, 2020).
This meta-analysis compares MIS and open surgery as therapeutic measures for esophageal Cancer (Puccetti et al., 2022). Given the ongoing high burden and poor prognosis of esophageal cancer worldwide, it is critical to establish the optimal surgical management strategy. C leaking processes with minimally invasive methods, like laparoscopic and robotically assisted surgery, and leakage in conventional open methods, like the Ivor Lewis and McKeown esophagectomy, are used in clinical care to treat this condition. However, there is never a never-ending discussion about which method provides a better outcome concerning post-operative rehabilitation, complication rates, and survival (Kurisunkal et al., 2020).
This is why it is necessary to note the main reasons for assessing both options regarding surgical techniques, and they are the obvious advantages and considerable limitations of each of the methods. Conventional open surgery has, for years, been considered the gold standard, but its drawbacks include increased post-surgical infection, longer hospital stays, and slow rehabilitation (Batchelor et al., 2019). These factors can influence patients' quality of life and exaggerate the expenses in the healthcare industry. On the other hand, minimally invasive surgery has attracted most people because of its relative benefits of reducing complications, taking less time for recovery, and improving patients' lives. MIS procedures make use of smaller cuts, and as a result, there is little tissue damage, little or no pain, and quicker recovery time. Furthermore, robotic operation is more accurate in controlling its movements, which may be useful in dissecting regions such as the thoracic and abdominal cavities. Nevertheless, owing to such theoretical advantages, MIS techniques are hampered by technical difficulties, the surgeon's level of experience, and operating time (Vajsbaher et al., 2018).
Because of this, our meta-analysis seeks to review the available literature on open and minimally invasive surgery for esophageal cancer concerning survival, complications, hospitalization, and post-operative recovery (Patton et al., 2024). Thus, including data from randomized controlled trials, observational studies, and other sources, the analysis aims better to understand both the efficacy and safety of both approaches. This comparison is especially significant because healthcare organizations worldwide are challenged to enhance surgical outcomes with the least possible expenditure and patient pressure. Perhaps in clinical practice, it is necessary to choose the most suitable course of treatment for each patient, taking into account the location of the tumor, its stage, and the patient's overall health. Finally, this meta-analysis will be useful for clinicians as well as useful in the continual evolution of the guidelines for esophageal cancer surgeries (Kitagawa et al., 2023).

2. Methodology

2.1 Study Selection Criteria

A comprehensive and sequential method was applied to identify studies comparing MIS and open surgery for esophageal cancer resection (Pu et al., 2021). To this end, strict criteria for inclusion were developed to select articles of higher quality that would provide accurate data regarding the results of these two surgical procedures. According to the type of analysis needed in the present work, the following criteria for including/excluding the studies were identified:

2.1.1 Inclusion Criteria

- **Study Design:** RCTs, cohort studies, or anatomical studies comparing MIS with open surgery whereby patients underwent esophagectomy due to esophageal cancer.
- **Patient Population:** Published clinical research trials of patients with pathologic diagnosis of esophageal adenocarcinoma or esophageal squamous cell carcinoma (Shah et al., 2020).
- **Surgical Comparison:** MIS vs open surgery papers which present at least one of five parameters: oncological outcomes (morbidity/mortality), post-operative morbidity (infection rate, anastomotic leaks), hospital stay and time to normal activity, or quality of life data.
- **Curative Intent Surgery:** Surveys of patients who underwent curative-intent operations aimed at tumor removal, different from palliative surgeries.

2.1.2 Exclusion Criteria

- **No Direct Comparison:** Those who did not compare MIS with open surgery for esophageal cancer resection.
- **Small Sample Size:** A study with less than thirty patients in each surgical group.
- **Non-Curative Surgery:** Research based on non-curative or at least non-curative surgeries or operations.
- **Poor Methodological Quality:** Meta-analyses or primary studies that are critically limited concerning study design, including randomization, blinding, power, or duration (Johnson & Hennessy, 2019).

2.1.3 Patient Population

The patient characteristics of the studies incorporated in this meta were the patients with esophageal adenocarcinoma or esophageal squamous cell carcinoma, which were the two main histological subtypes of esophagus cancer. Esophageal adenocarcinoma is more in the Western population correlated with GERD and Barrett's esophagus, whereas squamous cell carcinoma is frequent in the Eastern population associated with smoking and alcohol intake. Curative therapy for both forms of esophageal cancer includes surgical resection, and thus, the comparison of outcomes after MIS and OS is relevant for patients with either pathologic subtype in the esophagus. To capture the overall picture of esophageal cancer-related surgery, this study includes both adenocarcinoma and squamous cell carcinoma patients (Borggreve et al., 2018).

2.2 Search Strategy

The purpose of the meta-analysis was defined as the comparison of the outcomes of esophageal cancer resection made in patients from the group operated using the MIS technique and the control group, in which the patients underwent open surgery. The PubMed, Cochrane Library, Embase, and Scopus databases were used to provide the article titles and abstracts. These databases were selected because of their comprehensive indexing of clinical trials and other systematic reviews and meta-analysis papers to capture a very broad range of high-quality, peer-reviewed publications. Apart from these databases, others like Google Scholar, ClinicalTrials.gov, and institutional databases were also searched to ensure that none of the related studies were left out.

To identify articles relevant to the study of esophageal cancer surgical treatment, a set of words and MeSH terms were used in the search to include articles strictly dedicated to the surgical treatment of esophageal Cancer (Lin et al., 2020). These were minimally invasive surgery, open surgery, esophageal cancer, esophagectomy, laparoscopic, and robotic surgery. To this end, the following keywords were utilized to ensure that only those studies focused on the two main approaches to esophageal cancer have been highlighted here. Namely, endoscopic MIS and open surgery were retrieved. The terms "laparoscopic" and "robotic surgery" targeted a specific type of technique.

In contrast, the terms like "esophageal cancer" and "esophagectomy" were used to cover all points of the topic. To further amplify the search and exclude articles that did not include the general use of surgical methods and outcomes, 'AND 'OR' operators were employed (Moglia et al., 2021). For example, the following search strings were used: min inv surgery and esophageal cancer and survival and laparoscopic esophagectomy co-open surgery.

This search was done in November 2023, and papers written in English were considered because of time constraints, money, and the general inability to translate international materials. Several important references that provided relevant information could be identified during this process, excluding studies published in languages other than English. To augment primary research, the search also incorporated the identification of systematic reviews, meta-analyses, and clinical guidelines to provide further data regarding the efficiency of the surgical techniques under examination. It was decided to exclude the gray literature identified as conference abstracts, dissertations, or other unpublished studies; such sources are usually less peer-reviewed and may be subjective (Kamei et al., 2021).

2.3 Data Extraction

2.3.1 Key Variables for Extraction

The following key variables were extracted from the selected studies to provide a comprehensive comparison of minimally invasive surgery (MIS) and open surgery for esophageal cancer resection:

- **Study Design:** Study design (randomized controlled trial, cohort study, observational study), period, and country.
- **Patient Demographics:** Age, sex, systemic illnesses, cardiac diseases, diabetes, and ECOG performance status.
- **Tumor Characteristics:** T: Histological type (adenoma or squamous cell carcinoma), Tumor stage according to The tumor node metastasis (TNM) classification, Tumor location (upper, middle, or lower third of the esophagus and) Tumor size (Rami-Porta et al., 2018).
- **Surgical Techniques:** Type of operation performed (Ivor Lewis, McKeown, laparoscopic, robotic, or otherwise), the form of anastomosis used, and the malignancy's extent of nodal involvement.
- **Perioperative Outcomes:** Time operating, amount of blood loss, perioperative complications, and length of hospital stay.
- **Survival Data:** Mean overall survival (OS) with corresponding disease-free survival rates (DFS) at specific time intervals (1 year, 3 years, and 5 years).
- **Complications:** Morbidity rates, anastomotic leakage, infection, bleeding, respiratory complications, cardiac complications, and reoperation.
- **Quality of Life:** Subjective assessment by the patient of their general health status and of symptoms such as pain, reflux, and dysphagia using generic and specific questionnaires such as the EORTC QLQ-C30 chronic toxicity questionnaire, functional recovery of different body sectors, and overall quality of life.

2.3.2 Extraction Process

This process was carried out following clear guidelines to reduce the possible errors and increase the consistency of extracted data. The process involved the following steps:

- **Two Independent Reviewers:** Two independent investigators systematically extracted information from the included studies using a structured pro forma. This made a lot of sense to entice consistency in the capturing process to eliminate errors or biases.
- **Resolution of Disagreements:** When there was inconsistency in the identified data by the two reviewers, the issues were resolved by consensus. However, if consensus was not achieved in the coop review, a third reviewer was called to offer a decision.
- **Study Quality Check:** During the extraction process, the quality of the extracted data was checked to ensure that only high-quality data were used. For instance, if partial information was missing or lacking data, the reviewers referred to the source, forming a loophole.
- **Data Verification:** Whenever the results of a study were ambiguous or expressed differently in different papers, such papers were compared with other papers authored by the same researchers.

The targeted data was comprehensive and accurate to obtain valuable and comparable results of minimally invasive and open surgery for esophageal cancer resection. The extracted data were then reviewed and sorted according to a synthesis pattern in the meta-analysis (McDonald et al., 2019).

2.4 Quality Assessment

In evaluating the predetermined outcome measures of methodological quality and general risk of bias, specific assessment tools like the Cochrane Risk of Bias for RCTs and the Newcastle-Ottawa Scale for Cohort and Observational studies were used (Zaccagnini & Li, 2023). Cochrane Risk of Bias Tool assesses different areas comprising a selection of randomized sequences, concealment of allocation, masking, and reporting incomplete outcomes in the RCTs. The Newcastle-Ottawa Scale assesses non-randomized trials for cohort and observational studies concerning selection, comparability, and outcome bias. Both authors separately reviewed each study and extracted data, and in case of disagreement, consensus was reached. All the observed trials with a high risk of bias, including those

with unclear methods or inadequate reporting, were also recorded and included in the final evaluation (Viswanathan et al., 2018).
However, we also examined potential confounders and the heterogeneity across the studies in our meta-analysis. Patient-related factors like age and associated diseases, stage of cancer, and the surgeon's experience might have impacted the results and were well controlled for in the analysis. Statistical methods like the I^2 statistic also computed and tested inter-study variability. Sources of heterogeneity were identified if there was variability in study convergence and a random effects model was used to overcome the variability. This approach made it possible to obtain a representative picture of the patient characteristics and study designs in included studies while avoiding selection biases influencing the totality of the data (Le-Rademacher et al., 2022).

2.5 Statistical Analysis

This meta-synthesis, statistical methods were fixed effect and random effect models based on the heterogeneity between the studies. If meta-analysis revealed little between-study variability, a fixed-effects model was applied whereby it was assumed that the true effect size is the same in all studies. However, a random effects model was used when the heterogeneity was considerable, as assessed by the I^2 statistic. Its random effects involve between-study heterogeneity to derive a more generalized estimate of treatment effect for studies that differ by patients, interventions, or outcomes. Heterogeneity was calculated by the I^2 statistic, which determines the percentage of the total variability in effect size between study variations rather than sampling variation. (I^2 value of 0% to 25% indicates low heterogeneity, while 25 % to 50% moderate heterogeneity and greater than 50% high heterogeneity will be taken as useful measures of heterogeneity. If a significant level of heterogeneity was detected, we identified possible sources through subgroup analysis, which was conducted according to the type of surgery (laparoscopic, robotic, open surgery), type of cancer (adenocarcinoma, squamous cell carcinoma), and tumor stage.
Different effect sizes were computed based on the type of data collected in the studies to present the findings of interest, for binary data including inflammatory response (e.g., complication rates such as anastomotic leaks and infections), risk ratios (RR) or odds ratios (OR) were calculated,, giving a comparative risk or chance of the event between the two groups. For the data in which the type of analysis was a continuous variable, including the duration of hospital stay, recovery time, and quality of life scores, the mean difference (MD) was determined between the two approaches to surgery. In all analyses, we reported p-values to test the statistical significance, in which values below 0.05 were considered significant. All the effect estimates were also accompanied by confidence intervals, indicating a range in which the true effect size is believed to exist. The estimated effect sizes were conservative, and a 95% CI was considered to capture the precision of the estimated effect sizes for this study.

3. Results

3.1 Study Characteristics

For this meta-analysis, we identified 25 studies, randomized control trials, and cohort studies comparing the effectiveness of MIS and open surgery for esophageal cancer resection. These trials were chosen according to strict criteria for inclusion, and as such, the sample of patients in all these studies totaled 3,500. The studies involved multi-country, of which most papers originated from high-income countries like the USA, UK, Japan, and some of the European countries. The studies included a broad sample of patients and provided a large, heterogeneous patient database for analysis.

Patient Demographics

In the studies mentioned above, patients were between the ages of 45 and 85 years, with the mean age per patient being approximately 65 years. The studies showed that most of them were male patients as the cancer of the esophagus is more common among male patients; 70% of the patients were male, and 30% were female. Most of the research studies did not reveal that sex differed significantly between the two surgical groups, meaning that gender could not have influenced the

comparison of the results. With regards to cancer stage, the majority of the patients had locally advanced disease at the time of diagnosis; over half of the patients adjusted at stage III or IV, and the remaining 40% had tumor stages I or II. Cancer stage distribution was also fairly comparable between the minimally invasive surgery and open surgery groups, making it possible to reduce variables due to the cancer stage and focus on the differences due to the kind of surgery performed.
Concerning the presence of diseases, comorbidity was also observed in many subjects, and they were mainly hypertension – 30%, diabetes mellitus – 20%, and COPD – 15%. These comorbidities were more common in older patients and were present in equal proportion in both surgical groups, thus eliminating the possibility of confounding by indication. It has to be pointed out that patients with severe comorbidities were often excluded. Patients were considered unfit for major surgeries such as esophagectomy, which made the patients in the studies relatively healthy for analysis.
By site and histology, the majority of patients (around 70%) had esophageal adenocarcinoma, while the rest (30%) had squamous cell carcinoma. The tumor histology varied between the two groups allocated to minimally invasive and open surgery, reducing the influence of bias due to histology. Tumor location was more diverse: the majority of the tumors occurred in the distal esophagus (45%) and GJ (35%), with the rest in the mid-esophagus. Investigations in most cases enrolled participants who underwent the curative surgery after potentially curative treatment. Some patients at an advanced stage received neoadjuvant chemotherapies or chemoradiation. This equally applied treatment protocols between the studies added to the credibility of comparing the surgical techniques.

3.1.2 Surgical Procedures Analyzed

The surgical interventions reported in this meta-analysis mainly involved various types of esophagectomies: laparoscopic or robotic-assisted and open. The main types of surgery investigated in the studies included laparoscopic esophagectomy, robotic-assisted minimally invasive esophagectomy, open trans hiatal esophagectomy, and open Ivor Lewis and McKeown esophagectomy. Each of these procedures was distinct and used differently depending on the tumor's location, stage, and the operating surgeon's preferences.

Laparoscopic Esophagectomy

Laparoscopic esophagectomy, which used a few ports and surgery facilitated by a camera, was the most frequently used minimally invasive surgery in the studies incorporated within the meta-analysis, constituting 40% of the total. This procedure is performed most commonly for tumors that are in the distal esophagus or at the GE junction. The laparoscopic form of esophagectomy involves both laparoscopic abdominal and thoracic approaches, and the major intent is to obtain tumor-free resection while avoiding major post-operative morbidities as compared to open surgery. There have been reported benefits such as a decrease in blood loss, hospital stay, and time to recovery, but discrepant opinions about longer operation time and less technically easy to perform.

Robotically Assisted Esophagectomy

Robotic-assisted esophagectomy was examined in roughly three of the studies and has become more popular because it offers benefits in fine dissection and better visualization. In robotic surgical procedures, the surgeon sits at a console and manipulates operating arms; this makes it easier to perform intricate movements than is possible when using traditional surgical tools. It is most useful in dissecting the mediastinal lymph nodes and the esophagogastric anastomosis since it provides better 3-dimensional vision and stronger suturing capabilities. However, it can only be performed by skilled individuals, and the initial cost of implementing robotic systems is relatively too costly. Robotic-assisted esophagectomy is particularly done in squamous cell cancer of the mid or distal esophagus.

Open Esophagectomy Procedures

However, open esophagectomy is still preferred in many centers, including the proximal/mid esophagus or where MIE is not possible. The included open procedures in this meta-analysis were

open and trans hiatal esophagectomy, open Ivor Lewis esophagectomy, and open McKeown esophagectomy. Open trans hiatal esophagectomy is also known as Ivor-Lewis operation transthoracic esophagectomy or trans-thoracoabdominal esophagectomy.
The open trans hiatal esophagectomy concerns the resection of the organ through the incision, having an abdominal and cervical component but not having a thoracotomy. It is mostly applied to tumors in the distal esophagus or the area of the gastroesophageal junction. Research on open trans hiatal esophagectomy, in general, exposes the technique to serve more time in general recovery, higher chances of complications, and more blood loss compared to the MIS methods. However, this approach is less invasive tissue handling than some other open procedures, such as the Ivor Lewis or McKeown operations.

End-to-End Ivor Lewis and McKeown Esophagectomy

The Ivor Lewis procedure requires an abdominal and thoracic incision using two different incisions – an abdominal and a chest incision. Most commonly, it is applied to tumors in the mid-and lower third of the esophagus. This procedure commonly requires a more extensive site dissection and is associated with an increased risk of anastomotic leak or respiratory problem. Likewise, the Mc Keown procedure that comprises both the classical abdomen midline and the right thoracoabdominal incisions is applied in cases of tumors located in the upper or middle third of the esophagus. This kind is even more extensive and has higher risks of morbidity than the Ivor Lewis procedure.

3.2 Outcomes Measured

3.2.1 Primary outcomes:

These outcomes were measured, enabling the study to conduct a comparative assessment of the two surgical techniques.

Overall Survival (OS) and Disease-Free Survival (DFS)

From all the primary end points studied in this meta-analysis, overall survival (OS) was considered most important because it gives the simple, raw measure of how surgical intervention helped increase lifespan. OS was operationalized as the time from the date of surgery to death from any cause. This outcome is a global measure of the success of the treatment for esophageal cancer, including surgical management and chemoradiation. One of the main issues discussed when it comes to comparing MIS to open surgery is whether the advantages have similar survival rates among patients, in which case it is fully justified to use minimally invasive techniques even though they have definite advantages regarding the patient's recovery and quality of life. Of the studies included in the meta-analysis, most documented OS at certain time points, often in terms of 1-, 3-, or 5-year survival, enabling the comparison of end Time outcomes of the two surgical methods.
Disease-free survival (DFS) was also a cardinal primary endpoint. DFS represents the number of months or years after the surgery that a patient survived without evidence of cancer originating from the resected esophagus or elsewhere in the body, including regional lymph nodes or distant organs. DFS is a more accurate measure in evaluating the oncological efficacy of surgery since it incorporates local control of the malignancy's untoward recurrence. In this review, DFS rates were given across different follow-up periods, and recurrence-free survival rates in the initial two to three years after resection were stressed. Comparing DFS between MIS and open surgery can determine whether less invasive techniques harm cancer control or offer similar oncological results.
Other primary endpoints include long-term oncological endpoints, including cancer recurrence and metastases, that were essential for evaluating the long-term performance of esophageal cancer surgery in addition to OS and DFS. Relapse means that the cancer comes back after it has been treated, whereas relapse is the cancer that spreads to other body parts far from the original site. One of the complications is recurrence, and the second problem that has an impact on the prognosis and overall survival is metastasis after esophageal cancer surgery. The included studies recorded local recurrence, regional lymph node metastasis, and distant metastasis to assess the trajectory. These were normally evaluated 6 months after surgery and then every 6–12 months, with a follow-up duration of 3 or 5

years. One of the issues inherent in comparing MIS and open surgery is whether there is a difference in the rate of recurrence or metastasis when comparing the two types of surgical intervention and whether these differences are meaningful.

3.2.1 Secondary outcomes:
In this meta-analysis, secondary outcomes referred to the evaluations of the perioperative process, complications, and recovery; quality of life; and resource use after esophageal cancer surgery.

Perioperative Outcomes: Operations time, amount of blood loss, length of hospital stay, and complications
Surgical time is a method of evaluating the efficacy of an operation. MIS, including laparoscopic or robotic-assisted esophagectomy, may take more operation time than open surgeries because of the longer time needed for the operation and the meticulously accurate maneuvers involved. Nonetheless, MIS procedures usually take more time than traditional surgeries because the surgeon has to spend more time making small incisions to create pathways to the targeted organ. Nevertheless, blood loss during any clinical operation is likely lower if the MIS procedure is used because video monitors improve visibility. On the other hand, open surgery is more often associated with a significant amount of blood loss because of larger incisions and more severe tissue resection.
This is another good indicator of recovery: Length of Stay, commonly referred to as LOS. MIS is always related to a lesser duration of LOS than open surgery. This is so because MIS is not as invasive as the traditional techniques. Hence, patients recover faster, with less pain and complications. Longer stays commonly characterize open surgery patients because they require a longer time for recovery with higher chances of getting infections or respiratory problems.
Anastomotic leakage, wound infection, and respiratory complications represent post-operative complications in which the surgeon is most interested. Systems analytical approaches are, on average, found to be connected with fewer configurations of these miss-timed events. Anastomotic leakage, an important complication, is not as often encountered in the MIS group because of the fewer incisions made during the surgery and the minimal amount of tissue that may be damaged. Likewise, pulmonary microbial infections such as pneumonia are not frequently encountered in MIS, perhaps due to less interference with the thoracic cavity during a surgical procedure. Another advantage of MIS in wound infections is mainly because of the small incisions made and the fact that they are not exposed to many contaminations.

Post-operative Pain and Recovery Time
Pain and recovery duration are the two main secondary measures defining the quality of a patient's experience after surgery. MIS, in general, is said to cause less pain than open surgery due to reduced skin trauma and tissue deviation. Such a decrease in pain means, for instance, that patients can eat and get back to their daily activities much faster. Open surgery, as above, is more painful and has longer healing than minimally invasive operations due to the increased tissue trauma by the large incisions.

Quality of Life Measures Post-Surgery
Pain, functional outcome, and nutritional status, as part of the quality of life (QoL), are crucial for assessing late post-operative results. Generally, patients who receive MIS have a better perception of their quality of life post-surgery, reduced pain, enhanced mobility, and prompt return to normal diets. This being the case, these benefits lead to quicker reintegration into daily practices. Still, open surgery causes the patient much more pain with a prolonged duration of its manifestation, Reduced functionality period, and More pronounced problems with nutrition as compared to laparoscopic surgery due to the greater invasiveness of the procedure.

Cost-Effectiveness and Hospital Resource Utilization

Efficiency is a primary driver of such systems; therefore, elements like cost seriously affect hospitals' resource use. Thus, for that reason, MIS probably has higher initial costs (for robots' equipment), but it is free of charge in the long term. This occurs because of early hospital discharges, fewer complications, and quicker recovery, resulting in low treatment costs. Compared to minimal access surgery, however, open surgery, although perhaps initially less expensive, costs more primarily because patients stay in the hospital longer, suffer more complications, and use more resources.

3.3 Key Findings

3.3.1 Oncological Outcomes

When reporting on the oncological results of a study comparing OS and DFS in patients with esophageal Cancer after MIS and open surgery, the results tend to indicate that these two forms of surgery are equivalent in terms of the long-term. Some of the papers in this meta-analysis identified that one-year, three-year, and five-year survival was similar in both interventions. Both laparoscopic and robotic-assisted esophagectomy yield oncological results through OS and DFS similar to those of open surgery. Both groups experienced equal incidences of cancer reoccurrence, an essential aspect when evaluating the effectiveness of the surgery operation (Cattelani et al., 2018).

Concerning the recurrence ratio and the distant metastasis, the oncological results of MIS and open surgery appeared similar, according to the data (Kazi et al., 2021). Although a few of the comparative trials suggested that the MIS group had a slightly increased loco-regional relapse rate, it does not seem to impact overall or disease-free survival significantly. Over the distant metastasis, a critical issue for esophageal cancer patients, no significant difference was observed for the two groups as well. Specifically, according to the study, both approaches provided relatively similar levels of distance metastasis or the spread of cancer to other organs. However, the short-term MIS group was frequently associated with a shorter stay, meaning that it might afford better organization of adjuvant treatments. It minimized post-surgical treatment initiation times (You et al., 2020).

Finally, these results prove that MIS is ontologically comparable to open surgery concerning survival and recurrence; however, patients managed using MIS have fewer perioperative risks and a shorter recovery time.

3.3.2 Post-operative Recovery

When assessing post-operative recovery, it is evident that minimally invasive surgery has the characteristics of fewer short-term complications and quicker recovery time. Overall, the MIS group experienced significantly less early post-operative –, including wound infections, anastomotic leak, pleural effusion, and pneumonia. The trend in the use of MIS techniques cuts down on tissue injury and contact with bacteria and other contaminants that could lead to post-operative infections. Conversely, MIS was less associated with manipulation of chest wall and abdominal organs, and therefore, pulmonary infections such as pneumonia and atelectasis were less observed (Heath et al., 2018).

As shown, the recovery time was significantly less in the MIS group. In the comparison of LAP or robotic-assisted and open esophagectomy, there was less pain, earlier mobilization, and an earlier return to normal diet among patients who underwent esophagectomy through minimally invasive surgery. This great recovery time meant a cut down on the number of days the patient had to spend in the hospital. These works revealed that MIS patients also kept a much shorter LOS, between two to four days shorter on average than patients who underwent an open approach. Besides patient satisfaction, shorter LOS is preferred as it comes with manageable costs for health systems (Considine et al., 2020).

In addition, patients in the MIS group had a more rapid recovery from normal wearing of garments and usual employment than those in the open surgery group. It also shows that the uncomplicated MIS achieves faster recovery, lower incidences of complications, and comparatively shorter hospital stays, which carries both clinical and administrative advantages (Considine et al., 2020).

3.3.3 Complications

(Llerena-Velastegui et al., 2024) Explained the comparison of survival rates and highlighted that laparoscopic surgery had a better efficiency concerning post-surgery morbidity than open surgery. MIS patients had fewer instances of complications, inclusive of wound infection, anastomotic leakage, and pulmonary complications. I think that the number of cases of wound infections is reduced in MIS compared to normal surgical procedures because surgeons make small incisions in MIS, which do not cause much exposure to bacteria. Similarly, minimally invasive surgery portended a lower risk of anastomotic leaks, which are a significant complication of esophagectomy. The less invasive technique provides more effective control over the anastomosis site: reducing mechanical stress and tension shifts the focus towards the connection between the esophagus and stomach (Llerena-Velastegui et al., 2024).

As for pulmonary complications, MIS patients had a low rate of post-operative pneumonia, which is a well-known frequency after esophagectomy. The decreased chest wall movement in MIS probably accounts for the lower incidence of post-operative atelectasis and other Pulmonary issues. Further, other cardiac indexes like arrhythmias, though observed in both groups, also did not significantly differ between the MIS and open surgery groups (Smit et al., 2020).

In contrast, long-term side effects like lymphedema and gastric reflux were noted to occur more frequently after surgery, but there was no marked difference in occurrence between the two groups. Lymphedema involves swelling, commonly in the lower limbs and sometimes the buttock, due to interruption of lymphatic drainage, generally because of lymph node dissection. Likewise, gastric reflux or esophagitis may develop postoperatively since the lower esophageal sphincter may be injured during the operation (Yu et al., 2018). These long-term complications are significant but were mainly non-significant between MIS and open surgery.

All in all, MIS was related to early post-operative complications and shorter recovery time. Still, the long-term complications, such as reflux and lymphedema, were similar to those of open surgery, so it can be established that the advantage of MIS is in decreasing early surgery risks.

3.3.4 impact of tumor stage (early vs. advanced)

Regarding this element, the tumor stage’s role in determining surgical results was considered (Montroni et al., 2018). Patients with T1-T2 stage esophageal cancer largely show similar results between those who undergo minimally invasive surgery and those who undergo open surgery. Here, the malignancy is often localized to the esophagus only, and that makes it easier to reset the tumor without compromising on mastectomy. MIS is especially effective in stage I cancers because it results in quicker rehabilitation, less post-operative morbidity, and equal oncological efficacy compared with open surgery.

T3-T4 cancers are technically more challenging in staging because they involve either structures adjacent to the cancer or regional lymph nodes. Here, the oncological control of MIS and open surgery is similar. At the same time, MIS may be suboptimal in obtaining adequate resection margins or adequate lymphadenectomy in some cases due to the tumor location and size. Therefore, open surgery still appears as a valuable option for patients with advanced diseases. Still, it cannot be ruled out in cases requiring more extended resections or if the lymphadenectomy is considered essential. Therefore, the early-stage tumor will be more suitable for MIS. However, the advanced-stage tumor may need further customized intervention (Montroni et al., 2018).

3.3.5 analysis of esophageal cancer subtypes (adenocarcinoma vs. squamous cell carcinoma)

Esophageal Cancer is typically classified into two subtypes, of which the two most common types of lung cancers are adenocarcinoma and squamous cell carcinoma (SCC). Adenocarcinoma still occurs more frequently in populations of the Western world, whereas squamous cell carcinoma has a higher incidence in Asian nations. The decision between BMS and OMS depends on the type of tumor, and the results of oncological outcomes (survival, recurrent) are equally effective for both techniques.

Manning et al., (2020) stated that MIS is preferred for treating adenocarcinoma since MIS allows adequate esophageal resection without undermining the adjacent structures. There is evidence that

MIS can be an ontologically satisfactory approach to adenocarcinoma as open surgery, except when combined with neoadjuvant treatment. In the case of SCC, the disease is usually diagnosed at a more extensive stage, and open surgery might sometimes be chosen because of the intricacy of lymph node dissection and the necessity of resection. Nevertheless, MIS has shown relatively reasonable efficacy in SCC, especially in cases localized to the tongue and floor of the mouth. Thus, despite no differential survival rates according to the tumor subtype, the preference for MIS surgery or open procedure could be determined by the level of LN invasion and the disease stage at diagnosis (Manning et al., 2020).

3.3.6 Age, comorbidities, and frailty of patients

Recent studies have shown that seven factors, the age and general health of the patients and the degree of their frailty, determine the appropriateness of minimally invasive surgery (MIS) and open surgery for esophageal cancer. Elderly patients or those with major pre-existing conditions of some form of cardiovascular disease, diabetes, or pulmonary disease are likely to have serious complications commonly associated with major surgeries. For these patients, MIS offers several advantages: It may also lower operative trauma, shorten the length of hospital stay, and reduce time to recovery, all of which can effectively minimize perioperative hazards. Research by Fagard (2023) indicates that patients who are elderly or those with other severe illnesses record fewer post-operative complications and rapid recuperation when they undergo MIS (Fagard, 2023).

On the other hand, open surgery could sometimes be preferable in frail patients who cannot undergo a radical resection due to their poor tolerance to further post-operative morbidity or in those patients who require more extensive resections. Thus, improved extra surgical access and the possibility of accomplishing intricate resections and node dissection may not be possible through MIS. On the contrary, recent studies have proved that MIS can be safe for even the most debilitated of patients when it means avoiding big incisions and long post-operative rehabilitation processes.

3.3.7 Differences in robotic vs. laparoscopic techniques

Robotic surgery and endoscopy surgery are minimally invasive surgery, though the use of robots in the surgical technique differs in accuracy. Robotic surgery refers to a system where the surgeon sits in a console and manipulates robotic arms for better movements, visualization of the operation field, and better manipulability of tissue. However, laparoscopic surgery employs ordinary equipment placed through small ports and a scope for viewing.

Thus, comparing these techniques demonstrated that both proposed methods have comparable results in oncological control, complication rate, and early mobilization. Robotic surgery, however, was linked with decreased procedural duration and higher accuracy of tumor removal, especially in deep locations. Laparoscopic surgery is comparatively more accessible, and its utilization is less costly than open surgery. The selection between robotic and laparoscopic approaches varies depending on the surgeon experience, the availability of resources, and institutional capabilities. Both these techniques have shown comparable results for esophagectomy in patients with esophageal cancer, and robotic surgery may be more advantageous technical angle and better Cancer handling (Tagkalos et al., 2021).

3.3.8 impact of adjuvant therapies (e.g., chemotherapy, radiotherapy)

Systemic treatments with or without chemotherapy/radiotherapy for esophageal cancer are also considered essential for the treatment of esophageal cancer. These therapies could be local or systemic and administered before or after surgery in case the tumor has been reduced, or micro metastases have occurred. The influence of adjuvant therapies to choose between MIS and open surgery appears multifaceted and depends on the type and time when therapy is applied (Kakeji et al., 2021).

Patients who receive neoadjuvant chemotherapy or chemoradiotherapy before surgery still qualify for MIS. Numerous works showed that, when medically indicated, MIS esophagectomy following neoadjuvant treatment might provide the same oncological results as an open procedure (Kakeji et al., 2021). However, it can also have some benefits for the patient, including minimizing post-operative pain and shortening healing time, which will suit patients undergoing

4. Discussion

4.1 Interpretation of Results

Current data from this meta-analysis also supports MIS for the treatment of esophageal cancer with similar or even better results compared to the open operation in surgery safety, recovery of functions, and complication rate. In terms of the above-prescribed OS, DFS, and post-operative morbidity, the gap between MIS and open surgery is negligible which affirms that MIS is associated with suboptimal long-term cancer control. In the context of post-operative survival and recurrence, the results from both techniques were comparable, suggesting that MIS can be applied to provide oncological efficacy similar to that of open surgery (Yoshida et al., 2020). Further, MIS had statistically significant better morbidity by having a lower incidence of wound infection, anastomotic leak, and respiratory complications. This reduction in perioperative risks is a distinct advantage as Laparoscopic surgery provides faster recovery time and fewer days in a hospital bed than open surgeries (Yoshida et al., 2020).

The results support MIS as moderate invasive therapy for most conditions where open surgical intervention was conventionally employed. However, because of the complicated nature of the procedure and the requirement for special instruments, MIS could be considered for a large number of patients with esophageal cancer to alleviate post-operative recovery and complications (Branham et al., 2023). The reality that employing MIS as a means of performing surgery does not decrease oncological control while giving less post-operative pain, easier recovery, and diminished hospital resource usage (for instance, the duration of stay) increases MIS's appeal in a healthcare setting where cost efficiency and faster patient recovery time are paramount. Thirdly, this minimally invasive approach reduces, besides the extent of tissue and nerve damage, the followership and cosmetic consequences of large incisions, which ultimately enhances patient satisfaction after surgery (Branham et al., 2023).

However, as much as doing MIS provides several benefits concerning reduced morbidity rates and time spent on recovery, it does have some suboptimal outcomes. Schieman et al. (2018) stressed that Technical challenges are one of the main barriers, and they demand the specialized expertise of a surgeon to perform minimally invasive surgery, especially when addressing issues of esophageal resections or being at advanced-stage cancer. The experience related to both laparoscopic and, equally, the robotic-assisted approach is steep, and not all institutions can afford either the instrument or the expertise. Further, some minutes are longer with MIS than traditional procedures, such as complex procedures requiring robotic help. Robot-assisted surgery benefits from making minimal invasions, which can be more accurate but can also increase the costs and time and thus may not be suitable in all institutions (Schieman et al., 2018). However, there is evidence that supporting the role of MIS seems to benefit more from the drawbacks than it appears to have in certain cases, especially for suitable patients.

Comparing survival data (OS and DFS) concerning the discussed oncological treatment methods, it was found that there were no differences between MIS and open surgeries in most cases. Each of the approaches offered durable cancer outcomes, especially regarding primary cancers. It was found that survival postoperatively, metastasis, and recurrence rates were similar when taking Mesh central axis or not as long as the goal was to increase the area of malignancy.

However, there recently appeared some concerns concerning the oncological safety of MIS in certain settings, mainly in cases with advanced-stage tumors. As stated above, open surgery may provide better access for tumor resection, mainly if tumors are either T3 or T4 or if multiple lymph nodes are involved. Decreased contact sensation and constrained field of view during MIS may affect the chance of a surgeon to achieve adequate surgical margins in some of these complex cases and increase the risk of recurrent disease. While these concerns are not without merit, available data from patients receiving neoadjuvant treatments (chemotherapy and radiation) demonstrate that MIS can obtain acceptable oncological outcomes in stages beyond IA/IB if the tumor is resect able. The surgeon has sufficient experience (Nakauchi et al., 2021).

In addition, the current authors once again pointed out the crucial consideration that although MIS is technically possible in many patients with esophageal cancer, it may not be applicable for all patients, particularly those with extensive primary tumors or invading adjacent structures. However, in some of these situations, simple laparoscopy may not be enough due to the extent of the pathology or due to the general difficulty of the surgery required. This emphasizes the need for motorized treatment planning based on tumor size and grade, surgeon proficiency, and patient comorbidities to distinguish between MIS and open surgery (Toader et al., 2023).

4.2 Clinical Implications

Doing least-invasive surgery (MIS) has emerged as an important option in treating esophageal cancer since it enjoys a comparative advantage regarding recovery and complication profiles. The extent of MIS involvement strongly depends on the tumor stage, resect ability, and constituent factors of the patient's condition.

In Stage I esophageal cancer, where cancer is contained within the esophagus, and the lesion is surgically resect able, the use of MIS, such as lap or robotic-assisted esophagectomy, has been established to produce favorable outcomes. These procedures provide comparable oncological results, both overall survival and disease-free survival, to open surgery, but with the additional benefits of decreased post-operative pain, shorter lengths of stay, and fewer complications (Falk et al., 2021). MIS can be performed with satisfactory long-term survival rates and low trauma in patients with T1 or T2 tumours and, hence, is the treatment of choice in these patients.

However, the role of MIS in treating T3 and T4 cancers is unclear. Nevertheless, for patients with borderline resect able carcinoma, either after encountering a response to neoadjuvant therapy such as chemotherapy or radiotherapy, then open surgical resection might still be applied, or if there are large tumors that require more extensive tumors or complicated lymph node dissection, then there are advantages of open surgery. Open surgery provides more space and touch sensations, which are savings for these complicated surgeries. For patients with locally advanced disease, localized surgery is still appropriate because the disease often requires adequate tissue and lymph node resection (Obinu et al., 2018).

The practices recommended in guidelines from organizations such as the NCCN and ESTS involve using MIS in general in T1-T2 N0M0 esophageal cancers and select T3-T4 N0M0 cases. Both the NCCN and ESTS consider L&R esophagectomy for resect able SQCC of the esophagus, though open surgery remains superior, especially for extensive pathology.

(Samerski, 2019) demonstrated that Patient advice is crucial when it comes to the practice of MIS since not all patients can undergo the procedures. The stage of the tumor, the patient's comorbid conditions, and the surgeon's experience are considerations to be considered when determining the right type of surgery. However, in the case of elderly or frail patients, MIS can be safer and avoid the risks associated with any form of surgery. In the case of Insulin, a scope of work should involve a multi-disciplinary team to scrutinize every case to develop a treatment plan that suits a particular patient.

4.3 Challenges in Implementing MIS

However, the application of MIS for esophageal cancer suffers several challenges that limit its use all over the world. The main drawback, cost, has been identified as disconcerting. For instance, adopting Robotic-assisted surgery has very high capital and recurrent expenditures. These financial requirements pose a challenge to hospitals that can offer MIS but may not be able to do so sustainably, especially in the developing world low and middle-income countries. Conversely, open surgery has higher effectiveness and a lower cost and availability, especially in the LMICs (Patel et al., 2022).

The technical requirement also poses a standard hindrance to adopting MIS, particularly in the robotic surgery technique. It has also been observed that the learning curve of robotic and laparoscopic is geared towards gaining some special skills. Specialists' knowledge includes dealing with sophisticated tools, controlling the robotic console, performing acts of request on a surgeon's behalf, and controlling such constraints as a decrease in tactile feedback and field of vision. Without proper courses and apprenticeships for surgeons to demonstrate that they are in a position to perform such

surgeries without inflicting harm on patients, these electromechanical procedures can be a large expense for healthcare organizations.
Delmerico et al. (2019) also stated that the availability of robotic systems is restricted, mainly in small centers or those unable to invest in such technologies. Another problem is the availability of trained staff that will be able to operate these systems. These differences mean that while patients in well-equipped centers get to choose between whether to undergo MIS, some do not get this option.
Furthermore, there is a weak integration of robotic-assisted esophagectomy because of the absence of standardized protocols. With such types of surgeries, the results may be unpredictable and disheartening if the doctor has less experience. Emergency surgical training and the definite policies of laparoscopic and robotic surgeries should be standardized to have the same quality and effective outcomes throughout the healthcare facilities (Rusch et al., 2019).

4.4 Future Directions

Minimally invasive surgery (MIS) for esophageal cancer has already shown great promise, but to maximize its potential, several areas require further exploration. Advances in technology, more comprehensive long-term follow-up data, and well-designed randomized controlled trials (RCTs) will be key in determining the long-term role of MIS in esophageal cancer treatment.
One of the most exciting frontiers is the continued advancement in surgical technologies, particularly robotic surgery (Sheth & Koh, 2019). While laparoscopic surgery has already been widely adopted, robotic-assisted surgery offers increased precision, enhanced dexterity, and greater visual clarity through 3D imaging. As robotic systems evolve, we expect more intuitive interfaces and advanced features such as force feedback, which mimic tactile sensations for surgeons, improving their ability to make precise decisions. Additionally, artificial intelligence (AI) improvements are poised to enhance robotic surgery further. AI can assist in surgical planning, decision-making, and intraoperative tasks by analyzing patient-specific data, identifying optimal surgical approaches, and providing real-time feedback during operations. AI could also improve post-operative outcomes by optimizing recovery protocols and reducing complications. Alongside robotic advancements, enhanced imaging technologies like fluorescence-guided surgery and intraoperative MRI are expected to strengthen tumor visualization, aiding in more accurate resections and reducing the likelihood of positive margins or incomplete resection (de Kleijn et al., 2023).
In parallel with these technological advances, there is a critical need for long-term follow-up data to assess the effectiveness of MIS in esophageal cancer surgery (Qu et al., 2024). While short-term benefits like reduced blood loss, faster recovery, and fewer complications have been well-documented, the long-term oncological outcomes, such as overall survival (OS), disease-free survival (DFS), and cancer recurrence, still require more rigorous examination. Few studies have investigated whether the improved recovery associated with MIS converts into better long-term cancer control. Recurrence rates and the metastasis patterns in patients treated with MIS compared to open surgery need further investigation, especially in patients with advanced stages of cancer or positive lymph nodes. Similarly, quality of life (QoL) measures post-surgery, including swallowing function, nutritional status, and psychosocial impacts, must be better understood (Qu et al., 2024).
Another important future direction involves the need for prospective randomized controlled trials (RCTs). Although several studies have supported using MIS for esophageal cancer, the lack of large, high-quality RCTs means that the evidence base remains incomplete. RCTs comparing open surgery and MIS across various patient subgroups (early-stage vs. advanced-stage, adenocarcinoma vs. squamous cell carcinoma) will provide stronger evidence of MIS's true benefits and limitations. Additionally, RCTs would allow for better assessment of oncological outcomes, including long-term survival rates and cancer recurrence after MIS, addressing concerns that MIS might not be as effective as open surgery in achieving long-term cancer control. These trials should also assess the impact of neoadjuvant therapies (chemotherapy, radiotherapy) in conjunction with MIS, as downstaging tumors through these treatments could make MIS a more viable option even in advanced cases (Sedighim et al., 2023).

Moreover, the potential advantages of robotic-assisted MIS compared to laparoscopic techniques warrant further investigation. Some studies suggest that robotic systems offer superior precision, especially in complex anatomical regions, and may be associated with fewer complications. However, the increased cost and longer operative time associated with robotic surgery may limit its widespread adoption (Sedighim et al., 2023). Subgroup analyses comparing the outcomes of robotic vs. laparoscopic techniques will help determine when each approach is most beneficial, particularly for patients with advanced tumors or complex anatomical features.

Lastly, future research must also focus on developing standardized protocols for robotic-assisted esophagectomy and laparoscopic surgery. Variations in surgical techniques across centers can lead to inconsistent outcomes. Developing standardized guidelines for these procedures will ensure more predictable results and facilitate broader adoption of MIS. In addition, cost-effectiveness analyses will be important for determining whether the benefits of robotic surgery outweigh the higher upfront costs, especially in healthcare systems with limited resources (Nabi et al., 2020).

5. Conclusion

This meta-analysis supports increasing evidence that MIS has become an increasingly important treatment modality for esophageal cancer compared with open surgery. The results also show that MIS yielded near equivalent oncological outcomes to open surgery in terms of survival and low recurrence rates. For instance, it has demonstrated lower post-operative complications, shorter hospitalization, and more rapid restoration to non-surgical pursuits. These benefits help decrease healthcare costs, especially where hospital resources are immersed. Thus, based on the present review, MIS is a safe, efficient, and promising method for treating early-stage and some advanced-stage esophageal cancer, and the techniques are considered an essential constituent of contemporary surgical practice. However, open surgery continues to be customary for more advanced stages.

In choosing between MIS and open METH, factors to take into consideration are tumor extent, patient's age, comorbidities, frailty status, and availability of institutional premises. It might be reasonable to offer MIS to early-stage esophageal cancer patients with minor comorbidities due to its merits of fewer days required in recovery and low operation complication rate. In cases of larger and more invasive tumor masses or when a tumor is dissected extensively, open surgery might still be the best option. Moreover, operating room teams should receive special training and experience in robotic and laparoscopic equipment and techniques. The institutions should buy the latest technology and provide the surgical teams who perform the surgeries with continuous professional training and experience. Patient education is also important to manage their expectations regarding both methods intentions, benefits, and shortcomings.

In light of this, it is recommended that healthcare policy consider incorporating MIS into mainstream esophageal cancer treatment in cases where it is possible and benefits the patient. As MIS technologies improve in the future, policymakers should encourage proper cost-investment research that indicates how much is spent on acquiring robotic surgical equipment. Still, in the long run, the time taken in the hospital and the frequency with which such patients are readmitted is greatly reduced. To avoid significant disparities in patient access to such minimally invasive technologies, constant efforts should be made to make these surgical tools available in all types and settings of health organizations, regardless of the organization's size or the region of work.

MIS is not the standard of care for all esophageal cancer operations. However, it could likely ascend to become the primary standard modality of intervention for many patients, especially those with limited-stage and organ-confined malignancies. The future exploitation of MIS is so fundamental that as technology progresses and long-term studies and set standard training operationalize, it becomes the common mode for esophageal cancer resections

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