

Total Thymectomy Is Oncologically Superior to Partial Thymectomy in Patients with Thymic Carcinoma: Insights from a Multicenter Real-World Data Analysis

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Abstract

Background:

Although total thymectomy has been the standard surgical approach for thymic epithelial tumors, an increasing number of recent reports suggest that partial thymectomy for early-stage thymomas may yield outcomes comparable to those of total thymectomy.

However, whether partial thymectomy is a viable alternative for thymic carcinoma remains unclear.

Materials and Methods:

A total of 106 patients with thymic carcinoma underwent curative intended resection at 19 institutions between January 2010 and December 2021. Excluding 14 patients with incomplete resection, 92 patients with thymic carcinoma who underwent total (n = 73) or

partial thymectomy (n = 19) were compared. Overall survival (OS) and recurrence-free survival (RFS) were analyzed using Kaplan-Meier curves and Cox proportional hazard models. Overlap weighting was applied to adjust for potential confounding factors.

Results:

Among patients with clinical-stage I disease, 79.3% were upstaged to stage II or higher postoperatively. Unadjusted analyses revealed no statistically significant differences in OS and RFS between the total and partial thymectomy groups, although a trend toward poorer outcomes in the partial thymectomy group was observed. After overlap weighting, partial thymectomy was associated with significantly poorer OS ($p = 0.0027$) and higher recurrence risk ($p < 0.0001$). Early postoperative recurrence occurred more frequently in the partial thymectomy group.

Conclusion:

Partial thymectomy was associated with significantly worse survival and recurrence outcomes in thymic carcinoma. Given the limitations of preoperative diagnosis, total thymectomy should remain the preferred surgical approach for undiagnosed thymic epithelial tumors to achieve optimal oncologic control and minimize the risk of recurrence.

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Introduction

Since the 1980s, following reports on thymectomy as a treatment for thymic epithelial tumors, total thymectomy has been considered the standard surgical procedure for these tumors^{1,2}. However, recent studies, including prospective trials, have suggested that partial thymectomy, which involves resection of the tumor along with its surrounding thymic tissue, yields outcomes comparable to those of total thymectomy in cases of early-stage thymomas³⁻⁶. In addition, a previous study has reported that thymectomy may be associated with an increased risk of malignancies and autoimmune diseases, suggesting that preserving as much thymic tissue as possible could be beneficial⁷. These findings suggested that partial thymectomy could become a viable treatment option for suspected early-stage thymomas. However, preoperative diagnostic biopsy is not recommended for lesions suspected to be resectable thymic epithelial tumors due to the risk of local recurrence or dissemination associated with the procedure^{8,9}. The definitive diagnosis of thymoma or thymic carcinoma is typically established through postoperative pathological examination. Therefore, to demonstrate the overall efficacy of partial thymectomy for thymic epithelial tumors, it should be necessary also to establish its efficacy for thymic carcinoma, the most malignant form within the spectrum of thymic epithelial tumors¹⁰.

According to previous studies, approximately 10% of resected thymic epithelial tumors are diagnosed postoperatively as thymic carcinomas^{3,11,12}. Furthermore, while the 5-year survival rate for thymoma is approximately 90%^{13,14}, that for thymic carcinoma is approximately 55%^{2,14-16}, demonstrating substantial differences in malignancy and prognosis, despite both diseases belonging to the same spectrum of thymic epithelial tumors. In contrast to thymoma, thymic carcinoma is generally regarded as a highly invasive malignancy, with a high likelihood of metastases being present at the time of diagnosis^{17,18}. Although differences in

tumor morphology, extent of invasion into surrounding organs, heterogeneous enhancement on contrast-enhanced computed tomography (CT), and maximum standardized uptake value (SUV max) on positron emission tomography - CT (PET-CT) have been reported as potential markers to distinguish thymoma from thymic carcinoma, accurate diagnosis based solely on imaging alone remains challenging^{19–22}.

Most previous studies on limited resection for thymic epithelial tumors have excluded thymic carcinoma from their analysis. However, in clinical practice, the possibility of thymic carcinoma cannot be preoperatively excluded in cases without biopsy. While clinical experience may suggest that limited resection is less favorable for thymic carcinoma, there is little evidence to substantiate this perception. In this context, we recognized the need to evaluate whether partial thymectomy could demonstrate non-inferiority to total thymectomy even for thymic carcinoma, as limited resection is increasingly explored for thymic epithelial tumors. However, the rarity of surgery for thymic carcinoma has also posed challenges for single-institution studies to accumulate a sufficient number of cases for meaningful analysis. Furthermore, the difficulty of preoperative diagnosis makes it difficult to design prospective studies. Therefore, we conducted a retrospective multicenter real-world data analysis to address this clinical question. This cohort study has been reported in line with the STROCSS guidelines²³.

Materials and Methods

Ethical approval

This retrospective multicenter study was approved by the ethics committee of the principal institution (approval number: K2301-037). Approval was subsequently obtained from the ethics committees of each participating institution. Patients who were able to visit the outpatient clinic provided written informed consent after receiving an explanation. For those who were unable to attend outpatient visits or whose outpatient follow-up had concluded, informed consent was obtained orally, and the details were recorded. For patients who were deceased or unreachable, an opt-out approach was adopted, allowing them to decline participation through publicly available information.

Patients and Study Design

The study included 106 cases of thymic carcinoma treated with either total or partial thymectomy at 19 collaborative research institutions between January 2010 and December 2021, which we considered a reflection of real-world clinical situations. This study is an observational study, so the number of cases during the case accumulation period determined the sample size. To focus on the evaluation of surgical methods, 14 cases involving palliative surgery or incomplete tumor resection were excluded, leaving 92 cases for analysis. Of these, 73 patients underwent total thymectomy, and 19 patients underwent partial thymectomy. The choice of surgical procedure was left to the discretion of each institution. The total thymectomy group included both extended thymectomy and total thymectomy, with the distinction between the two procedures defined by whether the surrounding thymic adipose tissue was resected. In this study, the partial thymectomy group was defined as resection less extensive than total thymectomy, including hemi-thymectomy. For partial resections involving only removal of the tumor, the surgical margin was not prespecified; however,

patients with macroscopic residual tumor at the resection margin were excluded from the study. In the partial thymectomy group, the extent of resection was determined according to the practice of each institution. No cases underwent intraoperative frozen section diagnosis followed by conversion to total thymectomy. Tumor staging was based on the Masaoka classification¹. A definitive preoperative diagnosis based on biopsy was made in 18 cases by physicians' decision. In the remaining 75 cases, surgery was performed without histological confirmation, and the majority (64 cases; 86.5%) were clinically diagnosed before surgery as thymoma or ectopic thyroid tumor. All analyzed cases underwent central pathological review at the principal institution to ensure diagnostic consistency, and all were confirmed to be compatible with thymic carcinoma. Postoperative adjuvant therapy and treatment for recurrence were also determined by each institution.

Data were collected from medical records with the cooperation of participating institutions, including the following: demographic information (sex, age, and performance status), imaging findings (maximum tumor diameter on CT, mediastinal fat invasion, vascular invasion, adjacent organ invasion, mediastinal lymph node enlargement, and PET-CT SUV max values), preoperative and clinical data (presence of preoperative biopsy, clinical stage, and whether induction therapy was performed), surgical details (surgical approach (thoracotomy, video-assisted thoracoscopic surgery (VATS), or robot-assisted thoracoscopic surgery (RATS)), surgical method (total or partial thymectomy), and whether combined organ resection was performed), pathological findings and outcomes (pathological diagnosis, pathological stage, administration of postoperative adjuvant therapy, and post-treatment course). Recurrence was defined as follows: local recurrence included recurrence at the

resection margin, regional lymph node recurrence, and disseminated recurrence; distant recurrence was defined as metastasis to other organs, such as the lungs.

This multicenter retrospective observational study compared cases divided into two groups: the total thymectomy group and the partial thymectomy group. The primary endpoint was overall survival (OS) according to surgical method. Secondary endpoints included recurrence-free survival (RFS) and patterns of recurrence.

Statistical analysis

Descriptive statistics presented continuous variables as median (interquartile range; IQR) and categorical variables as frequency and percentage. Welch's t-test was employed for continuous variables, while Pearson's chi-square test was used for categorical variables to assess differences between total and partial thymectomy groups.

A logistic regression model was used to calculate the propensity score (PS), with the surgical procedure as the response variable and the following covariates as explanatory variables: sex, age, performance status, axial size, Masaoka clinical stage, surgical approach, combined resection, histopathology, Masaoka pathological stage, adjuvant radiotherapy, and adjuvant chemotherapy. Among the covariates, only PET-CT SUV max had substantial missingness and was therefore excluded from adjustment; its missing data pattern was not formally assessed. Additionally, a logistic regression model without explanatory variables was used to calculate the marginal probability (MP). The common support between PS groups was confirmed by the histogram.

Overlap weights were calculated using the formulas: $\text{overlap weight} = (1-PS)/(0.5 \times (1-MP))$

for partial thymectomy, and overlap weight = $PS/(0.5 \times MP)$ for total thymectomy. The denominator serves as a stabilization factor. These overlap weights were used to balance potential confounders between the total thymectomy and partial thymectomy groups^{24,25}.

Covariate differences before and after weighting were assessed using the standardized mean difference (SMD). An absolute SMD value of less than 0.1 was considered well-balanced. The SMD was also calculated for the non-adjusted variable (PET-CT SUV max).

Kaplan-Meier curves were plotted to compare OS and RFS between surgical groups, and the log-rank test was used to determine statistical significance. Five-year survival rates were calculated. Proportional hazard assumption was verified by log-log plot, and hazard ratios (HR) with 95% confidence intervals (95%CI) were estimated using the Cox proportional hazards model. Both unadjusted and adjusted models weighted by Overlap Weight were calculated for all analyses. Analyses were conducted using Stata 18/MP4 (Stata Corp, College Station, TX, USA). $p < 0.05$ was considered statistically significant. As this is an exploratory analysis, the p-value multiplicity has not been adjusted²⁶. The statistical power was calculated using the Schoenfeld approximation based on the log-rank test. Implementation was performed using the power log-rank command in Stata 18.

Results

Patient characteristics

Table 1 summarizes the baseline characteristics of both groups. The partial thymectomy group was significantly older and had a poorer performance status compared to the total thymectomy group. The tumor size was significantly smaller in the partial thymectomy group. Although PET-CT was not performed in all cases, the SUV max on PET-CT was not significantly different between the groups. Additionally, none of the patients in the partial thymectomy group underwent preoperative biopsy. The Masaoka clinical stage included higher proportion of early-stage cases in the partial thymectomy group. With respect to surgical approaches, thoracotomy was performed in 79.5% of patients in the total thymectomy group, whereas VATS or RATS was selected in 68.4% of patients in the partial thymectomy group. The proportion of cases requiring combined resection, including pericardial resection, was significantly higher in the total thymectomy group. Histopathological findings did not show significant differences between the groups. Although each institution determined the postoperative adjuvant therapy at its own discretion, no significant differences were observed between the groups in the administration of adjuvant chemotherapy or radiotherapy. Table 2 presents the patient characteristics after overlap weighting, with all variables except for PET-CT SUV max adjusted to achieve the balance between the two groups.

Discrepancy of clinical and pathological stage

A Sankey chart was used to visualize the differences between clinical and pathological staging in the entire patient cohort (Figure 1). Most cases diagnosed as clinical stage II or higher showed concordance with their pathological stage. In contrast, 31.5% of all cases were initially diagnosed with clinical stage I, and 79.3% of those were subsequently upstaged

to pathological stage II or higher. This result indicated that radiological image findings underestimated the disease stage in thymic carcinoma.

Overall survival and recurrence-free survival between the groups

With simple analyses for total cases, there was no statistically significant difference in OS rates between the groups, although the partial thymectomy group tended to have lower survival ($p = 0.0575$) (Figure 2). The 5-year OS rate was 90.7% (95% CI: 0.803 - 0.957) in the total thymectomy group and 67.2% (95% CI: 0.373 - 0.852) in the partial thymectomy group. Similarly, the partial thymectomy group showed a trend toward a worse RFS ($p = 0.0556$) (Figure 3). The 5-year RFS rate was 68.9% (95% CI: 0.561 - 0.786) in the total thymectomy group and 49.2% (95% CI: 0.241 - 0.703) in the partial thymectomy group. In the total thymectomy group (22 patients), the median time to recurrence was 877.5 days (IQR: 359–1189), whereas in the partial thymectomy group (7 patients), it was 343 days (IQR: 246–715). This analysis considered the time to recurrence only, distinct from RFS, which defines events as either recurrence or death.

After adjustment using propensity score weighting, OS in the partial thymectomy group was significantly inferior compared to that in the total thymectomy group ($p = 0.0027$) (Figure 4). The adjusted 5-year OS rate was 87.1% (95% CI: 0.763 - 0.932) in the total thymectomy group and 54.4% (95% CI: 0.235 - 0.775) in the partial thymectomy group. Likewise, the partial thymectomy group had a significantly worse RFS compared to the total thymectomy group ($p < 0.0001$) (Figure 5). The adjusted 5-year RFS rate was 77.6% (95% CI: 0.654 - 0.860) in the total thymectomy group and 34.1% (95% CI: 0.100 - 0.604) in the partial thymectomy group. A pronounced early decrease in the Kaplan-Meier curve was observed in

the early postoperative period in the partial thymectomy group, suggesting that partial thymectomy may be responsible for early recurrence.

In the unadjusted analysis using the Cox proportional hazards model, there was no significant difference between the groups for OS (HR = 2.48, 95% CI: 0.94 – 6.50, $p = 0.066$) and RFS (HR = 2.02, 95% CI: 0.97 – 4.22, $p = 0.061$), although the partial thymectomy group tended to have a worse RFS. After adjustment using overlap weights, no significant difference in OS was observed between the groups (HR = 3.72, 95% CI: 0.75 – 18.34, $p = 0.107$). However, the partial thymectomy group exhibited a significantly worse RFS than the total thymectomy group (HR = 5.02, 95% CI: 1.67 – 15.01, $p = 0.004$). The statistical power for OS and RFS in this study exceeded 0.99.

Cause of death and sites of recurrence

There was no significant difference in the causes of death and sites of recurrence between the groups in the unadjusted data (Table 3). There was no significant difference between the groups in terms of cause of death even after adjustment (Table 4). However, in the adjusted data, both local and distant metastatic recurrences were significantly more frequent in the partial thymectomy group (Local recurrence: 22.1% /Distance recurrence: 31.0%) than in the total thymectomy group (Local recurrence: 5.1% /Distance recurrence: 5.9%).

Discussion

This study investigated the differences in prognosis and recurrence associated with the choice of surgical procedure, total thymectomy versus partial thymectomy, for thymic

carcinoma using real-world data. As a multicenter retrospective observational study, inherent differences in patient backgrounds existed between the groups. To minimize selection bias, we performed propensity score matching using overlap weighting, and analysis of OS and RFS with the adjusted data revealed significantly unfavorable outcomes in the partial thymectomy group. These findings indicated that partial thymectomy for thymic carcinoma were associated with an increased risk of poor prognosis, providing important insights that may aid in surgical decision-making for thymic epithelial tumors.

The International Thymic Malignancy Interest Group reports that thymic carcinoma accounts for approximately 3–7% of all thymic epithelial tumors, being an independent risk factor for increased recurrence²⁷. However, only a few studies have specifically focused on cases of thymic carcinoma to evaluate surgical procedures. This is due to the rarity of thymic carcinoma itself and the long-standing standard surgical approach of total thymectomy for thymic epithelial tumors, which has left little opportunity to explore alternative methods. Nonetheless, recent reports demonstrating the non-inferiority of partial thymectomy for early-stage thymoma suggested that this approach may be selected more frequently in the future³. As a result, the number of thymic tumors with recurrence may be increasing due to cases where partial resection is performed under the preoperative suspicion of early-stage thymoma, but postoperative diagnosis reveals thymic carcinoma. To mitigate such risks, it is advisable to always consider the possibility of thymic carcinoma and to opt for total thymectomy whenever possible unless a definitive preoperative diagnosis can be established.

The primary reason for promoting minimally invasive surgery in early-stage thymic epithelial tumors is to reduce surgical trauma, including pain and complications. Traditionally, total

thymectomy has been performed via median sternotomy; however, there are clear differences in pain levels and cosmetic outcomes between median sternotomy and VATS. Consequently, VATS thymectomy has also been utilized for early-stage thymic epithelial tumors. Previous studies have reported that minimally invasive surgery for thymic malignancies shows no significant difference in R0 resection rates or recurrence rates compared with open surgery, while also being associated with shorter hospital stays²⁸. Moreover, even in studies limited to patients with thymic carcinoma, no significant difference in survival has been observed between VATS and open surgery²⁹. More recently, the techniques for VATS and RATS total thymectomy using unilateral, bilateral, and subxiphoid approaches have been further refined. Open surgery remains indicated for large tumors measuring ≥ 10 cm or for those invading the great vessels or chest wall; however, all cases deemed resectable by VATS have also been found to be resectable by RATS, suggesting that the indications for RATS may further expand in the future^{30,31}. As a result, there is no longer a significant difference between minimally invasive partial and total thymectomy in terms of thoracic invasiveness, including surgical incision. Moreover, a meta-analysis comparing partial and total thymectomy for Stage I and II thymomas found no significant difference in complication rates between the two procedures⁵. Therefore, aside from operative time, there is no clear advantage to selecting partial thymectomy. Another important factor in determining the choice of surgical procedure is the potential influence of resection margins. Among total thymectomy cases (n = 73), 4 patients (5.5%) had positive margins, whereas among partial thymectomy cases (n = 19), 2 patients (10.5%) had positive margins, suggesting a tendency for margin positivity in partial resections. Regarding recurrence, 28 of 86 patients (32.6%) with negative margins developed either local or distant recurrence, while 1 of 6 patients

(16.7%) with positive margins experienced recurrence. Thus, in this study, the relationship between margin positivity and recurrence was not evident. Further accumulation of data is needed to clarify the underlying mechanisms.

Another concern regarding limited resection for thymic carcinoma is the discrepancy between the clinical and pathological staging. In this study, approximately 80% of cases preoperatively diagnosed with clinical stage I thymic carcinoma were later upstaged to a higher pathological stage. Previous studies have reported that distinguishing thymoma from thymic carcinoma is sometimes difficult, particularly in cases with small tumor size or no radiologically apparent invasion into surrounding organs^{19,20}. Certain CT findings, such as irregular tumor contour, areas of necrosis or cystic change, heterogeneous contrast enhancement, lymph node enlargement, and great vessel invasion, have been reported as characteristic features suggestive of thymic carcinoma; however, clinical stage I cases were not included in those reports¹⁷. In general, thymic carcinoma tends to present as a large, highly invasive tumor and is often diagnosed at an advanced stage¹⁷. In contrast, in our cohort, 86.5% of patients were preoperatively diagnosed with thymoma and proceeded to surgery, suggesting that radiologic findings in these cases indicated limited invasiveness. Our results indicate that even in cases without the typical imaging features suggestive of thymic carcinoma and with small tumor size, the lesion may still be pathologically confirmed as thymic carcinoma. This finding highlights the difficulty of diagnosing clinical stage I thymic carcinoma based on imaging alone. Currently, the National Comprehensive Cancer Network (NCCN) guidelines indicate that postoperative adjuvant radiotherapy improves survival in thymic carcinoma patients with pathological stage II or higher after complete resection^{32–34}. However, these recommendations are based on studies involving total thymectomy. Whether

the same benefit can be expected with adjuvant radiotherapy following limited resection remains an area for further investigation. Given the difficulty of diagnosing stage I thymic carcinoma, it is not advisable to assume that a tumor is a thymoma and selected for partial resection solely based on small tumor size and the absence of apparent invasion. Furthermore, intraoperative frozen section analysis is often insufficient to distinguish thymic carcinoma from thymoma and therefore cannot be recommended as a guide for conversion to total thymectomy^{35,36}.

This study has several limitations. First, the sample size was limited, as thymic carcinoma is rare and often presents with metastases, reducing the number of eligible cases. In addition, the difficulty of preoperative diagnosis makes it challenging to design prospective studies. Second, selection bias was present in the limited resection group, as these patients were generally older, had poorer performance status, and had tumors appearing less malignant on imaging. To minimize these biases, we applied overlap weight and concluded partial thymectomy resulted in poor prognosis in the patients with thymic carcinoma. Furthermore, factors dependent on each institution, such as surgeon experience and protocols for adjuvant therapy, may also represent potential limitations. While this is a limitation inherent to retrospective studies, we believe that our multicenter real-world data still provide valuable clinical insights.

Conclusion

Partial thymectomy for thymic carcinoma demonstrated unfavorable clinical outcomes compared to total thymectomy. Total thymectomy should remain the preferred surgical approach for undiagnosed thymic epithelial tumors to achieve optimal oncologic control and minimize the risk of recurrence.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Conflicts of Interest

All authors declare that they have no financial or personal relationships that could inappropriately influence (bias) their work.

Sources of Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical Approval

This retrospective multicenter study was approved by the ethics committee of the principal institution (approval number: K2301-037). Approval was subsequently obtained from the ethics committees of each participating institution.

Consent

Written informed consent was obtained from patients where applicable. For deceased or unreachable patients, an opt-out method approved by the institutional ethics committees was employed. No identifying information or images are included in this manuscript.

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Figure Legends

Figure 1

Sankey chart showing the relationship between Masaoka clinical stage and pathological stage. 79.3% of patients with clinical stage I disease were Upstaged to stage II or higher.

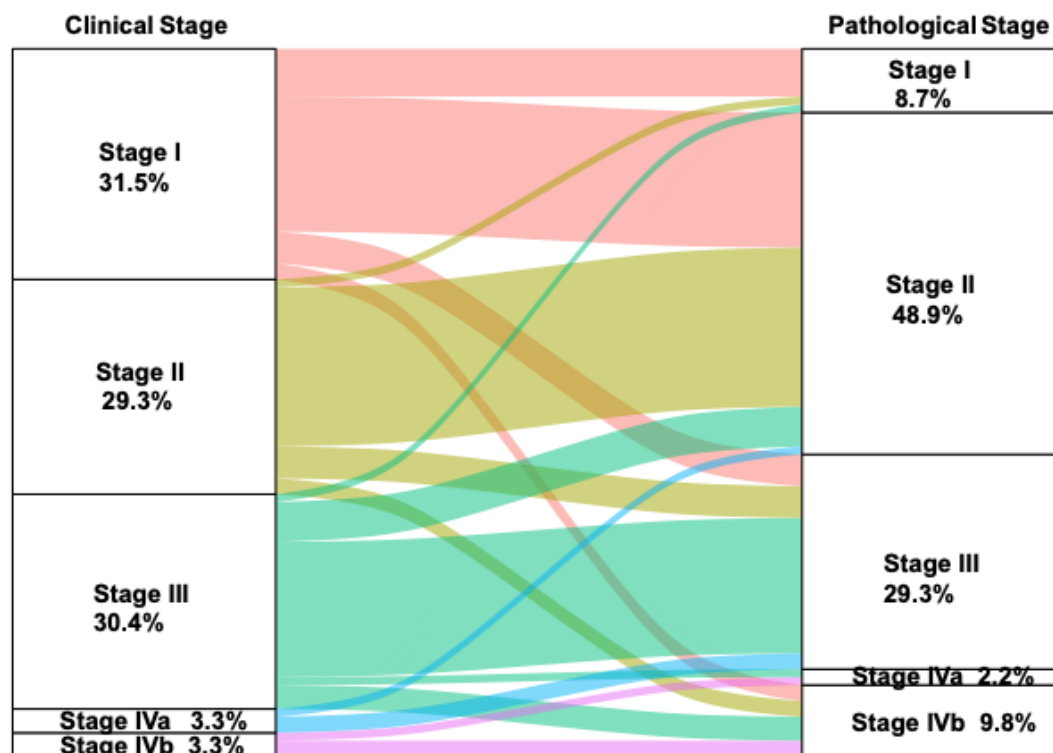


Figure 2

Kaplan-Meier survival analysis revealed a relationship between surgical procedure and Overall survival probability. The partial thymectomy group had a worse prognosis than the total thymectomy group (Log-rank test: $p = 0.0575$).

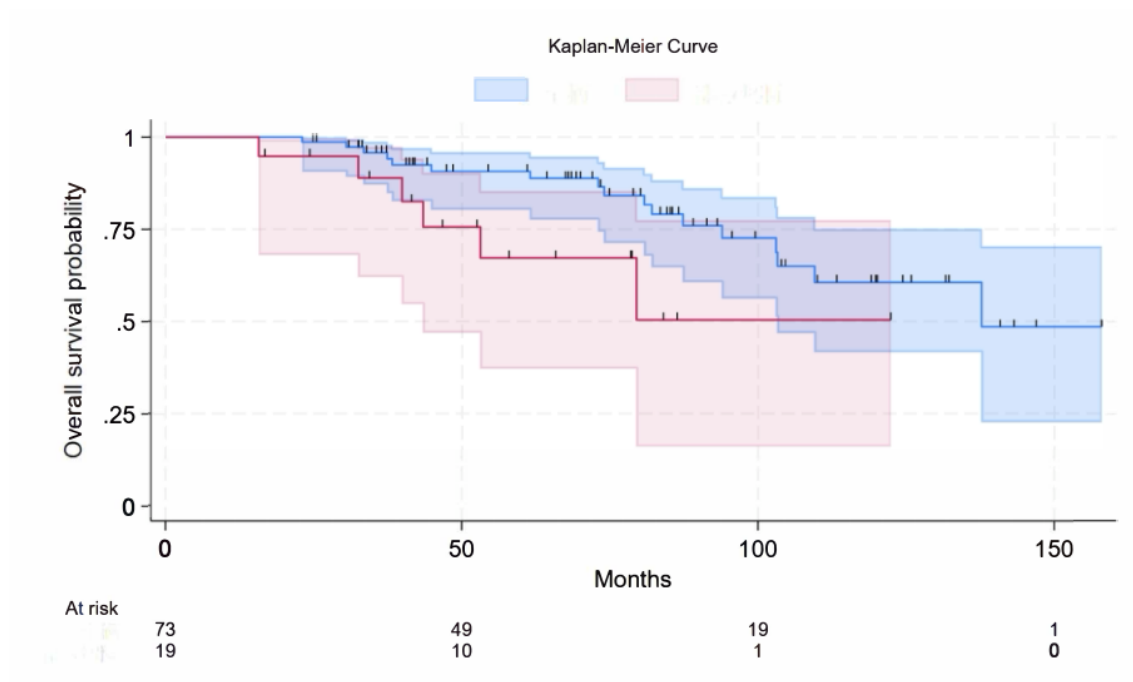


Figure 3

Kaplan-Meier survival analysis revealed a relationship between surgical procedure and Recurrence-free survival probability. The partial thymectomy group had a worse prognosis than the total thymectomy group (Log-rank test: $p = 0.0556$).

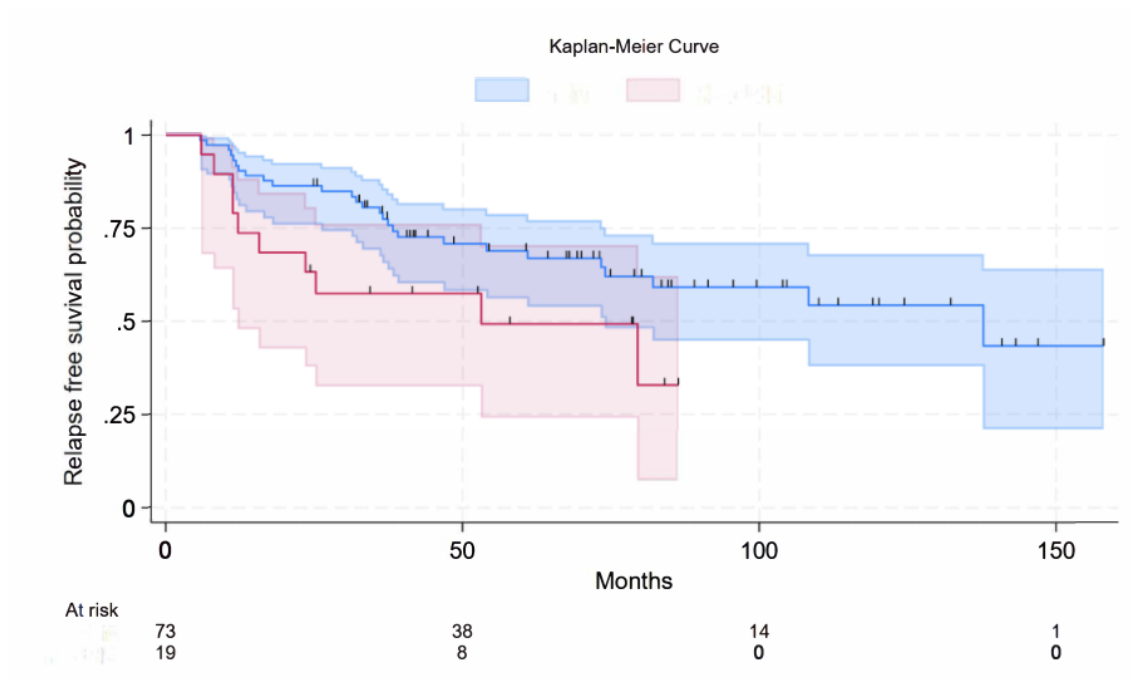


Figure 4

Kaplan-Meier survival curves after adjustment for propensity score weighting by overlap weight. Partial thymectomy resulted in significantly lower survival than total thymectomy (Log-rank test: $p = 0.0027$).

Note: The temporary narrowing of the confidence interval in the total thymectomy group reflects the characteristics of weighted Kaplan–Meier estimation. This phenomenon can occur due to the dynamic structure of the weighted at-risk set and a transient absence of events during this interval. Such behavior is theoretically consistent and has been confirmed with Stata technical support.

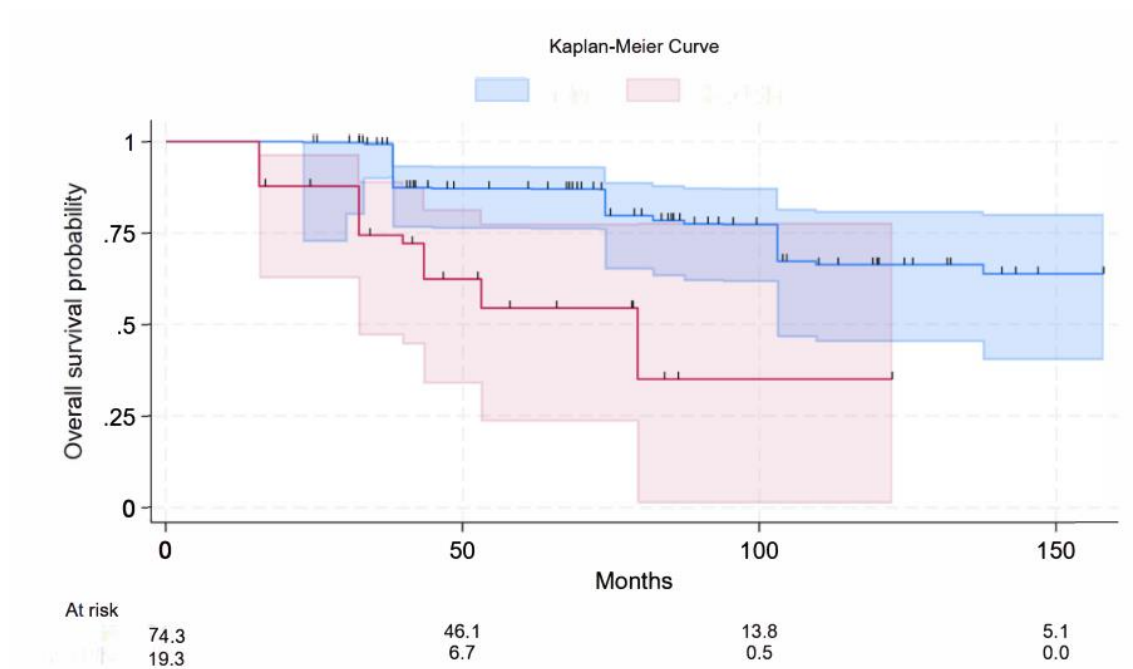


Figure 5

Recurrence-free survival analysis using Kaplan-Meier survival after adjustment for propensity score weighting by Overlap weight. Partial thymectomy resulted in significantly lower recurrence-free survival compared to total thymectomy (Log-rank test: $p < 0.0001$).

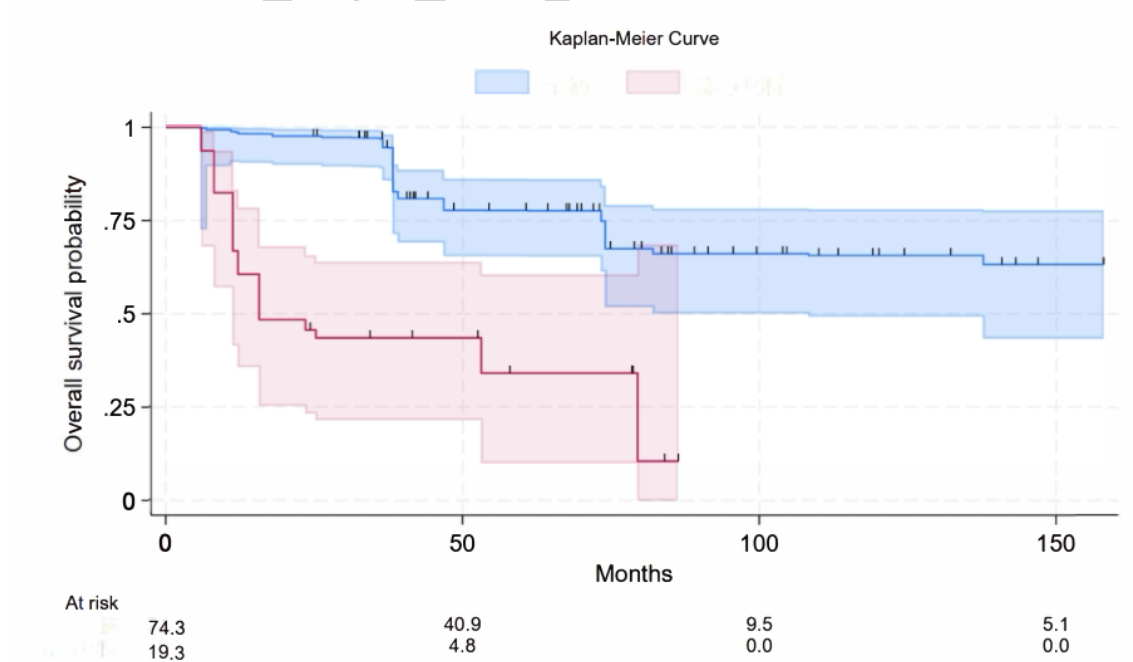


Table 1. Baseline characteristics of both groups

	Total thymectomy (N=73)	Partial thymectomy (N=19)	p value
Sex (Male)	41 (56.2%)	11 (57.9%)	0.892
Age (Median)	65 [57-72]	75 [68-81]	<0.001
Performance status (0/1/2)	67/6/0	12/6/1	0.003
CT findings			
Axial size (Median) (cm)	4.2 [3.1-5.6]	2.6 [1.7-3.4]	<0.001
Fat tissue invasion, positive	46 (63.0%)	5 (26.3%)	0.004
Mediastinal lymphadenopathy	9 (12.3%)	0 (0%)	0.107
Pulmonary nodule	3 (4.2%)	1 (5.3%)	0.845
PET-CT SUV max (Median)	7.9 [5.7-11.0]	4.6 [3.2-6.1]	0.175
Biopsy	18 (24.7%)	0 (0%)	0.016
cMasaoka (I/II/III/IV)	17/24/27/5	12/3/1/1	0.001
Neoadjuvant therapy	6 (9.1%)	0 (0%)	0.359
Surgical Approach			<0.001
Thoracotomy	58 (79.5%)	6 (31.6%)	
VATS/RATS	15 (20.5%)	13 (68.4%)	
Combined resection	43 (58.9%)	6 (31.6%)	0.032
Histopathology			0.313

Squamous cell carcinoma	63 (86.3%)	18 (94.7%)	
Others	10 (13.7%)	1 (5.3%)	
Pathological invasion	59 (80.8%)	16 (84.2%)	0.734
pMasaoka (I/II/III/IV)	5/33/24/10	3/12/3/1	<0.001
Adjuvant therapy	40 (54.8%)	10 (52.6%)	0.866
Adjuvant chemotherapy	14 (19.2%)	1 (5.3%)	0.144
Adjuvant Radiotherapy	33 (45.2%)	9 (47.4%)	0.866

N (%)

Median [IQR]

CT, computed tomography; PET-CT, Positron Emission Tomography - Computed Tomography; SUV-max, Standardized Uptake Value (SUV) max; cMasaoka, Masaoka clinical stage; VATS, video-assisted thoracic surgery; RATS, robot-assisted thoracic surgery; pMasaoka, Masaoka pathological stage, IQR; interquartile range.

Table 2. Patient's characteristics after Overlap weight

Unadjusted data			Overlap weight		
Total	Partial	SM	Total	Partial	SM
thymectomy	thymectomy	D	thymectomy	thymectomy	D
73 (79.3%)	19 (20.7%)		74.3	19.3 (20.6%)	
			(79.4%)		

Sex

0	32 (43.8%)	8 (42.1%)	0.0	36.45	9.49 (49.1%)	0.0
			3	(49.1%)		0

1	41 (56.2%)	11 (57.9%)		37.85	9.85 (50.9%)	
				(50.9%)		
Age	63.45	73.74 (7.27)	1.0	72.07 (8.48)	72.07 (8.05)	0.0
	(11.76)		5			0
Performance status						
0	67 (91.8%)	12 (63.2%)	0.7	55.44	14.78	0.0
			2	(74.6%)	(76.4%)	0
1	6 (8.2%)	6 (31.6%)		18.86	4.21 (21.8%)	
				(25.4%)		
2	0(0.0%)	1 (5.3%)		0.00 (0.0%)	0.35 (1.8%)	
Axial size (Median)	4.20 [3.10,	2.60 [1.70,	-1.	3.00 [1.90,	2.80 [2.00,	0.0
(cm)	5.50]	3.40]	07	3.60]	3.60]	0
PET-CT SUV max	7.90 [5.80,	4.60 [3.20,	-0.	5.90 [5.60,	4.60 [3.20,	-0.
(Median)	10.50]	6.09]	55	10.24]	6.09]	72
cMasaoka						
(3categories)						
I	17 (23.3%)	14 (73.7%)		42.22	10.99	
				(56.8%)	(56.8%)	
II	24 (32.9%)	3 (15.8%)	-0.	22.41	5.83 (30.2%)	0.0
			40	(30.2%)		0
≧ III	32 (43.8%)	2 (10.5%)	-0.	9.67	2.52 (13.0%)	0.0
			80	(13.0%)		0

Surgical Approach

Thoracotomy	58 (79.5%)	6 (31.6%)	1.0	28.85	7.51 (38.8%)	0.0
			8	(38.8%)		0
VATS/RATS	15 (20.5%)	13 (68.4%)		45.45	11.83	
				(61.2%)	(61.2%)	
Combined						
resection						
No	30 (41.1%)	13 (68.4%)	-0.	50.58	13.16	0.0
			56	(68.1%)	(68.1%)	0
Yes	43 (58.9%)	6 (31.6%)		23.72	6.17 (31.9%)	
				(31.9%)		
Histopathology						
Squamous cell carcinoma	63 (86.3%)	18 (94.7%)	-0.	69.57	18.11	0.0
			29	(93.6%)	(93.6%)	0
Others	10(13.7%)	1 (5.3%)		4.73 (6.4%)	1.23 (6.4%)	
pMasaoka						
I-II	39 (53.4%)	15 (78.9%)	-0.	53.03	13.80	0.0
			55	(71.4%)	(71.4%)	0
III-IV	34 (46.6%)	4 (21.1%)		21.26	5.53 (28.6%)	
				(28.6%)		
Adjuvant						
Radiotherapy						
No	40 (54.8%)	10 (52.6%)	0.0	41.36	10.76	0.0
			4	(55.7%)	(55.7%)	0

Yes	33 (45.2%)	9 (47.4%)	32.94	8.57 (44.3%)		
			(44.3%)			
Adjuvant chemotherapy						
No	59 (80.8%)	18 (94.7%)	-0.43	67.72 (91.2%)	17.63 (91.2%)	0.0
Yes	14 (19.2%)	1 (5.3%)	6.57 (8.8%)	1.71 (8.8%)		

Mean (SD) or N (%)

Median [IQR]

SMD, Standardized Mean Difference; SD, standard deviation; IQR; interquartile range.

Table 3. Cause of death and recurrent sites

	Total thymectomy (n=73)	Partial thymectomy (n=19)	p value
Total deaths	17	6	
Primary cause	9 (52.9%)	2 (33.3%)	0.408
Other cause	8 (47.1%)	4 (66.7%)	
Total recurrence	22 (30.1%)	7 (36.8%)	0.575
Local recurrence	15 (20.6%)	4 (21.1%)	0.961
Distant recurrence	10 (13.7%)	5 (26.3%)	0.185

Table 4. Cause of death and recurrent sites in the adjusted data.

* The weighted chi-square test was adjusted using the Rao-Scott correction.

	Total thymectomy	Partial thymectomy	p value *
	(n=74.3)	(n=19.3)	
Total deaths	13.8	7.1	
Primary cause	1.1 (7.9%)	2.5 (35.6%)	0.154
Other cause	12.7 (92.0%)	4.6 (64.4%)	
Total recurrence	7.9 (10.6%)	8.5 (44.0%)	0.006
Local recurrence	3.8 (5.1%)	4.3 (22.1%)	0.040
Distant recurrence	4.4 (5.9%)	6.0 (31.0%)	0.009

Highlight

- Partial thymectomy for thymic carcinoma was associated with an increased risk of recurrence and poorer overall survival compared to total thymectomy.
- Preoperative imaging modalities were insufficient for accurately distinguishing thymic carcinoma from thymoma and for precise staging, which may have resulted in misclassification and suboptimal surgical decision-making.
- In light of the potential risks associated with limited resection, total thymectomy should be recommended for patients with undiagnosed thymic epithelial tumors, even in cases that preoperatively appear to exhibit low-grade malignancy.