

Impact of Anatomical Extent of Chest Wall Resection on Health-Related Quality of Life: A retrospective, single-center study

Chuan Gao

Affiliated Jinling Hospital, Medical School of Nanjing University

Changyong Wang

Affiliated Jinling Hospital, Medical School of Nanjing University

Maierhaba Maitiyasen

Affiliated Jinling Hospital, Medical School of Nanjing University

Lele Wang

Affiliated Jinling Hospital, Medical School of Nanjing University

Weinan Li

Affiliated Jinling Hospital, Medical School of Nanjing University

Jun Yi

Affiliated Jinling Hospital, Medical School of Nanjing University

Yi Shen

Affiliated Jinling Hospital, Medical School of Nanjing University

Kang Wang

lw37413@sina.com

Affiliated Jinling Hospital, Medical School of Nanjing University

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Abstract

OBJECTIVES

This study aimed to quantify the effect of each anatomical component of chest wall resection on 6-month HRQoL, identify a component burden threshold for clinically meaningful deterioration, and evaluate other prognostic factors after controlling for resection extent.

METHODS

Thirty-five consecutive patients undergoing chest wall tumour resection were retrospectively reviewed. Resections components were classified into six subtypes. The total number resected defined the *component burden*. EQ-5D-5L was measured preoperatively and at 1 and 6 months postoperatively. A factorial decomposition framework addressed collinearity.

RESULTS

27/35 (77.1%) recovered to baseline EQ-5D-5L. Patients with ≤ 2 components ($n = 27$) improved ($\Delta = +0.074 \pm 0.062$), whereas ≥ 3 components ($n = 8$) deteriorated ($\Delta = -0.094 \pm 0.155$; $P = 0.0010$, $d = 1.86$). Anatomical hierarchy: T3 ($d = -1.83$) > T4 ($d = -1.33$) > T2 ($d = -0.98$) > T1 ($d = -0.12$). Isolated first rib resection (Pattern A, $n = 4$) achieved 100% recovery ($\Delta = +0.078$) vs 33% for joint-involving resection (Pattern B, $n = 6$, $\Delta = -0.071$).

CONCLUSIONS

Resection of ≥ 3 components is the dominant determinant of persistent HRQoL impairment. The burden threshold and anatomical hierarchy (T3 > T4 > T2 > T1) provide a framework for preoperative risk stratification. Limiting resection to ≤ 2 components enables near-complete recovery, even at the thoracic inlet.

Introduction

Chest wall resection encompasses a wide procedural spectrum, from isolated rib excision to multicomponent resection. While advances in rigid reconstruction with titanium plates and biocompatible mesh have reduced the incidence of postoperative flail chest and wound complications¹, the functional and quality-of-life consequences of varying anatomical extent have not been systematically characterized. Health-related quality of life (HRQoL) is an essential outcome domain in oncological surgery, yet the evidence base for chest wall resection is limited. Heuker et al. documented moderate impairments in SF-36 scores among long-term survivors², but the absence of preoperative

baseline assessments precluded attribution to the resection itself. Besides, large multicentre series have focused predominantly on survival and complications^{3,4}.

As a result, surgeons currently lack an anatomy-based framework for preoperative HRQoL risk stratification and counselling. However, anatomical components resected in chest wall surgery are rarely removed in isolation. Standard multiple regression is therefore precluded by severe collinearity. To address this, we developed a factorial decomposition framework that decomposes the overall resection into individual anatomical components and estimates their marginal effects on postoperative HRQoL.

Patients and Methods

2.1 Study Design and Patient Selection

We conducted a retrospective review of all consecutive patients who underwent chest wall tumour resection with or without reconstruction in our centre between March 2023 and October 2025. Patients diagnosed with thoracic outlet syndrome (TOS) who underwent isolated first rib resection were also included to evaluate the anatomical component burden. Patients with incomplete preoperative or 6-month postoperative EQ-5D-5L data were excluded. The final analytic cohort comprised 35 patients. The study was approved by the institutional ethics committee, and written informed consent was obtained from all participants.

2.2 Anatomical Classification of Resection Extent

Each resection component was independently classified by two surgeons according to six predefined anatomical subtypes: T1: rib(s), cortical and/or cartilaginous; T2: costosternal joint; T3: sternoclavicular joint; T4: manubrium sterni (partial or total); T5: chest wall soft tissue (muscle, fascia, subcutaneous tissue); T6: combined organ resection (lung parenchyma, diaphragm, and/or pericardium).

Inter-rater agreement was assessed using Cohen's kappa. The total number of distinct subtypes involved in a given resection was defined as the component burden (range, 1–5). Resections were further dichotomized at a burden threshold of ≤ 2 vs. ≥ 3 components for primary comparative analysis.

2.3 Outcome Measures

Three outcome domains were assessed: (1) Perioperative safety: All complications were graded by the Clavien-Dindo (CD) classification. Major complications were defined as CD grade $\geq$ III. Perioperative mortality was defined as death within 30 days of surgery or before hospital discharge. (2) Postoperative pain: Pain intensity was assessed using the Numeric Rating Scale (NRS; 0–10) at 1 week and 6 months postoperatively. (3) Health-related quality of life: EQ-5D-5L was administered at three timepoints: immediately before surgery (baseline), at 1 month, and at 6 months postoperatively. Utility scores were derived using the Chinese population value set⁵. The primary HRQoL outcome was the 6-month utility change (Δ = EQ-5D at 6 months – EQ-5D at baseline). A patient was defined as having achieved baseline

recovery if the 6-month utility score equalled or exceeded the preoperative value. The minimal clinically important difference (MCID) for the EQ-5D-5L was set at 0.03–0.08⁶.

2.4 Statistical Analysis

Continuous variables are reported as mean $\pm$ SD or median (IQR). Between-group comparisons used the Mann-Whitney U test; paired comparisons used the Wilcoxon signed-rank test; categorical variables were compared with Fisher's exact test. Effect sizes were expressed as Cohen's d. As the six anatomical subtypes are rarely resected in isolation, standard multivariate regression is precluded by collinearity. We therefore applied a primarily descriptive, hypothesis-generating three-strategy factorial decomposition: (1) component burden thresholding, patients stratified by number of resected components to identify the burden level at which Δ utility crosses the MCID within this cohort; (2) marginal effect sizing, Cohen's d and univariate R^2 calculated for each subtype independently; and (3) controlled pairwise contrasting,

subgroups matched on all co-resected components except the one under evaluation. The contributions of tumour nature, surgical site, approach, and reconstruction method were examined by stratified analysis with component burden as the primary control. All analyses used Python (SciPy v1.12, statsmodels v0.14).

Results

3.1 Patient Characteristics and Overall Outcomes

Baseline demographics, tumor characteristics, and operative details of the 35 consecutive patients are summarized in **Table 1**. The median age was 52 years (IQR, 35–63), and 19 patients (54.3%) were male. Twenty patients (57.1%) had benign lesions, 5 (14.3%) had borderline tumors, and 10 (28.6%) had malignant neoplasms. Tumor locations included the anterior chest wall in 18 patients (51.4%), lateral in 9 (25.7%), and posterior in 8 (22.9%).

Complete (R0) resection was achieved in 30 of 35 patients (85.7%). The median number of resected ribs was 2 (range, 0–6). Chest wall reconstruction was performed in 15 patients (42.9%), including rib plate with biological mesh in 11 (31.4%) and biological mesh alone in 4 (11.4%). The median operative time was 155 minutes (IQR, 110–210), and the median postoperative length of stay was 5 days (IQR, 3–7). There was no perioperative mortality. Overall, 14 patients (40.0%) developed at least one postoperative complication, and 5 (14.3%) experienced a major complication (Clavien-Dindo grade $\geq$ III). One patient required ICU admission with noninvasive ventilation (CD grade IV). No patient developed paradoxical chest wall motion or prosthesis-related infection requiring removal during the follow-up period.

Pain assessed by the Numeric Rating Scale (NRS) decreased significantly from 4.5 ± 1.9 at 1 week postoperatively to 1.2 ± 1.2 at 6 months ($P < 0.001$), with 34 of 35 patients (97.1%) showing

improvement. The EQ-5D-5L utility index showed an early decline followed by later recovery. At 6 months, 27 of 35 patients (77.1%) had EQ-5D utility scores equal to or exceeding their preoperative baseline.

3.2 Anatomical Classification of Resection Extent

The distribution of subtypes is shown in **Table 2**. Single anatomical subtype resection was performed in 23 patients (65.7%), most commonly T1 alone ($n = 15$). The remaining 12 patients (34.3%) had resections involving two or more subtypes, with the combination of T1 + T2+T4 + T5+T6 representing the most extensive pattern. Joint or sternal involvement (T2, T3, or T4) was performed in 9 patients (25.7%), including 6 with costosternal joint (T2), 4 with sternoclavicular joint (T3), and 3 with manubrial (T4) resection.

3.3 Factorial Decomposition of Resection Components and Health-Related Quality of Life

Patients were stratified by the number of resected anatomical components (range, 1–5). The 6-month EQ-5D utility change ($\Delta = \text{post6m} - \text{preoperative}$) revealed a clear threshold: patients with ≤ 2 components showed utility improvement ($\Delta = +0.074 \pm 0.062$, $n = 27$), whereas those with ≥ 3 components experienced clinically meaningful deterioration ($\Delta = -0.094 \pm 0.155$, $n = 8$; Mann-Whitney U, $P = 0.0010$, Cohen's $d = 1.86$) (**Table 3**).

The effect sizes, expressed as Cohen's d , demonstrated an anatomical hierarchy (Fig. 1): T3 (sternoclavicular joint, $d = -1.83$) > T4 (manubrium, $d = -1.33$) > T2 (costosternal joint, $d = -0.98$) > T6 (combined organ, $d = -0.87$) > T5 (soft tissue, $d = -0.70$) > T1 (rib, $d = -0.12$).

The univariate R^2 values corroborated this ranking: T3 alone explained 26.5% of the variance in Δ utility, T4 18.6%, and T2 12.6%, whereas T1 contributed only 0.1%. T1, present in 32 of 35 patients (91%), is near-universal and its independent effect cannot be reliably estimated, consistent with its role as the core procedure of chest wall surgery.

The addition of T5 to T1 produced a marginal change of +0.019 (T1-only: $\Delta = +0.072$, $n = 16$; T1 + T5: $\Delta = +0.091$, $n = 6$), and the addition of T1 to T5 yielded +0.042 (T5-only: $\Delta = +0.049$, $n = 3$; T1 + T5: $\Delta = +0.091$, $n = 6$), indicating that neither rib resection nor soft tissue excision independently impairs QoL recovery. In contrast, the addition of T6 (lung, diaphragm, or pericardium) to a baseline of T1 + T5 produced the largest isolated decrement ($\Delta = -0.253$; T1 + T5: $\Delta = +0.091$, $n = 6$ vs. T1 + T5+T6: $\Delta = -0.163$, $n = 2$)(Fig. 2).

3.4 Recovery Trajectories After Resection Involving the Thoracic Inlet: An Exploratory Subgroup Contrast

To examine whether resection at the thoracic inlet impairs patients' quality of life, we isolated four patients with single first rib resection and compared their trajectories with six patients whose resection disrupted the anterior thoracic inlet (T2/T3/T4 involvement, burden 3–5). Two contrasting patterns emerged (Fig. 3).

Pattern A: Isolated first rib resection (robotic-assisted)

EQ-5D utility declined modestly from 0.814 ± 0.068 preoperatively to 0.669 ± 0.206 at 1 month, then recovered to 0.893 ± 0.114 at 6 months ($\Delta = +0.078 \pm 0.090$). All four patients exceeded baseline at 6 months (baseline recovery rate, 100%).

Pattern B: Anterior chest wall disruption (open incision)

EQ-5D fell from 0.855 ± 0.086 preoperatively to 0.623 ± 0.197 at 1 month, and remained below baseline at 6 months (0.784 ± 0.136 ; $\Delta = -0.071 \pm 0.144$). Only 2 of 6 patients (33%) recovered to baseline.

3.5 Contribution of Other Factors

Tumor nature

Malignant tumors were strongly associated with higher component burden: 6 of 10 malignant cases (60%) involved ≥ 3 resected components, whereas only 1 of 20 benign cases (5%)

reached this threshold. The 6-month EQ-5D utility differed significantly between malignant (0.815 ± 0.139) and benign (0.958 ± 0.084) groups ($P = 0.0001$). However, after balancing the number of resected components, the difference in HRQoL between benign and malignant tumors was reduced: among the 27 patients with ≤ 2 components, the 4 malignant cases had a mean 6-month EQ-5D of 0.886, compared with 0.971 for the 19 benign cases. Because baseline EQ-5D, tumor stage, and neoadjuvant therapy status were not adjusted for, we cannot determine whether the residual difference reflects tumor biology, baseline functional status, or selection bias. Thus, this analysis does not establish a causal chain; rather, it demonstrates that component burden is the dominant observable correlate of HRQoL in this dataset.

Surgical approach (robotic-assisted vs. open)

The higher complication rate in the robotic-assisted subgroup (4/9) at the perioperative period likely reflects selection bias, specifically the over-representation of first-rib resections in this group, rather than an inherent disadvantage of the approach. Given the small and highly selected subsample, no further inference regarding the robotic approach is warranted. Intraoperative views of the two surgical approaches are provided in Fig. 4.

Surgical site and reconstruction method.

Differences in EQ-5D and complication rates across chest wall locations (anterior vs. lateral vs. posterior) were no longer significant after controlling for component burden. Similarly, reconstruction method (simple closure vs. biological mesh vs. rib plate + mesh) was highly collinear with component

burden: 19 of 19 patients (100%) with 1 component underwent simple closure, whereas 7 of 8 patients (87.5%) with ≥ 3 components required plate + mesh reconstruction.

Discussion

Literature Review and Study Significance

The literature on health-related quality of life (HRQoL) following chest wall resection remains sparse. Heuker et al.² reported moderate impairments in SF-36 scores among long-term survivors. However, the absence of baseline data and a chest-wall-specific instrument precludes attributing these deficits specifically to the resection itself. Recent multicentre studies^{3,4} have focused predominantly on survival and complications, without systematic HRQoL assessment. They highlight catastrophic structural failures but overlook the subclinical biomechanical inefficiency that constitutes the principal HRQoL burden in survivors.

To our knowledge, this is the first study to apply the EQ-5D-5L with the Chinese value set⁵ to chest wall tumour resections and to identify joint and sternal involvement (T2/T3/T4) as a discrete anatomical threshold for HRQoL impairment. This extends the “critical defect” concept^{7,8} to a more nuanced question: how much functional limitation persists after technically successful reconstruction.

Mechanistic and Clinical Implications

The chest wall fulfills two distinct roles: respiratory stabilization and dynamic musculoskeletal support for upper extremity motion. Rigid reconstruction (mesh, plates, or methyl methacrylate) effectively restores the former, preventing flail chest and paradoxical motion even for large defects (≥ 5 cm or ≥ 4 ribs)^{7,8}. However, it cannot replicate the native viscoelastic compliance or coordinated segmental kinematics required for the latter. This dissociation explains why stability can be salvaged, but motion-related HRQoL declines irreversibly after extensive resection. The pattern of motion loss is site-specific, determined by which structural components are sacrificed: Resection of the sternoclavicular joint eliminates the sole bony articulation linking the upper extremity to the axial skeleton, abolishing clavicular rotation and limiting shoulder elevation⁹. Manubrial resection destabilizes the anterior tension band and compromises trunk flexion¹⁰. Rib resection, by detaching the origins of the serratus anterior and latissimus dorsi, disables critical kinetic anchors for scapular protraction and arm adduction¹¹. The anatomical hierarchy provides a roadmap for intraoperative decision-making.

Given the disproportionate HRQoL burden associated with sternoclavicular joint and manubrial involvement, the reconstruction strategy for these structures warrants targeted investigation. Losken et al.¹² emphasised that the sternoclavicular joint is the most challenging anatomical site to compensate for with conventional techniques, because its loss eliminates the “suspension effect” of the shoulder girdle. Bergovec et al.¹³ demonstrated that titanium plates combined with mesh, the conventional rigid

reconstruction strategy for large chest wall defects, carried a high risk of complications for anterior chest wall repair. Alternative reconstructive modalities are tried to lower the risk of implant-related complications^{10,14,15}, the long-term improvement in HRQoL remains to be confirmed by a larger number of cases and multi-center studies.

When resection involves ≥ 3 anatomical units, the cumulative loss overwhelms the remaining framework's compensatory capacity. The component burden threshold of ≥ 3 provides a clinically actionable summary metric: patients crossing this threshold experience a mean utility loss of approximately 0.09 at 6 months, such patients should be advised that persistent impairment is probable and postoperative rehabilitation will be necessary.

An instructive contrast emerges from the two recovery patterns observed at the thoracic outlet. Despite similar surgical location, their HRQoL trajectories diverged dramatically: Pattern A

achieved full recovery ($\Delta = +0.078$, 100% baseline recovery at 6 months), whereas Pattern B showed persistent deterioration ($\Delta = -0.071$, only 33% recovery). This divergence indicates that the proximity of resection to critical neurovascular structures is not the determinant of long-term functional outcome; the extent of anatomical disruption is. In Pattern A, although the first rib was resected in immediate contact with the brachial plexus and subclavian vessels, the surrounding musculoligamentous framework, including the sternoclavicular joint, costosternal articulation, pectoralis major insertion, and serratus anterior origin, remained intact. The bony lever of the rib was removed, but the shoulder girdle's anchorage and the thoracic cage's structural continuity were preserved (Fig. 4B). In Pattern B, by contrast, resection of ≥ 3 components invariably involved disruption of the costosternal or sternoclavicular joint (T2/T3/T4), detaching the pectoralis major and destabilizing the shoulder girdle^{8,13}. The damage to these articular and musculotendinous structures is partially irreversible; reconstruction can restore skeletal continuity but cannot reconstitute native joint mechanics or muscular leverage⁹ (Fig. 4A). These observations indicate that preserving the musculoskeletal framework is essential for motor function and HRQoL recovery.

Limitations

This study has several limitations: small sample ($n = 35$) weakens subgroup statistical power; single-center retrospective design causes selection bias and poor generalizability; only 6-month

follow-up cannot reflect long-term HRQoL changes in patients with extensive resection. EQ-5D-5L fails to detect chest wall-specific dysfunction. Without pulmonary function and chest compliance tests, biomechanical links to patient-reported outcomes cannot be confirmed.

Conclusions

In patients undergoing chest wall tumor resection, resection of ≥ 3 anatomical components, particularly when costosternal, sternoclavicular, or manubrial structures are involved, was identified in this

exploratory cohort as the predominant factor associated with persistent postoperative HRQoL impairment. The likely mechanism is the irreversibility of structural disruption, which standard reconstruction cannot fully address. This finding provides a preliminary anatomy-based framework for preoperative risk stratification that requires external validation in larger, prospective cohorts.

Declarations

Acknowledgements

We would like to acknowledge we used WorkBuddy (Tencent Cloud Studio, China), an AI-assisted research companion, to support statistical code verification and manuscript drafting. All clinical data were collected, curated, and verified by the surgical team. The AI tool did not generate, alter, or interpret patient-level data; its role was limited to facilitating data management and providing language editing. The authors take full responsibility for the integrity and accuracy of the work.

Data availability

The data underlying this article cannot be shared publicly for the privacy of individuals that participated in the study. The data will be shared on reasonable request to the corresponding author.

Author contributions

Chuan Gao, Changyong Wang and Kang Wang: Conceptualization; Data collection; Formal analysis; Supervision; Validation; Visualization; Writing—original draft; Writing—review and editing. Maierhaba Maitiyasen: Data curation; Methodology; Resources; Supervision; Visualization; Writing—review and editing. Lele Wang: Data curation; Visualization; Methodology. Weinan Li: Supervision; Validation; Visualization. Yun Yi and Yi Shen: Conceptualization; Supervision; Validation.

Ethics approval and consent to participate

Ethical approval was granted by the Ethics Committee of Jinling Hospital, Nanjing University (Jiangsu, China), and the requirement for patient consent was waived.

Competing interests

The authors declare no competing interests

Clinical trial number

not applicable

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Tables

Tables 1 to 3 are available in the Supplementary Files section.

Figures

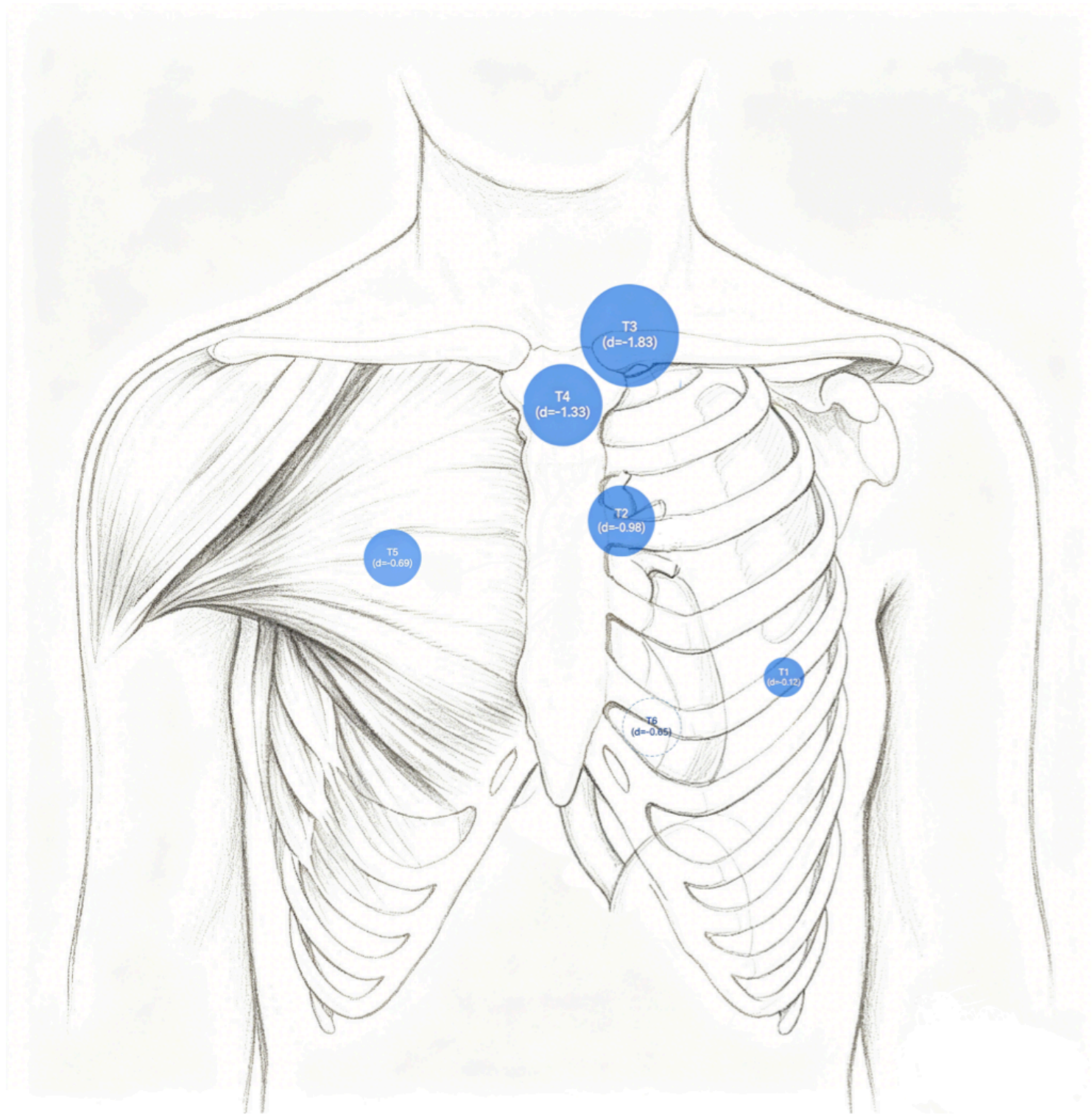


Figure 1

Anatomical distribution of chest wall resection subtypes and their effect on health-related quality of life

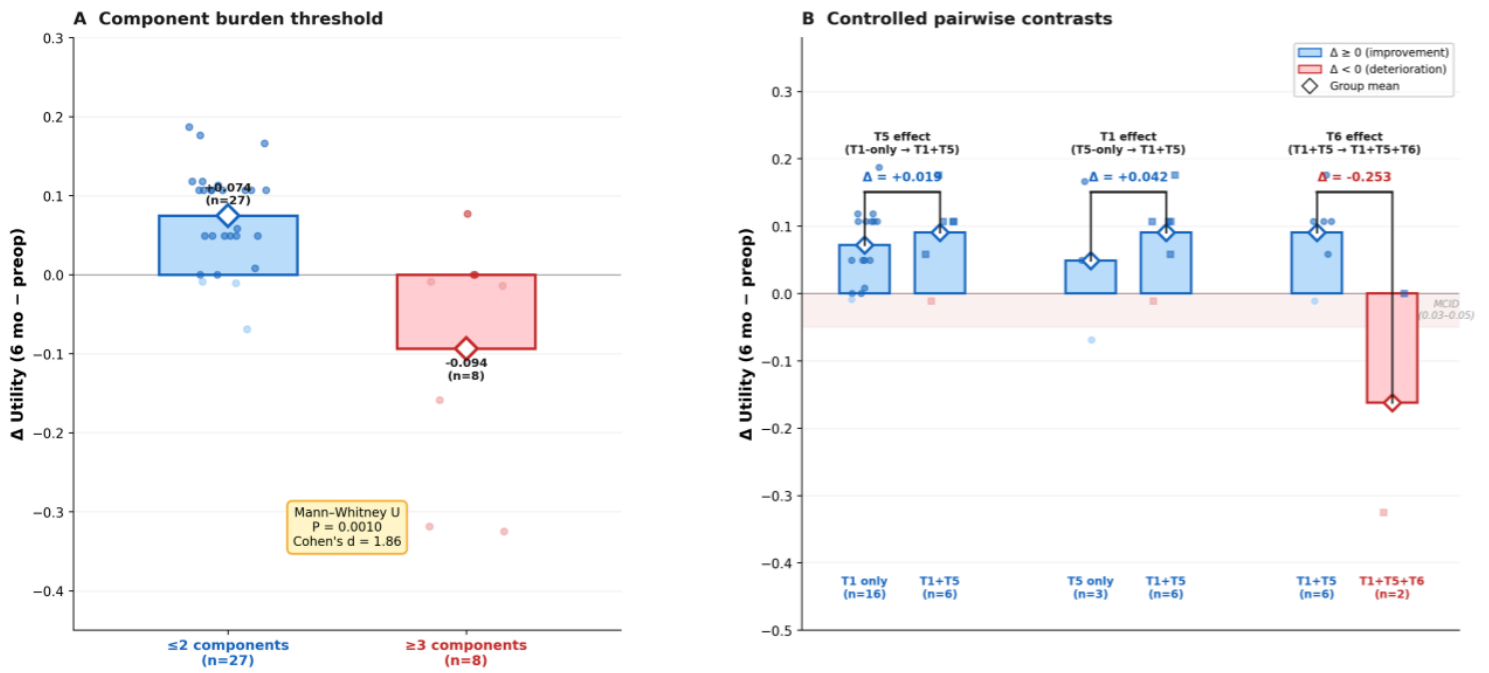


Figure 2

Component burden threshold and controlled pairwise contrasts identify the anatomical drivers of postoperative HRQoL impairment

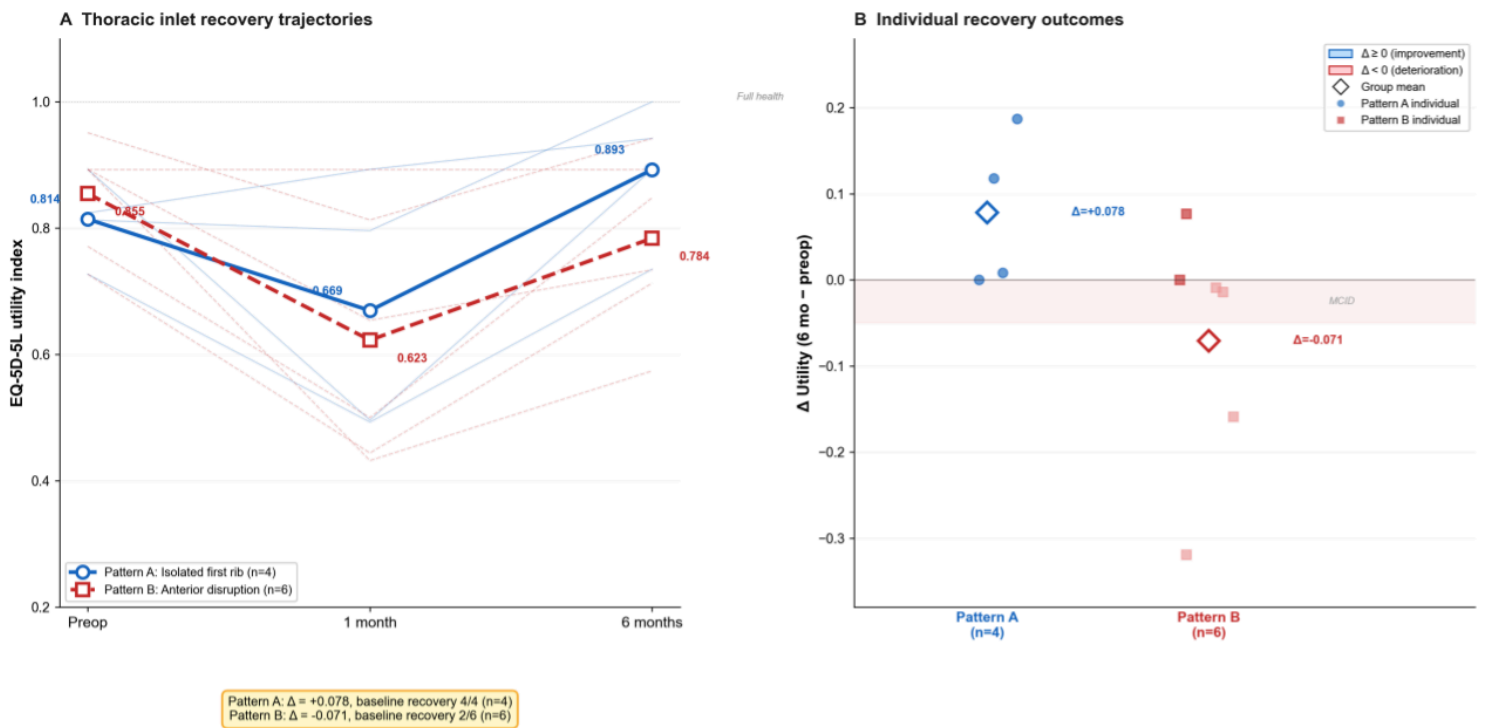
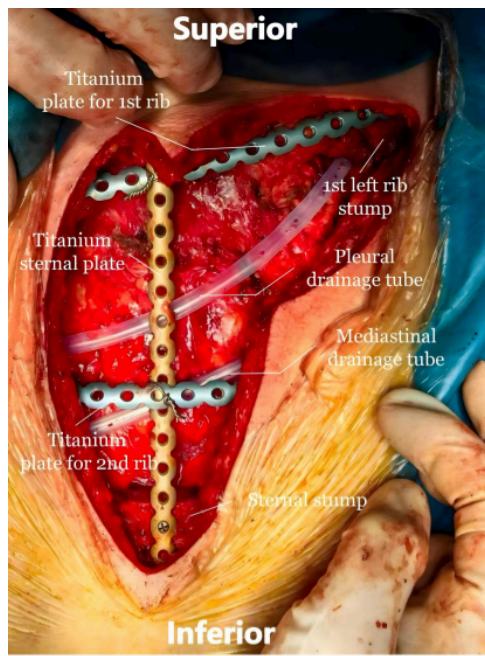


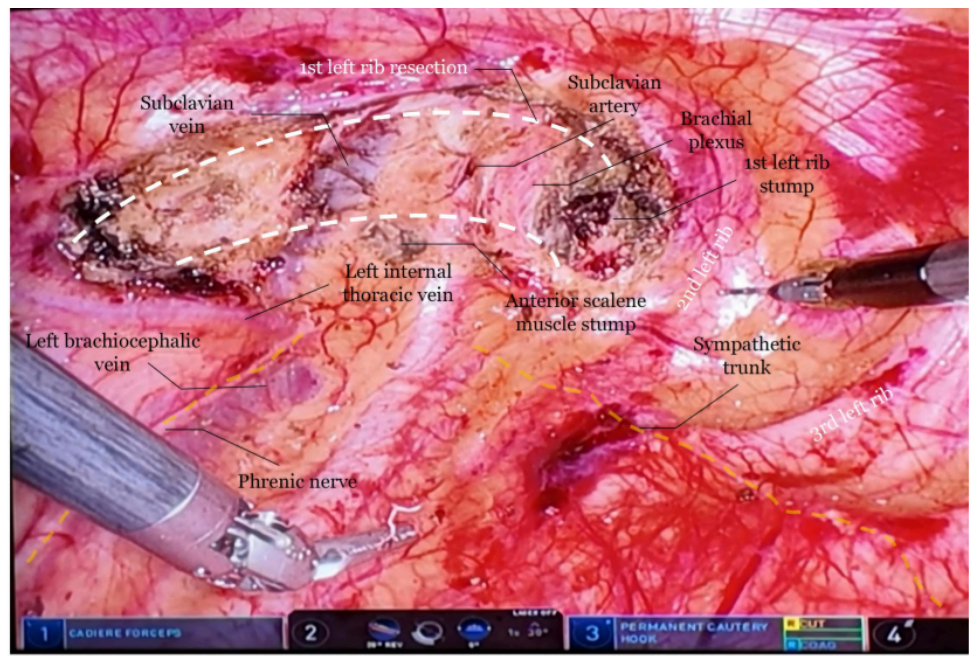
Figure 3

Divergent HRQoL trajectories after Pattern A versus Pattern B resection at the thoracic inlet



A

Resection of multiple components
by open approach



B

Resection of left 1st rib
by robotic-assisted approach

Figure 4

Representative intraoperative views of two surgical approaches illustrating the contrast in component burden

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table.docx](#)