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# Optimal lymph node yield for long-term survival in elderly patients with right-sided colon cancer: a large population-based cohort study

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## Abstract

**Background** Although the recommended minimal lymph node yield (LNY) in colon cancer is 12, this standard remains controversial in elderly patients with right-sided colon cancer (RSCC) due to insufficient evidence. This study aims to clarify this issue by assessing the relationship between LNY and long-term survival in elderly patients with RSCC.

**Methods** Data from the SEER database (split into 7:3 training and testing sets) and patients from the colorectal surgery departments of two tertiary hospitals in China (validation set) were analyzed. Elderly patients with stages I-III RSCC undergoing resection were included. The correlation between LNY and overall survival (OS) was evaluated by a multivariate model and the application of the restricted cubic spline curve (RCS). The odds ratios (ORs) for stage migration and the hazard ratios (HRs) for OS with increased LNY were estimated using Locally Weighted Scatterplot Smoothing (LOWESS), with structural breakpoints identified using the Chow test.

**Results** The distribution of LNY was similar across the training (median: 18, IQR [14, 23]), testing (median: 18, IQR [14, 23]), and validation (median: 17, IQR [14, 20]) sets. Increasing LNY was associated with significantly improved OS in all datasets (Training set: HR = 0.983; Testing set: HR = 0.981; Validation set: HR = 0.944, all $P < 0.001$) after adjusting for confounders. Cut-point analysis identified an optimal LNY threshold of 18, validated across datasets, effectively discriminating survival probabilities.

**Conclusions** A higher LNY is associated with improved survival. Our findings robustly support 18 LNYs as the optimal threshold for assessing the quality of lymph node dissection and prognosis stratification in elderly patients with RSCC.

**Keywords** Lymph node yield, Right-sided colon cancer, Elderly, Survival

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## Introduction

Colon cancer is one of the leading causes of cancer-related deaths worldwide, with a notable rise observed in the prevalence of right-sided colon cancer (RSCC), particularly among the elderly population (aged ≥ 75 years) [1, 2]. This increase can be attributed to shifts in dietary patterns and population aging trends [3]. For most operable elderly patients with RSCC, radical surgical resection combined with extensive lymphadenectomy remains the cornerstone of therapeutic intervention, offering the most promising avenue towards achieving a cure.

The lymph node yield (LNY) harvested during surgical procedures serves as a critical indicator in assessing the quality of curative resection in clinical practice [4–6]. Patients with positive lymph node metastasis face elevated risks of disease recurrence. To ascertain the precise N stage in colorectal cancer, both the National Comprehensive Cancer Network (NCCN) guidelines and the American Joint Committee on Cancer (AJCC) staging system require the examination of a minimum of 12 LNY. However, in the realm of clinical practice, the determination of LNY in colorectal cancer encounters multifaceted influences, including patient-specific characteristics and tumor heterogeneity [7, 8]. Consequently, the proposition of standardizing LNY for colorectal cancer utilizing a uniform criterion has sparked considerable debate.

Given the mesenteric anatomy, numerous studies have highlighted that the LNY in patients with RSCC surpasses the suggested threshold of 12 LNY, even among elderly individuals [9, 10]. However, due to differences in methodological approaches and study cohorts, determining the optimal LNY remains contentious. Several prior studies have proposed that retrieving 15 to 23 or even more LNY may enhance the prognosis of patients with RSCC [11–14].

In elderly patients, there are several anatomical and physiological differences that could influence LNY, potentially requiring a different threshold for survival outcomes compared to younger patients or those with left-sided colon cancer. Age-related changes in the lymphatic system, such as reduced lymph node size and the degeneration of immune function, may lead to less effective lymphadenectomy in older individuals. Additionally, the immune response in elderly patients is often weaker, which may result in fewer lymph nodes being harvested or fewer detected during surgery. These factors, in conjunction with variations in mesenteric anatomy in RSCC, further support the hypothesis that elderly patients may benefit from a higher threshold of LNY for better survival outcomes.

In this study, we hypothesized that there exists an optimal LNY for predicting prognosis in elderly individuals with RSCC. Consequently, we conducted this longitudinal cohort study, employing robust statistical methods, to investigate the optimal LNY and evaluate the long-term survival outcomes among elderly patients with RSCC.

## Method

### Study population

Data for this study were sourced from the Surveillance, Epidemiology, and End Results (SEER) database, an open-access database containing patient demographics, tumor data, perioperative treatment data, and survival data. Records of elderly individuals diagnosed with RSCC between January 2010 and December 2017 were retrieved from the SEER database using SEER*Stat version 8.1.5. The SEER database is an open-access resource that allows researchers worldwide to utilize its data for legitimate research purposes. Furthermore, data on elderly patients with RSCC who underwent surgical resection from January 2011 to December 2018 at the Colorectal Surgery Department of the Second Affiliated Hospital of Harbin Medical University and the Colorectal Surgery Department of Shanxi Provincial Cancer Hospital were also collected. All patients were staged in accordance with the 8th edition of the AJCC TNM staging system.

The inclusion criteria included: (1) Patients pathologically diagnosed with stage I to III RSCC; (2) Age ≥ 75 years; and (3) Detection of at least one LNY based on pathological findings. The exclusion criteria comprised: (1) Patients who received preoperative chemotherapy or radiotherapy; (2) Patients treated with local resection or total colectomy; and (3) Individuals with missing LNY or tumor characteristic data.

The patients extracted from the SEER database were randomly stratified into training and testing sets at a ratio of 7:3, whereas the dataset from the Colorectal Surgery Department of the Second Affiliated Hospital of Harbin Medical University and the Colorectal Surgery Department of Shanxi Provincial Cancer Hospital served as a validation set due to its smaller sample size. The variables considered in the analysis comprised age, sex, LNY, tumor-related characteristics (stage, grade, histological type, size), chemotherapy administration, and outcome variables (follow-up duration and survival status).

### Statistical analyses

Categorical variables were expressed as proportions, while continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range, IQR) based on data distribution. The 5-year overall survival (OS) rates were computed using the Kaplan–Meier method, and differences were evaluated through the log-rank test. Multivariate analysis was conducted employing the Cox proportional hazards regression model to calculate hazard ratios (HRs) with their corresponding 95% confidence intervals (CIs), adjusting for potential confounders such as sex, age, grade, histology type, tumor size, tumor stage, and adjuvant chemotherapy.

The relationship between LNY and OS were explored on a continuous scale using restricted cubic splines (RCS) within a multivariable Cox model featuring three knots situated at the 10th, 50th, and 90th percentiles of LNY. RCS is widely recognized as a robust methodology for examining the association between survival rates and independent variables [15]. It comprises smoothly interconnected polynomial functions, thereby circumventing the assumption of linearity in the relationship between variables and the response, such as survival. Additionally, RCS facilitates the detection of the inflection point of the risk function, commonly referred to as the threshold [16, 17].

we utilized a binary logistic regression model to assess stage migration by examining the relationship between LNY and the proportion of each node stage category (node-negative versus node-positive) [18]. This analysis was adjusted for additional potential confounders linked to LNY.

**Table 1** Clinicopathologic characteristics of included patients

| Variable | Training set | Testing set | Validation set |
|---|---|---|---|
| | **N = 20,385** | **N = 8736** | **N = 454** |
| **Age, years** | | | |
| 75–84 | 13,367 (65.6) | 5750 (65.8) | 406 (89.4) |
| ≥ 85 | 7018 (34.4) | 2986 (34.2) | 48 (10.6) |
| **Sex** | | | |
| Female | 12,227 (60.0) | 5240 (60.0) | 228 (50.2) |
| Male | 8158 (40.0) | 3496 (40.0) | 226 (49.8) |
| **LNY, (IQR)** | 18 [14, 23] | 18 [14, 23] | 17 [14, 20] |
| **AJCC Stage** | | | |
| Stage1 | 4933 (24.2) | 2098 (24.1) | 22 (4.8) |
| Stage2 | 8868 (43.5) | 3908 (44.7) | 262 (57.7) |
| Stage3 | 6584 (32.3) | 2730 (31.2) | 170 (37.5) |
| **AJCC T stage** | | | |
| T1-T2 | 5612 (27.5) | 2368 (27.1) | 28 (6.2) |
| T3-T4 | 14,773 (72.5) | 6368 (72.9) | 426 (93.8) |
| **AJCC N stage** | | | |
| N0 | 13,801 (67.7) | 6006 (68.8) | 284 (62.6) |
| N1-N2 | 6584 (32.3) | 2730 (31.2) | 170 (37.4) |
| **Grade** | | | |
| Well/Moderately | 15,514 (76.1) | 6604 (75.6) | 346 (76.2) |
| Poorly/Undifferentiated | 4871 (23.9) | 2132 (24.4) | 108 (23.8) |
| **Histology** | | | |
| Adenocarcinoma | 17,732 (87.0) | 7539 (86.3) | 384 (84.6) |
| Mucinous adenocarcinoma | 2653 (13.0) | 1197 (13.7) | 70 (15.4) |
| **Tumor Size, cm (Mean ± SD)** | 4.9 ± 2.8 | 4.9 ± 3.2 | 5.6 ± 2.2 |
| **Chemotherapy** | | | |
| No/Unknown | 17,738 (87.0) | 7593 (86.9) | 335 (73.8) |
| Yes | 2647 (13.0) | 1143 (13.1) | 119 (26.2) |

The odds ratios (ORs) for stage migration and the HRs for OS, comparing each LNY count to one LNY as a reference, were fitted using Locally Weighted Scatterplot Smoothing (LOWESS) with a default bandwidth of 2/3 [19, 20]. Subsequently, structural breakpoints were identified using the Chow test and piecewise linear regression, employing the 'strucchange' and 'segmented' R packages. These breakpoints were deemed thresholds indicative of clinical significance. All statistical analyses were performed using R software (version 4.3.2; http://www.r-project.org). A significance level of $P < 0.05$ was considered statistically significant.

## Results

### Patient and tumor characteristics

The cohort comprised 29,121 patients from the SEER database, divided into a training set (70%) and a testing set (30%), alongside 454 patients from the colorectal surgery departments of two tertiary hospitals in China forming the validation set. These patients met the eligibility criteria for inclusion in the study. The baseline characteristics of the cohorts are shown in Table 1. Notably, the validation set exhibited a lower proportion of individuals aged 85 years and older (10.6%) compared to the training and testing sets. While the gender distribution of the training and test sets was greater for females (60%) than males, the validation set displayed a nearly equal gender ratio. The incidence of stage I patients in the validation set was notably lower (4.8%) than in the training and testing sets. However, consistent tumor differentiation patterns were observed across all datasets. Furthermore, the average tumor size approximated 5 cm across all datasets (4.9, 4.9, and 5.6 cm). Postoperative chemotherapy was more prevalent in the validation set (26.2%) compared to the training and testing sets (approximately 13%), likely influenced by the lower proportion of elderly patients aged 85 years and older in the validation set.

Figure 1 illustrates the distribution of LNY among patients from the training and testing sets, with an average LNY of 18. Among these patients, over 89.2% had an LNY of 12 or more. Similarly, a high percentage of patients in the validation set (91.6%) had an LNY of 12 or more.

### LNY and survival

Table 2 demonstrates that, after adjusting for various prognostic factors such as age, sex, stage, grade, histology, tumor size, and adjuvant chemotherapy, higher LNY consistently correlated with improved OS in all three datasets (Training set: HR = 0.983, 95% CI = 0.980–0.985, $p < 0.001$; Testing set: HR = 0.981, 95% CI = 0.977–0.985, $p < 0.001$; Validation set: HR = 0.944, 95% CI = 0.915–0.974, $p < 0.001$).

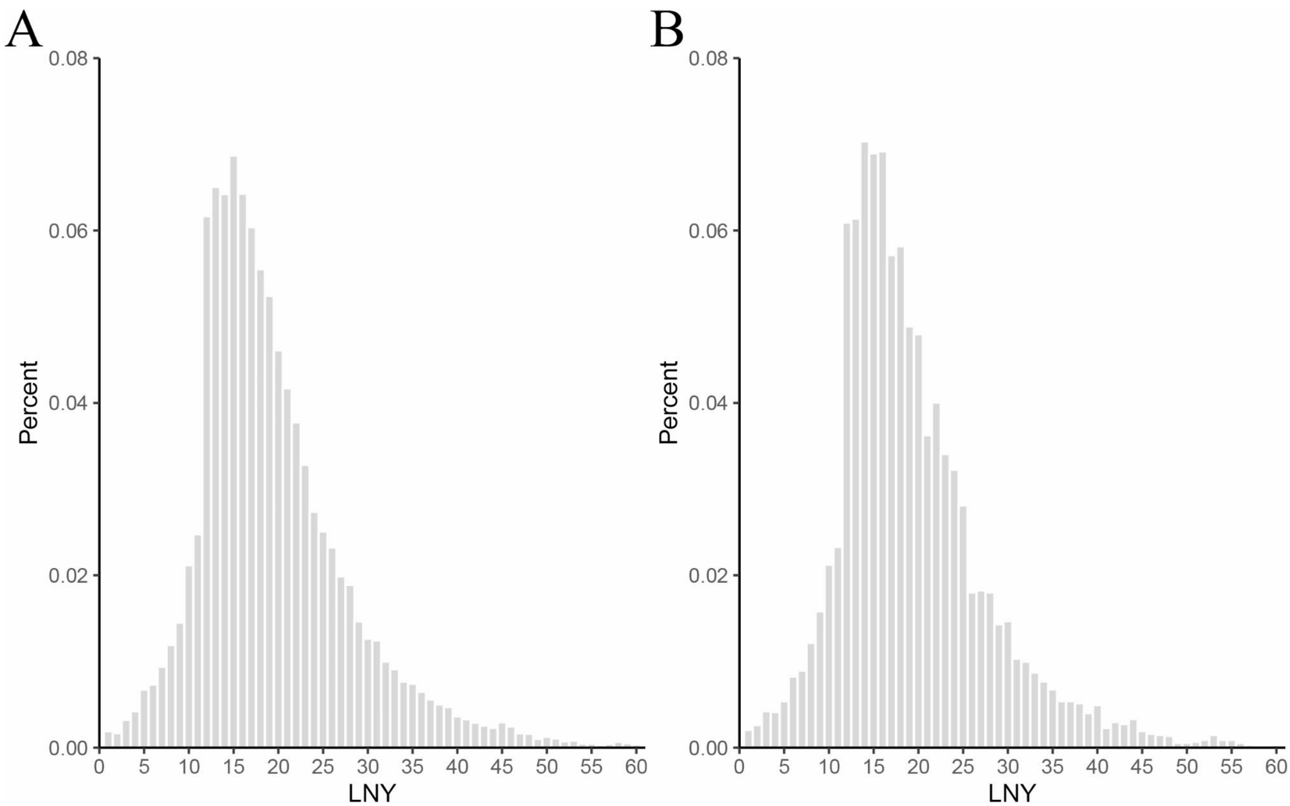


**Fig. 1** Distribution of the harvested lymph node yield (LNY) in the training set (**A**) and testing set (**B**)

**Table 2** Multivariate cox analysis for overall survival in elderly patients with right-sided colon cancer

| Variable | Training set | | Testing set | | Validation set | |
|---|---|---|---|---|---|---|
| | HR (95% CI) | *p*-value | HR (95% CI) | *p*-value | HR (95% CI) | *p*-value |
| **LNY** | **0.983(0.980–0.985)** | **<0.001** | **0.981(0.977–0.985)** | **<0.001** | **0.944(0.915–0.974)** | **<0.001** |
| **Age** | | | | | | |
| 75–84 | Reference | | Reference | | Reference | |
| ≥ 85 | 1.606(1.538–1.676) | <0.001 | 1.621(1.518–1.731) | <0.001 | 2.768(1.769–4.331) | <0.001 |
| **Sex** | | | | | | |
| Female | Reference | | Reference | | | |
| Male | 1.249(1.197–1.303) | <0.001 | 1.231(1.154–1.313) | <0.001 | | |
| **AJCC Stage** | | | | | | |
| Stage1 | Reference | | Reference | | Reference | |
| Stage2 | 1.323(1.245–1.407) | <0.001 | 1.401(1.276–1.538) | <0.001 | 1.690(0.530–5.395) | 0.375 |
| Stage3 | 2.583(2.422–2.755) | <0.001 | 2.611(2.364–2.885) | <0.001 | 3.271(1.023–8.458) | 0.046 |
| **Grade** | | | | | | |
| Well/Moderately | Reference | | Reference | | | |
| Poorly/Undifferentiated | 1.240(1.182-1.300) | <0.001 | 1.247(1.160–1.340) | <0.001 | | |
| **Histology** | | | | | | |
| Adenocarcinoma | Reference | | Reference | | | |
| Mucinous adenocarcinoma | 1.040(0.979–1.105) | 0.203 | 1.058(0.967–1.157) | 0.221 | | |
| **Tumor Size** | 1.022(1.016–1.029) | <0.001 | 1.015(1.006–1.023) | 0.001 | | |
| **Chemotherapy** | | | | | | |
| No/Unknown | Reference | | Reference | | | |
| Yes | 0.546(0.508–0.586) | <0.001 | 0.572(0.512–0.638) | <0.001 | | |

### Cut-point analysis and comparison of optimal thresholds

To comprehensively assess the relationship between LNY and OS, a Cox model with RCS was constructed to flexibly model and visualize this association. As depicted in Fig. 2, both the training and testing sets exhibited an L-shaped curve, indicating a sharp decline in mortality risk before an LNY of less than 18, followed by a relatively stable trend thereafter (nonlinearity $p < 0.001$).

Figures 3 and 4 portray the fitted curves and corresponding structural breakpoints for the OR of stage migration and the HR of OS, respectively, after adjusting for potential confounders in both the training and testing sets. The breakpoints were largely consistent, ranging from 17 to 19. Considering the significance of survival and the pursuit of representativeness and generalizability, we recommend utilizing 18 LNY as the optimal threshold based on the RCS curves in both sets, as well as the fitted curve derived from the training set.

Given the universal adoption of the proposed threshold of 12 LNY in international guidelines for colorectal cancer, we categorized LNY into three groups (LNY < 12, LNY: 12–17, LNY ≥ 18) across all datasets. Survival analysis results depicted in Fig. 5 confirmed a significantly reduced mortality risk for patients with at least 18 LNY harvested across all datasets after adjusting for other prognostic factors.

## Discussion

To our knowledge, this study represents the largest investigation to date on the optimal LNY among elderly patients with RSCC, utilizing real-world datasets and with robust statistical methods. The total LNY stands as a significant prognostic marker for predicting survival outcomes in colorectal cancer patients within clinical settings. While prior studies have endeavored to ascertain the optimal LNY for colon cancer, with proposed figures ranging widely from 15 to 23, these studies have primarily employed univariate approaches and lacked statistical robustness [11–14]. Moreover, there is a dearth of research exploring the optimal LNY in elderly patients with RSCC based on large population-based studies.

We observed that 90% of elderly patients in the study had at least 12 LNY harvested during primary tumor resection. Consistent with existing literature, RSCC patients typically surpass the 12 LNY threshold, even among the elderly [14, 21]. This underscores the potential inadequacy of employing this threshold for assessing elderly patients with RSCC. As demonstrated, our

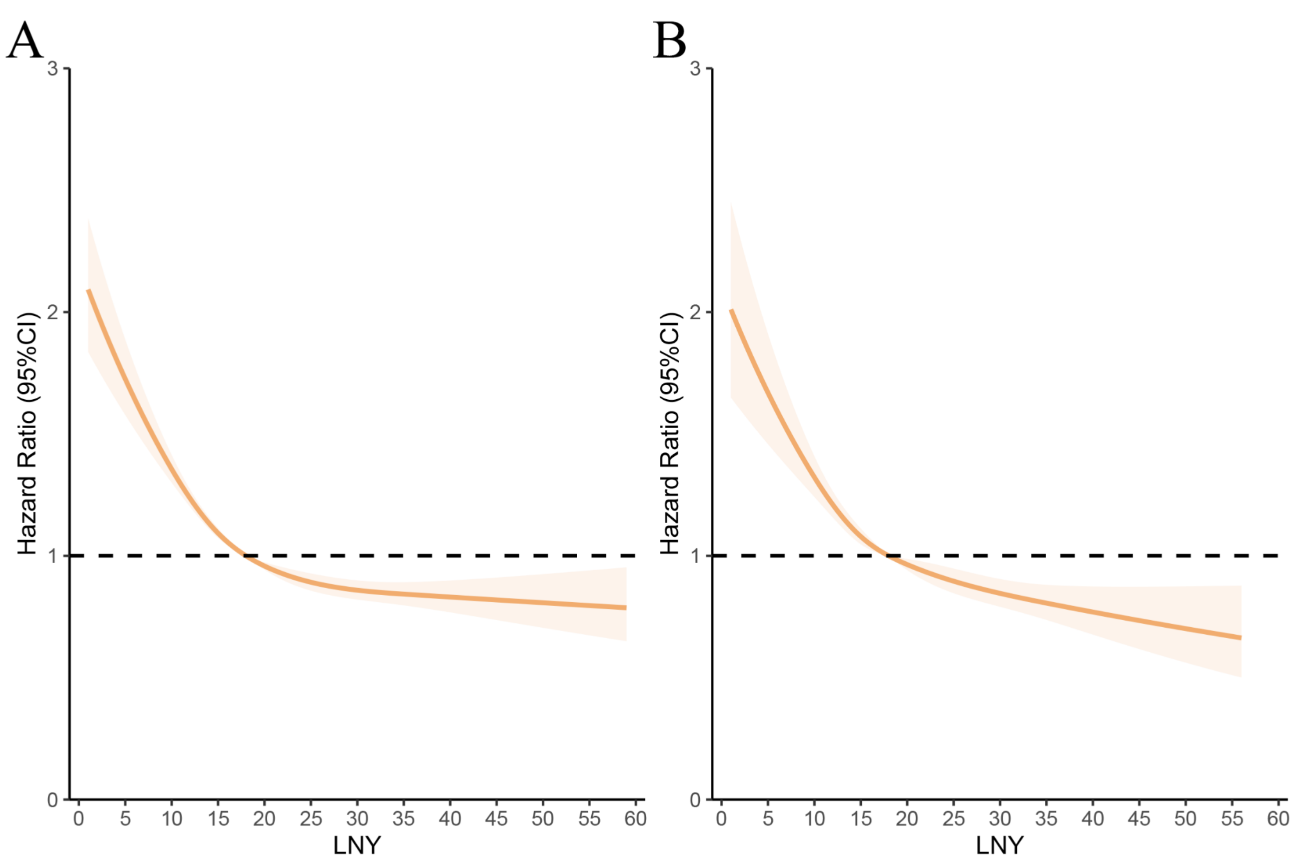


**Fig. 2** Association between lymph node yield (LNY) and overall survival (OS) using restricted cubic splines model in the training set (**A**) and testing set (**B**). Hazard ratios (HRs) are indicated by solid lines and 95% confidence intervals (CIs) by shaded areas

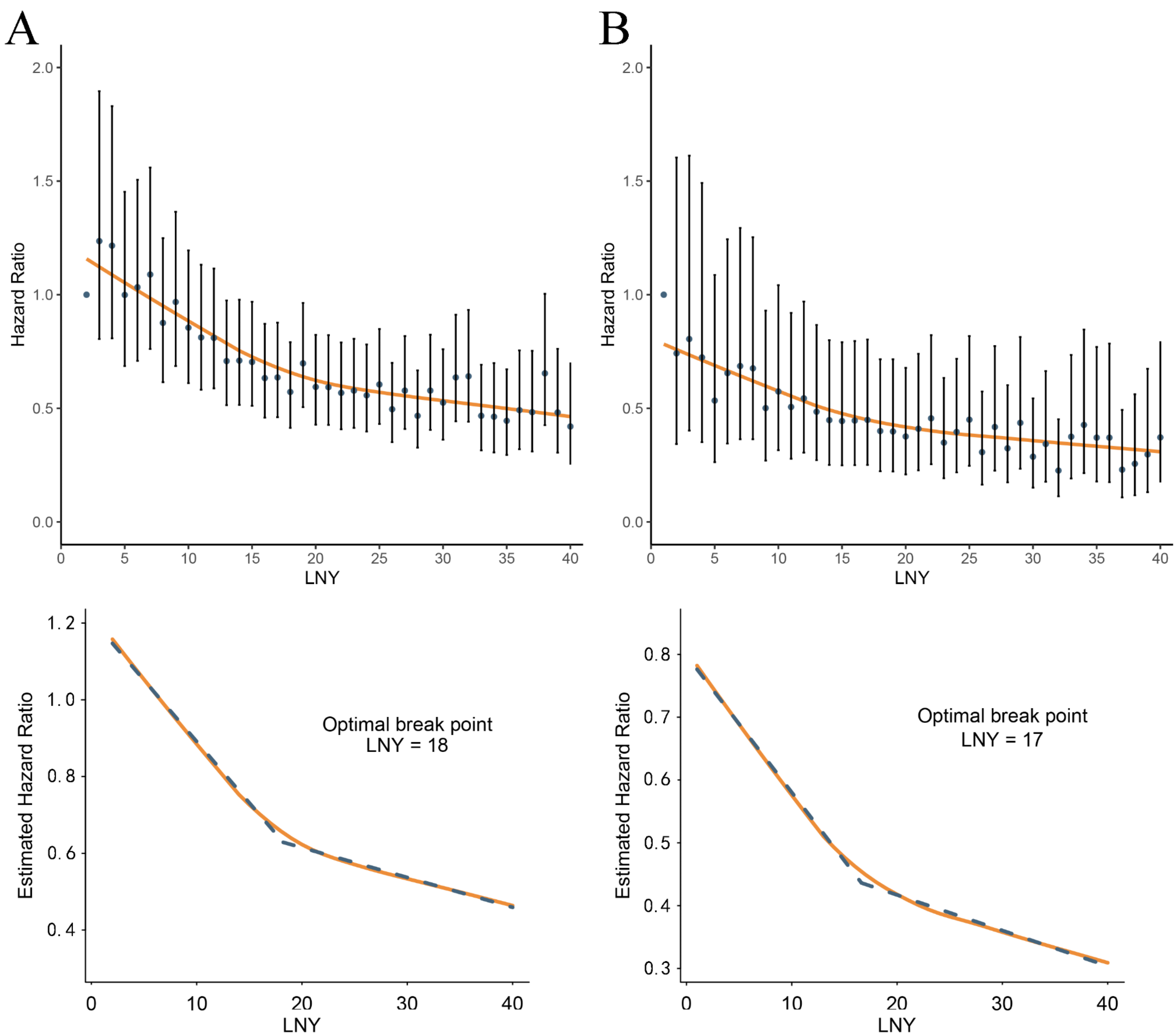


**Fig. 3** Associations of the Hazard ratios (HRs) for overall survival (OS) and lymph node yield (LNY). Locally Weighted Scatterplot Smoothing (LOWESS) smoothing fitting curves with a fitting bandwidth of 2/3 are shown in orange and the structural breakpoint was determined with use of the Chow test in the training set (**A**) and testing set (**B**)

findings suggest that a minimum of 18 LNY is linked to improved survival among elderly individuals with RSCC, serving as a crucial metric for standardizing care.

In our study, elderly patients with RSCC were frequently associated with advanced disease characteristics, such as an average tumor size of 5 cm and a pT3-T4 proportion exceeding 70%, consistent with findings reported in existing literature. This often leads to a higher LNY harvested. Orsenigo et al. investigated 2319 colorectal cancer patients and found that the T stage independently influenced LNY [22]. On one hand, heightened tumor invasion elicits a more robust inflammatory reaction in lymph nodes due to tumor-specific antigens. On the other hand, surgeons tend to conduct extensive lymph node dissections for advanced-stage diseases. Chou et al. found that for every 1-cm increase in tumor diameter, the LNY would increase by 2–3% [23]. Larger tumors are associated with wider margins around the tumor periphery, leading to stronger antigenic immune responses. This makes lymph nodes more easily detectable, resulting in an increased LNY.

Patients with RSCC typically undergo resection of more mesenteric tissue, contributing to increased LNY, possibly due to anatomical disparities in colonic anatomy stemming from distinct embryological development [24, 25]. Furthermore, pathological factors may also play a pivotal role in driving the augmented LNY observed in RSCC patients. Advancements in fat clearance methods and the utilization of lymph node tracers have led to

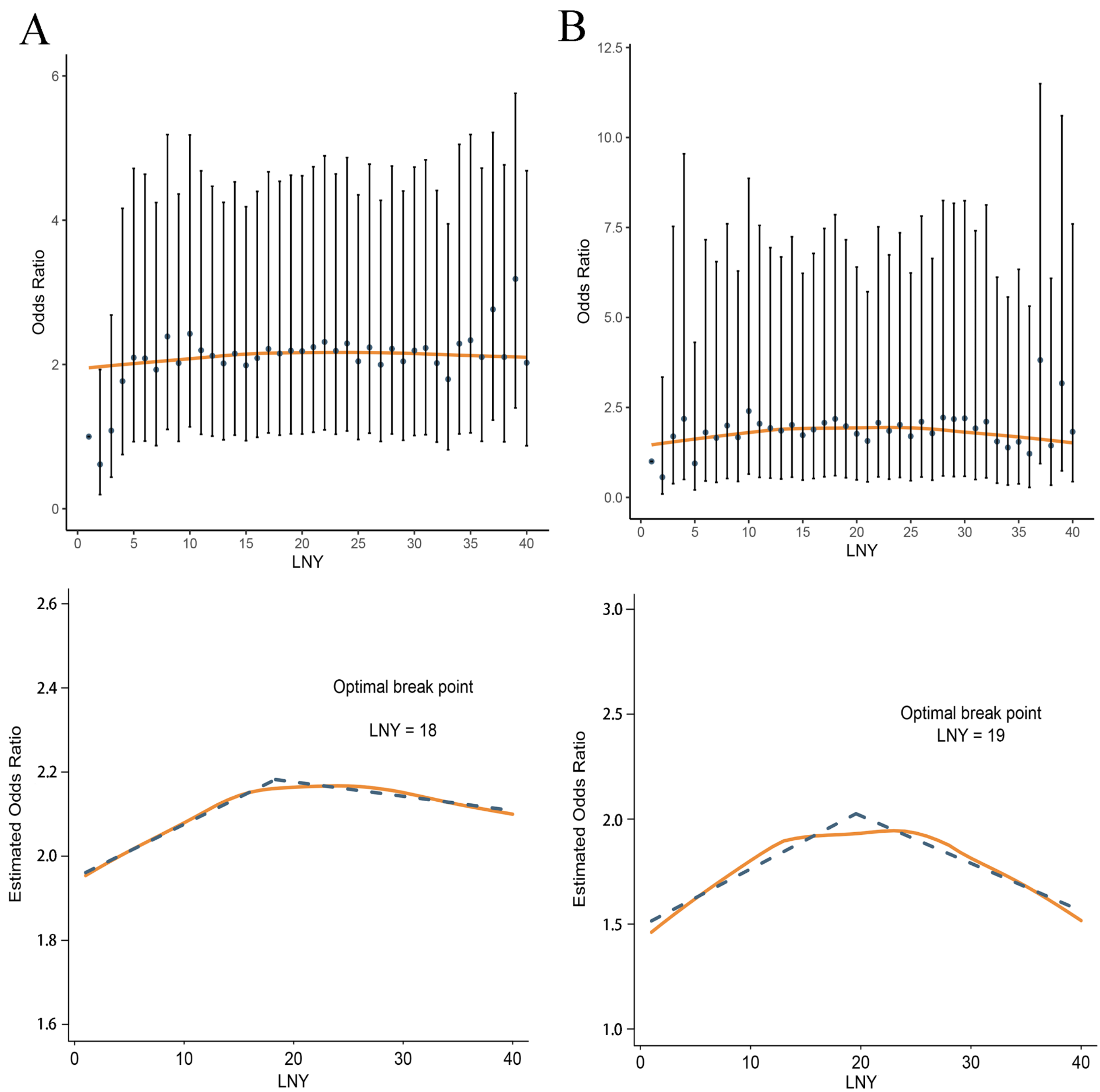


**Fig. 4** Associations of odds ratio for stage migration (negative-to-positive node) and lymph node yield (LNY). Locally Weighted Scatterplot Smoothing (LOWESS) smoothing fitting curves with a fitting bandwidth of 2/3 are shown in orange, and the structural breakpoint was determined with the use of the Chow test in the training set (**A**) and testing set (**B**)

studies suggesting an elevation in LNY in colorectal cancer cases [26].

In terms of age, extensive research indicates a decline in LNY with advancing age. Chou et al. observed that with each decade of age increase, the average LNY decreases by approximately 9%[23]. Several factors may explain why elderly patients exhibit reduced LNY retrieval during primary tumor resection. Surgeons may adjust lymphadenectomy plans based on elderly individual health status and procedural complexity. Recent studies have suggested a link between LNY and tumor immunity, highlighting the role of lymph node dissection in resetting the "cancer-friendly" immune response, even in non-metastatic nodes. Concerns regarding surgical outcomes in elderly patients, particularly those deemed high-risk due to potential life-threatening complications such as myocardial infarction or stroke from prolonged anesthesia during the perioperative period, may prompt less extensive mesenteric resection [27]. Furthermore, advancing age results in physiological lymph node

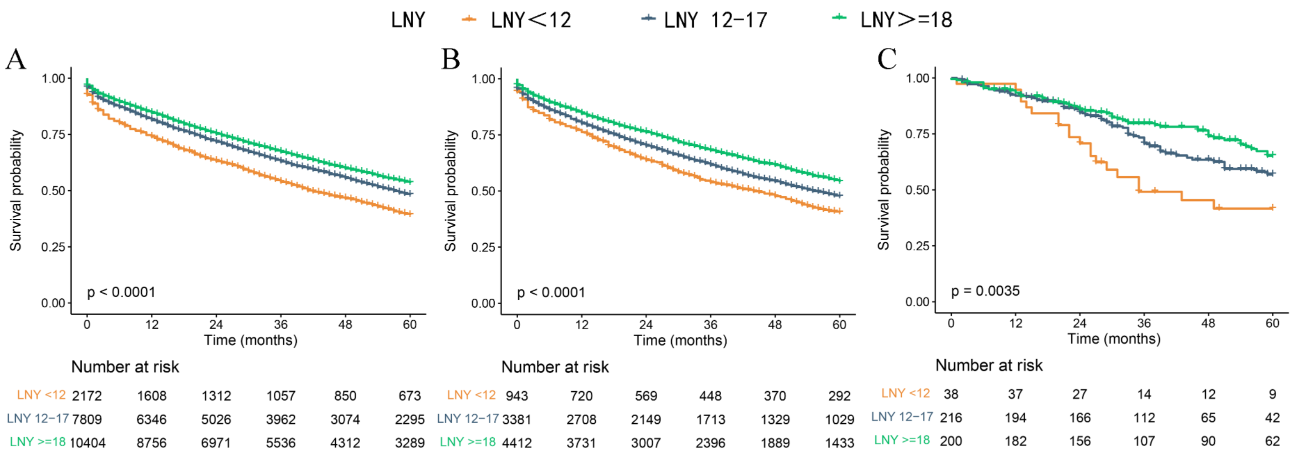


**Fig. 5** Kaplan–Meier curves of overall survival (OS) are shown for different groups of lymph node yield (LNY) in the training set (**A**), testing set (**B**) and validation set (**C**)

degeneration, weakening the immune response to tumors and reducing lymph node size, complicating their identification and retrieval.

In this study, LNY demonstrated an independent prognostic significance on long-term survival, consistent with findings from numerous previous studies [28, 29]. Several reasons may partially explain this observed survival correlation. The Will Rogers phenomenon underscores that cancer staging may be underestimated if LNY is insufficient to accurately determine stages [18]. Examining more LNY can mitigate the risk of undetected positive lymph nodes, resulting in more thorough remnant elimination and proper delivery of adjuvant therapies, thus enhancing long-term survival. We have also highlighted that while achieving the optimal LNY is beneficial, over-harvesting may not always be necessary or safe for certain subgroups of patients, particularly those with comorbidities or higher surgical risks. Balancing the "optimal" and "adequate" LNY is essential for individualized patient care.

Some researchers propose that tumor-draining lymph nodes exert two aspects of cancer immunity: antitumor immunity and tolerance for cancer. The balance of cancer immunity tends to lean toward tolerance as cancer progresses [30]. Therefore, resection of regional lymph nodes, even when not metastatic, may reset this "cancer-friendly" immunological balance, thereby improving patient prognosis. Emerging evidence suggests that lymph node dissection may influence the tumor immune microenvironment. For instance, research on head and neck squamous cell carcinoma has demonstrated that PD-1 and PD-L1 expression in both primary tumors and metastatic lymph nodes are significantly correlated with nodal metastasis, indicating that the immune checkpoint status in lymph nodes is crucial for tumor progression [31]. Similarly, studies in lung cancer and breast cancer have revealed that PD-1/PD-L1 expression levels differ between primary lesions and lymph node metastases, suggesting that the removal of PD-L1-high lymphatic tissues may alleviate local immunosuppression and potentiate antitumor immune responses [32, 33]. Additionally, observations from gastric adenocarcinoma also indicate notable intra-patient heterogeneity in PD-L1 expression between primary tumors and lymph nodes [34], further emphasizing the potential impact of lymph node status on therapeutic outcomes. These findings support our hypothesis that a higher LNY in RSCC may improve survival by enhancing staging accuracy and eliminating immunosuppressive lymph nodes. Future studies should explore the molecular and immunological mechanisms underpinning the survival benefits of lymph node dissection, particularly how it affects the tumor immune microenvironment.

Additionally, several studies suggest that the LNY in a given patient reflects, at least in part, the underlying tumor-host interaction [35]. Robust antitumor immune responses lead to lymph node enlargement, easily detected by clinicians, and pathologists in clinical practice. Consequently, examining a larger LNY may enhance survival due to a stronger immune response [36]. Although the interplay between tumor biology and host conferring this survival improvement requires elucidation, the native host's antitumor immune response may play a key role. Further researches are warranted to explore the biological reasons underpinning patient prognosis with LNY and antitumor immune responses.

Several limitations should be acknowledged. First, the present study had its selection bias due to its retrospective nature. Secondly, the SEER database lacks detailed information on individual surgeons, pathologists, and hospital-related factors, which can influence surgical outcomes and LNY. Thirdly, the SEER database does not provide detailed information on postoperative treatments such as chemotherapy and radiotherapy, which could also significantly impact patient prognosis. This is particularly important, as these treatments may influence long-term survival outcomes, and future studies should aim to incorporate datasets that include more comprehensive treatment-related information.

Additionally, while this study recommends 18 LNY as the optimal threshold for elderly RSCC patients, it is important to recognize that in resource-limited regions or primary hospitals, achieving this standard may be challenging. The feasibility of obtaining the "optimal" LNY in such settings should be further explored, and efforts may need to focus on ensuring "adequate" LNY based on the available resources.

Moreover, while our study highlights the importance of LNY in predicting survival, it does not fully address the clinical implications of over-harvesting lymph nodes. Not all patients may benefit equally from a higher LNY, and for certain subgroups, excessive lymph node dissection could be unnecessary or even harmful. Further research is needed to better understand the balance between optimal and adequate LNY, as well as to investigate the potential risks of over-harvesting, especially in elderly or frail patients.

In this study, we validated our findings using a smaller cohort from China compared to the SEER dataset. While the SEER dataset is significantly larger and more diverse, the smaller sample size from the Chinese cohort may influence the robustness and generalizability of the validation results. Although the Chinese cohort provides valuable insights into a specific population, further validation using larger and more diverse datasets is recommended for confirming the external applicability of the results.

## Conclusions

A higher LNY is associated with improved long-term survival among elderly patients undergoing resection for RSCC. We propose 18 LNY as the benchmark for evaluating postoperative LNY quality and prognostic stratification. In clinical practice, surgeons should ensure thorough lymph node dissection, especially in elderly patients, using advanced techniques like laparoscopic or robotic surgery. Furthermore, medical institutions should continue to advocate for safe, high-quality surgical care delivered by experienced teams. This aims to ensure appropriate lymphadenectomy as an integral component of comprehensive multidisciplinary cancer management for elderly patients with RSCC.

**Abbreviations**

| | |
|---|---|
| LNY | Lymph node yield |
| RSCC | Right-sided colon cancer |
| OS | Overall survival |
| RCS | Restricted cubic spline curve |
| OR | odds ratios |
| HR | hazard ratios |
| LOWESS | Locally weighted scatterplot smoothing |
| NCCN | National comprehensive cancer network |
| AJCC | American joint committee on cancer |
| SEER | Surveillance, epidemiology, and end results |
| IQR | interquartile range |
| SD | standard deviation |
| CI | confidence intervals |

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**Author contributions**
TYL: conceptualization, study design, writing, and revising final manuscript. SJ: study design, data curation, statistical analysis, and writing. SG: data collections. YS: conceptualization, study design and revising final manuscript.

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**Data availability**
All data generated during the study process are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
This study was approved by the Institutional Review Board (Ethics Committee) of Shanxi Province Cancer Hospital/Hospital Affiliated to Cancer Hospital, Chinese Academy of Medical Sciences/Cancer Hospital Affiliated to Shanxi Medical University (Approval No. KY2024049). The Institutional Review Board (Ethics Committee) of Shanxi Province Cancer Hospital waived the requirement for informed consent due to the retrospective nature of the study. The study complies with the Declaration of Helsinki and the International Ethical Guidelines for Health-related Research Involving Humans.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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