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ORIGINAL RESEARCH

Effectiveness and Safety of Neoadjuvant Immunochemotherapy with and without Surgery in Patients with Resectable Esophageal Squamous Cell Carcinoma: A Retrospective Cohort Study

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Background: This study aimed to retrospectively compare the effectiveness and safety of neoadjuvant immunochemotherapy with and without surgery for locally advanced esophageal squamous cell carcinoma (ESCC).

Methods: This study included patients with ESCC who received neoadjuvant immunochemotherapy from May 2021 to July 2023. Patients were divided into a surgery cohort and a non-surgery cohort. Outcomes included R0 resection rate, pathological complete response (pCR), major pathological response (MPR), objective response rate (ORR), event-free survival (EFS), overall survival (OS), and safety.

Results: Among the 61 patients undergoing neoadjuvant immunochemotherapy, 33 received subsequent surgery, and 28 did not undergo surgery due to unsuitability or refusal. Totally, 8 (13.1%) achieved complete response, and 38 (62.3%) had partial response, resulting in an overall ORR of 75.4%. In the surgery cohort, the R0 resection rate was 87.9% (29/33), with 24.2% (8/33) achieving pCR and 66.7% (22/33) achieving MPR. The EFS was 23.0 months (95% CI 16.8-NA) for the surgery cohort and 9.2 months (95% CI 6.1–12.8) for the non-surgery cohort. The 2-year OS rates were 65.4% (95% CI 48.7–82.1) and 41.3 (95% CI 22.3–60.3) in the surgery and non-surgery cohorts, respectively. Common adverse events included vomiting (70.5%), nausea (45.9%), and fatigue (19.7%). Common postoperative complications included anastomotic leakage (11.8%) and pulmonary infection (11.8%).

Conclusion: Neoadjuvant immunochemotherapy represents a promising treatment strategy for patients with locally advanced resectable ESCC, with high rates of R0 resection, pCR and MPR. The subsequent surgery leads to several postoperative complications which can be well-managed, and surgery contributes to improved survival.

Keywords: neoadjuvant therapy, locally advanced esophageal squamous cell carcinoma, surgery, immunotherapy, tislelizumab

Introduction

In 2022, esophageal cancer (EC) affected approximately 510,000 individuals, and accounted for 445,000 deaths globally.[1] China is a region with a particularly high incidence of EC, with esophageal squamous cell carcinoma (ESCC) constituting about 90% of cases.[2,3] While surgical resection remains the primary treatment for early-stage EC, the majority of patients present with advanced disease at diagnosis. Consequently, the 5-year survival rate for surgery alone remains dismal, ranging from 15% to 24%.[4] To enhance surgical outcomes and prognosis, neoadjuvant therapy is frequently employed to downstage tumors, increase the likelihood of complete resection, and improve overall survival (OS) rates in patients with resectable ESCC.[5–7]

Neoadjuvant therapy, such as chemotherapy and chemoradiotherapy, is widely utilized in the treatment of ESCC. The CROSS study highlighted the benefits of preoperative chemoradiotherapy, demonstrating a higher pathological complete response (pCR) rate in patients with ESCC compared to those with adenocarcinoma (49% vs 23%), alongside significant improvements in OS.[5] Similarly, the NEOCRTEC 5010 study reported a pCR rate of 43.2% and a higher R0 resection

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rate in the neoadjuvant chemoradiotherapy cohort compared to surgery alone (98.4% vs 91.2%). Additionally, progression-free survival (PFS) and OS were significantly extended in the chemoradiotherapy cohort.[8] A Phase II clinical study in Japan demonstrated a 64.3% overall response rate (ORR) and a 17% pCR rate in patients with stage IIA-III ESCC receiving chemotherapy followed by surgery, with 2-year PFS and OS rates of 74.5% and 88.0%, respectively.[9] A meta-analysis[10] and the Japanese JCOG9907 study[11] also supported the efficacy of neoadjuvant chemotherapy in improving resectability and survival outcomes in potentially resectable ESCC. Compared to chemoradiotherapy, neoadjuvant chemotherapy is also associated with a high response rate, but fewer severe adverse events (AEs),[12] making it a suitable preoperative treatment strategy for ESCC.

Tislelizumab, a humanized IgG4 monoclonal antibody targeting PD-1, has shown significant efficacy in ESCC.[13] The RATIONALE 306 study reported a median OS of 17.2 months with tislelizumab combined with chemotherapy, compared to 10.6 months with chemotherapy alone (hazard ratio, 0.66) for advanced or metastatic ESCC.[14] This has contributed to the recommendation of tislelizumab and chemotherapy combination as a first-line treatment for metastatic ESCC in the Chinese Society of Clinical Oncology (CSCO) guideline. Additionally, the TD-NICE phase II study showed that neoadjuvant tislelizumab with chemotherapy achieved a major pathological response (MPR) rate of 72% and a pCR rate of 50%, with manageable AEs.[15] These results suggest that tislelizumab and chemotherapy combination as neoadjuvant might be a promising option for ESCC patients.

The high rate of pCR following neoadjuvant therapy has prompted growing interest in whether esophagectomy is necessary for all patients, particularly given the substantial risks of postoperative morbidity and mortality. In this context, active surveillance, or a "watch-and-wait" strategy, has emerged as a promising organ-preserving alternative for patients who achieve a clinical complete response (cCR) after neoadjuvant treatment. This approach may enable selected patients to avoid the morbidity of surgery while maintaining oncologic safety, especially in the absence of distant metastasis. The preSANO trial demonstrated that a multimodal clinical response evaluation (incorporating endoscopic ultrasonography, bite-on-bite biopsies, and fine-needle aspiration of suspicious lymph nodes) can provide an adequate assessment of locoregional residual disease following neoadjuvant chemoradiotherapy. In addition, positron emission tomography-computed tomography (PET-CT) was shown to be effective in identifying distant metastatic spread, further supporting the feasibility of surveillance-based strategies.[16] Building upon this, the SANO trial reported that patients with esophageal cancer who underwent active surveillance after achieving cCR experienced non-inferior two-year OS and median disease-free survival compared to those who underwent immediate esophagectomy. Moreover, patients in the surveillance group reported superior health-related quality of life outcomes.[17] Taken together, these findings suggest that achieving cCR or pCR through optimized neoadjuvant therapy offers both prognostic and therapeutic implications, potentially allowing for individualized, less invasive treatment approaches in selected patients. Therefore, this retrospective study aims to evaluate the effectiveness and safety of neoadjuvant immunochemotherapy with or without subsequent surgery in patients with locally advanced, resectable ESCC, thereby contributing to the ongoing refinement of response-adapted treatment strategies.

Methods

Study Design and Patients

This retrospective study was conducted in the Department of Thoracic Surgery at Hainan Provincial People's Hospital, focusing on patients with resectable, locally advanced ESCC treated with neoadjuvant immunochemotherapy between May 2021 and July 2023. The study protocol was reviewed and approved by the Ethics Committee of Hainan Provincial People's Hospital (Approval No. Med-Eth-Re [2024]253). All procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the Helsinki Declaration. All patient data were anonymized and handled in strict accordance with institutional confidentiality guidelines.

Patients were eligible for inclusion if they met the following criteria: 1) Histologically or cytologically confirmed diagnosis of ESCC; 2) No evidence of distant metastasis as determined by imaging examinations; 3) No prior anti-tumor treatment; 4) Eastern Cooperative Oncology Cohort (ECOG) performance status of 0–1; 5) Tumors were evaluated as resectable by the MDT; 6) Patients had received neoadjuvant immunochemotherapy; 7) Both patients who underwent

surgery following neoadjuvant immunochemotherapy and those who did not were eligible for inclusion. The study excluded patients who received salvage surgery or palliative surgery.

Treatment

All patients received 1–4 cycles of neoadjuvant immunochemotherapy, administered every 3 weeks. The regimen included the PD-1 monoclonal antibody tislelizumab at a dose of 200 mg on day 1 of each cycle. Chemotherapy was based on taxane and platinum agents, including paclitaxel (175 mg/m²), albumin-bound paclitaxel (260 mg/m²), docetaxel (75 mg/m²), nedaplatin (80–100 mg/m²), cisplatin (80–120 mg/m²), and carboplatin (200–400 mg/m²).

After neoadjuvant immunochemotherapy, therapeutic effectiveness was assessed using enhanced chest and abdominal computed tomography (CT) scans. The resectability of the tumor was comprehensively evaluated, and surgery indication was considered based on their overall physical condition. Patients who met the criteria and consented to surgery underwent minimally invasive esophagectomy (MIE) with standard 2-field or 3-field lymphadenectomy and gastric reconstruction, which was performed 4 to 6 weeks following the completion of neoadjuvant therapy. Patients who had not completed 4 cycles of neoadjuvant treatment received additional 4 cycles as adjuvant therapy and then volunteered to continuing immunotherapy until disease progression or until no further clinical benefit was observed.

Outcomes and Assessments

The outcomes of this study included R0 resection rate, pCR, MPR, ORR, event-free survival (EFS), OS, and safety. R0 resection rate referred to the proportion of patients with no residual tumor at the resection margins. pCR was defined as the absence of residual tumor in the resected specimen. MPR indicated a substantial reduction in tumor burden, with less than 10% viable tumor cells remaining. ORR was determined based on the proportion of patients achieving complete response (CR) or partial response (PR) according to Response Evaluation Criteria in Solid Tumors (RECIST) 1.1 criteria. EFS was defined as the time from the start of treatment to the first occurrence of any event (recurrence, progression or distant metastasis), or death from any cause, and is censored till the latest day when the patient is alive without these defined events. OS was defined as the time from treatment initiation to death from any cause. Besides, cCR was defined as the absence of detectable tumor on imaging (based on RECIST 1.1), endoscopic examination with negative biopsies, and no evidence of regional or distant metastasis. AEs were evaluated through symptoms, vital signs, routine urine and blood tests, liver and kidney function tests, and electrocardiograms. Surgical complications were retrieved from medical documents. Patients were followed up regularly in accordance with the CSCO Guidelines for the Diagnosis and Treatment of Esophageal Cancer.

Statistical Analysis

Continuous variables were presented as mean ± standard deviation (SD), and categorical variables were expressed as frequencies and percentages. Kaplan-Meier survival curves were used to estimate EFS and OS, with 95% confidence intervals (CIs) calculated for these estimates. No inferential statistical tests were performed, as the analyses were purely descriptive in nature. Statistical analyses were performed using R language (version 4.1.2).

Results

Baseline Characteristics of Patients

A total of 61 patients were included in the study. Among these patients, 33 underwent surgery while 28 did not. The total cohort comprised 59 males (96.7%) and 2 females (3.3%), with a mean age of 56.0 ± 9.0 years (range, 32–75 years). Thirty-nine patients (63.9%) have an ECOG score of 1, and 22 patients (36.1%) have a score of 0. Regarding smoking status, only 11 patients (18.0%) were never smoker. The clinical staging was predominantly stage III (73.8%), followed by stage IVA (23.0%) and stage II (3.3%). The distribution of these characteristics between the surgery and non-surgery cohorts is detailed in Table 1.

Seven patients (11.5%) received one cycle of neoadjuvant therapy, 26 (42.6%) received two cycles, 18 (29.5%) received three cycles, and 10 (16.4%) completed four cycles. The decision not to undergo surgery was primarily based on

Table 1 Baseline Characteristics of Patients

Variables	All (n=61)	Surgery Cohort (n=33)	Non-Surgery Cohort (n=28)
Sex, n (%)			
Male	59 (96.7)	32 (96.97)	27 (96.43)
Female	2 (3.3)	1 (3.03)	1 (3.57)
Age, n (%)			
≤65	52 (85.2)	30 (90.91)	22 (78.57)
>65	9 (14.8)	3 (9.09)	6 (21.43)
≤75	61 (100)	33 (100)	28 (100)
>75	0	0	0
ECOG performance status, n (%)			
1	39 (63.9)	21(63.64)	18 (64.29)
0	22 (36.1)	12 (36.36)	10 (35.71)
Smoking status, n (%)			
Never	11 (18.0)	8 (24.24)	3 (10.71)
Ever	24 (39.3)	15 (45.45)	9 (32.15)
Current	26 (42.6)	10(30.3)	16 (57.14)
Stage, n (%)			
II	2 (3.3)	2 (6.06)	0
III	45 (73.8)	25 (75.76)	20 (71.43)
IVA	14 (23.0)	6 (18.18)	8 (28.57)
Efficacy at latest follow-up, n (%)			
CR	4 (6.56)	4 (12.12)	0
PR	22 (36.06)	17 (51.52)	5 (17.86)
SD	1 (1.64)	1 (3.03)	0
PD	34 (55.74)	11 (33.33)	23 (82.14)
Neoadjuvant treatment cycles, n (%)			
1	7 (11.5)	0	7 (25.0)
2	26 (42.6)	20 (60.61)	6 (21.43)
3	18 (29.5)	10 (30.3)	8 (28.57)
4	10 (16.4)	3 (9.09)	7 (25.0)

Abbreviations: ECOG, Eastern Cooperative Oncology Cohort; CR, complete response; PR, partial response; PD, progressive disease.

one of the following categories: unresectable disease (n=16), patient refusal due to satisfactory treatment response (n=7), economic constraints (n=1), and other personal reasons (n=4). A detailed breakdown of these reasons is provided in Supplementary Table S1. Among these 28 patients, 17 experienced disease progression. Following progression, treatment details were as follows: 4 patients received traditional Chinese medicine, 1 patient received a combination of immunotherapy, chemotherapy, and targeted therapy, and 5 patients underwent radiotherapy.

Effectiveness

Among the 61 patients, 8 (13.1%) achieved CR and 38 (62.3%) had PR, resulting in an overall ORR of 75.4% following neoadjuvant therapy (Table 2). In the surgery cohort, 7 patients reached CR and 24 reached PR, leading to an ORR of 93.9%. The R0 resection rate was 87.9% (29 out of 33), while 24.2% (8 out of 33) achieved pCR and 66.7% (22 out of

Table 2 Tumor Response

Response, n (%)	All (n=61)	Surgery Cohort (n=33)	Non-Surgery Cohort (n=28)
CR	8 (13.1)	7(21.2)	1 (3.6)
PR	38 (62.3)	24 (72.7)	14 (50.0)
SD	11 (18.0)	2 (6.1)	9 (32.1)
PD	3 (4.9)	0	3 (10.7)
NE	1 (1.6)	0	1 (3.6)

Abbreviations: CR, complete response; PR, partial response; SD, stable disease; PD, progressive disease; NE, not evaluable.

33) achieved MPR. On the other hand, 1 and 14 patients obtained CR and PR in the non-surgery cohort, respectively, with an ORR of 53.6%.

The follow-up period concluded on February 1, 2025, with 60 out of 61 patients completing follow-up, and 1 patient lost to follow-up. The median EFS was 23.0 months (95% CI 16.8-not available [NA]) for the surgery cohort and 9.2 months (95% CI 6.1–12.8) for the non-surgery cohort. The median OS was not reached, and the 2-year OS rates were 65.4% (95% CI 48.7–82.1) for the surgery cohort and 41.3% (95% CI 22.3–60.3) for the non-surgery cohort (Figure 1).

Safety

AEs were reported in 50 out of 61 patients (82.0%) who received neoadjuvant therapy, with the majority of AEs being of grade 1–2 severity. The most common AEs included vomiting (70.5%), nausea (45.9%), and fatigue (19.7%). Grade ≥3 AEs were observed in six patients (9.8%), comprising five cases of febrile neutropenia and one case of immune-related pneumonia. Immune-related AEs were reported in three patients (4.9%), including grade 1 hypothyroidism (1.7%), grade 2 pruritus (1.7%), and grade 3 pneumonia (1.7%) (Table 3).

All 33 patients in the surgery cohort underwent MIE with standard 2-field or 3-field lymphadenectomy and gastric reconstruction. Postoperative complications included anastomotic leakage (11.8%), pulmonary infection (11.8%), hypoproteinemia (8.8%), multiple organ failure (2.9%), sepsis (2.9%), hoarseness (2.9%), and pneumonia (2.9%). No treatment-related deaths were reported.

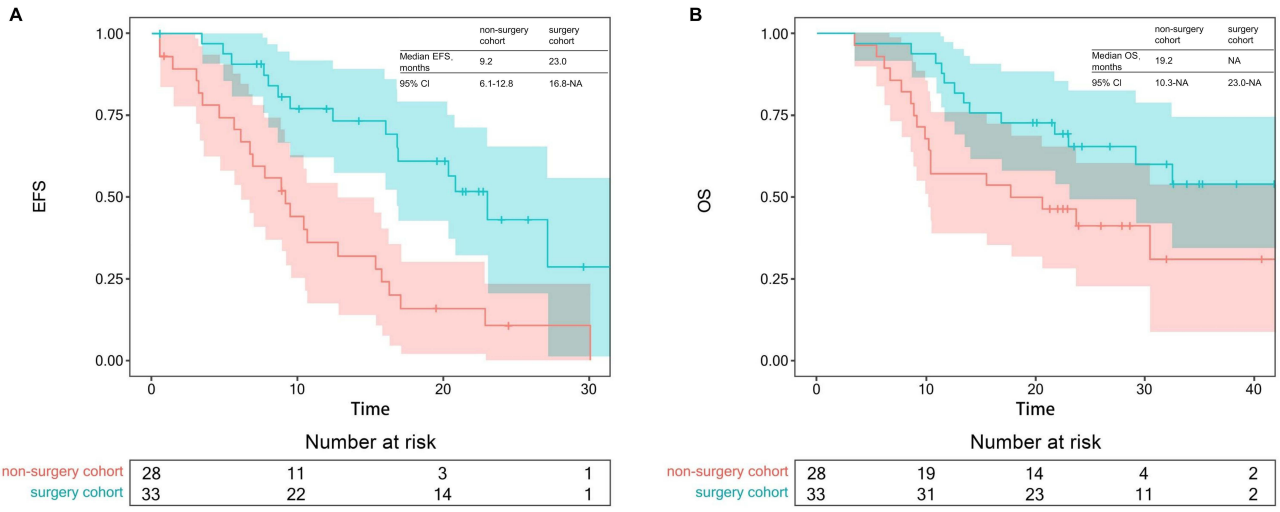

Figure 1 Kaplan-Meier curves for (**A**) event-free survival (EFS) and (**B**) overall survival (OS).
Abbreviation: NA, not available.

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Table 3 Adverse Events (AEs) of Neoadjuvant Therapy

Events, n (%)	Any Grade	Grade ≥3
Any AEs	50 (82.0%)	6 (9.8%)
Vomiting	43 (70.5%)	0
Nausea	28 (45.9%)	0
Fatigue	12 (19.7%)	0
Neutropenia	10 (16.4%)	0
Febrile neutropenia	5 (8.2%)	5 (8.2%)
Pruritus	4 (6.6%)	0
Decreased appetite	3 (4.9%)	0
Gastrointestinal reaction	2 (3.3%)	0
Diarrhea	2 (3.3%)	0
Pneumonia	1 (1.6%)	1 (1.6%)
Hypoproteinemia	1 (1.6%)	0
Fever	1 (1.6%)	0
Peripheral sensory Neuropathy	1 (1.6%)	0
Alopecia	1 (1.6%)	0
Hypothyroidism	1 (1.6%)	0
Immune related AEs	3 (4.9%)	1 (1.6%)
Pneumonia	1 (1.6%)	1 (1.6%)
Pruritus	1 (1.6%)	0
Hypothyroidism	1 (1.6%)	0

Discussion

Surgery remains the cornerstone treatment for patients with resectable EC. According to the latest CSCO Guidelines for the Diagnosis and Treatment of Esophageal Cancer, surgery is typically indicated for tumors invading the submucosa (T) or deeper. Although regional lymph node metastasis (N+) presents a relative contraindication, tumors classified as T1-T3 can still be resected depending on the patient status and disease condition. Additionally, T4a tumors involving structures such as the pleura, pericardium, or diaphragm are also deemed resectable Neoadjuvant chemoradiotherapy followed by radical resection is recommended for patients with locally advanced EC; however, the recurrence rate post-surgery remains high at 35%.[18] The advent of immunotherapy has revolutionized the treatment landscape for EC. Agents such as tislelizumab[14,19] and pembrolizumab[20,21] have demonstrated substantial efficacy and safety in both first-line and second-line settings for advanced EC. Quite a few clinical trials and observational studies have investigated the use of neoadjuvant immunochemotherapy, reporting favorable outcomes in terms of efficacy and tolerable safety profiles.[15,22–28] These developments underscore the promising potential of integrating immunotherapy into neoadjuvant treatment regimens to improve outcomes in patients with resectable ESCC.

In this retrospective study, we evaluated 61 patients with resectable, locally advanced ESCC, of whom 34 underwent surgery following neoadjuvant immunochemotherapy, while 27 did not. Conventionally, the downstaging achieved through neoadjuvant therapy is usually followed by surgical resection,[29] thus making the direct comparisons between surgery and active surveillance challenging. This study contributes valuable clinical evidence regarding the effectiveness and safety of neoadjuvant immunochemotherapy with and without subsequent surgical intervention. Our findings suggest that neoadjuvant immunochemotherapy can effectively eliminate cancer and potentially enhance resectability, offering a potential survival advantage to those who undergo surgery. For patients who do not proceed to surgery, mainly due to personal choice and medical contraindications, immunochemotherapy alone still provides substantial therapeutic benefit. These insights are crucial for refining treatment strategies for resectable ESCC, highlighting the potential role of immunochemotherapy both as a standalone treatment and in combination with surgery to optimize patient outcomes.

Neoadjuvant immunochemotherapy has demonstrated significant efficacy in tumor reduction and enhancing surgical outcomes. In this retrospective study, 37 patients (60.7%) achieved PR, and 8 patients (13.1%) attained CR, resulting in an ORR of 73.8%. The pCR rate was 23.5%, aligning closely with the 25.8% reported in Li et al's study,[27] thus confirming the capability of neoadjuvant immunochemotherapy to create more favorable conditions for surgery. The safety profile of neoadjuvant

immunochemotherapy was also acceptable, with most AEs being manageable and predominantly grade 1–2. The occurrence of grade ≥3 AEs was limited (9.8%) and could be effectively controlled with appropriate management. This aligns with the findings from previous studies on the safety outcomes. For instance, a meta-analysis including 621 patients revealed that neoadjuvant immunochemotherapy had a pooled grade 3–4 treatment-related AEs of 19.4%, which is considerably lower compared to traditional neoadjuvant chemoradiotherapy and neoadjuvant immunotherapy combined with chemoradiotherapy.[30]

In the present study, median EFS in the surgery cohort was 27.1 months, longer than the 11.79 months observed in the non-surgery cohort. Additionally, the 2-year OS rate was higher in the surgery cohort (92.8%) compared to the non-surgery cohort (74.6%), indicating that neoadjuvant immunochemotherapy followed by MIE enhances survival outcomes. However, this benefit comes with risks, as evidenced by complications such as anastomotic leakage and pulmonary infection in the surgery cohort, which necessitate vigilant management. These complications may adversely impact the short-term quality of life but may be outweighed by the potential long-term survival benefits of surgery. Despite the efficacy of surgery after neoadjuvant immunochemotherapy, some patients may refuse surgery due to personal reasons. For these patients, neoadjuvant immunochemotherapy alone becomes the treatment modality to achieve disease control, prolonged survival, and quality of life maintenance. There remains a lack of consensus on the optimal subsequent treatment for patients who achieve cCR after neoadjuvant therapy but do not undergo surgery. Some studies advocate for a course of consolidation chemoradiotherapy,[31] highlighting the need for individualized follow-up treatment approaches. In our study, among the 27 patients who did not undergo surgery, 17 experienced disease progression. Post-progression treatments varied, including traditional Chinese medicine, radiotherapy, and combination of immunotherapy, chemotherapy, and targeted therapy. These findings underscore the necessity for tailored treatment strategies and further research to optimize post-neoadjuvant therapy management for patients with ESCC, particularly those achieving cCR and opting out of surgery.

It is important to acknowledge the inherent difference in response evaluation between the surgical and non-surgical cohorts. While pCR and MPR can be directly assessed in resected specimens, no equivalent gold standard exists for confirming CR in patients managed without surgery. cCR, defined by imaging and endoscopic criteria, has been used as a surrogate, but studies such as preSANO have demonstrated that the concordance between cCR and true pCR remains imperfect, with false-negative rates ranging from 10–15%.[16] This diagnostic gap introduces uncertainty in response classification for non-surgical patients. Nevertheless, surrogate pathological endpoints like pCR or MPR, while informative, may not fully capture long-term benefit. In this study, EFS provides a more robust and uniformly applicable endpoint, allowing a fairer comparison of treatment effectiveness across both cohorts.

In our study, the postoperative recurrence or progression rate in the surgical cohort was approximately 35%, which is within the lower range compared to previous trials such as CROSS and NEOCRTEC5010, where recurrence rates after neoadjuvant chemoradiotherapy followed by surgery ranged from 33.7% to 49%.[32,33] This suggests that, despite being a real-world retrospective analysis, the oncologic outcomes of patients undergoing surgery were comparable to those reported in controlled trial settings. Moreover, our patient population reflects a diverse and pragmatic clinical landscape. Several patients in the non-surgical cohort did not undergo surgery due to a range of factors, including personal preference, economic limitations, relative or absolute contraindications, and complex clinical scenarios. These reasons underscore the reality that surgical candidacy is not solely determined by tumor response or guidelines but is also influenced by socioeconomic and individual-level considerations. This heterogeneity may limit the internal comparability of the two groups but enhances the external validity of our findings by capturing the nuanced decision-making processes seen in routine clinical practice. As such, the study provides insight into real-world outcomes and supports the need for individualized treatment strategies for patients with locally advanced ESCC.

This study has several limitations that need to be considered. As a retrospective study, it is subject to inherent biases and limitations in data accuracy and completeness. The sample size was relatively small, which may affect the generalizability of the findings. Additionally, the follow-up period was limited, preventing a comprehensive assessment of long-term outcomes and late-onset adverse effects. Another limitation of this study is the loss to follow-up of one patient in the non-surgical cohort who had achieved cCR. As a result, the long-term outcome remains unknown, which introduces uncertainty in the interpretation of prognosis following non-surgical management.

Conclusion

Neoadjuvant immunochemotherapy represents a promising treatment strategy for patients with locally advanced resectable ESCC, with notable effectiveness in enhancing surgical outcomes, reducing recurrence risk, and improving survival. Our data demonstrate that neoadjuvant immunochemotherapy leads to significant tumor reduction, with high EFS and OS rates, particularly benefiting those undergoing subsequent surgical intervention. Future studies should further refine the application of neoadjuvant immunochemotherapy by optimizing treatment duration, dosing, and combinations with other therapeutic modalities to maximize efficacy and minimize complications. Additionally, for patients who opt out of surgery, research should focus on evaluating the long-term efficacy and quality of life associated with non-surgical treatments, including radiotherapy and targeted therapies. These efforts will contribute to developing more personalized and comprehensive treatment approaches for patients with ESCC, ultimately enhancing patient outcomes and quality of life.

Data Sharing Statement

The data that supports the findings of this study are available in this article.

Ethics Approval Statement

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study protocol was reviewed and approved by the Ethics Committee of Hainan Provincial People's Hospital (Approval No. Med-Eth-Re [2024]253). All procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the Helsinki Declaration. The need for informed consent was waived by the Institutional Review Board because of the retrospective nature of the study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

All authors have completed the ICMJE uniform disclosure form. The authors have no conflicts of interest to declare.

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