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Fractures and other chest wall abnormalities after thoracotomy for esophageal cancer: A retrospective cohort study

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Abstract

Background: Chest pain following a thoracotomy for esophageal cancer is frequently reported but poorly understood. This study aimed to (1) determine the prevalence of thoracotomy-related thoracic fractures on postoperative imaging and (2) compare complications, long-term pain, and quality of life in patients with versus without these fractures.

Methods: This retrospective cohort study enrolled patients with esophageal cancer who underwent a thoracotomy between 2010 and 2020 with pre- and postoperative CTs (<1 and/or >6 months). Disease-free patients were invited for questionnaires on pain and quality of life.

Results: Of a total of 366 patients, thoracotomy-related rib fractures were seen in 144 (39%) and thoracic transverse process fractures in 4 (2%) patients. Patients with thoracic fractures more often developed complications (89% vs. 74%, $p = 0.002$), especially pneumonia (51% vs. 39%, $p = 0.032$). Questionnaires were completed by 77 after a median of 41 (P_{25}–P_{75} 28–91) months. Long-term pain was frequently (63%) reported but was not associated with thoracic fractures ($p = 0.637$), and neither were quality of life scores.

Conclusions: Thoracic fractures are prevalent in patients following a thoracotomy for esophageal cancer. These thoracic fractures were associated with an increased risk of postoperative complications, especially pneumonia, but an association with long-term pain or reduced quality of life was not confirmed.

KEYWORDS

chest wall injury, chronic pain, quality of life, rib fractures, thoracotomy

Esther M. M. Van Lieshout and Mathieu M. E. Wijffels contributed equally.

1 | INTRODUCTION

Esophageal cancer ranks globally as the eighth most prevalent cancer and as a cause of cancer-related death.[1] The primary curative treatment for resectable locally advanced esophageal cancer is neoadjuvant chemoradiation or perioperative chemotherapy followed by surgery.[2,3] An Ivor Lewis or McKeown esophagectomy is the preferred approach for resecting the esophagus with two- or three-field lymph node dissection, which requires a thoracotomy (or scopy).[4] Approximately 50% of patients who undergo an open transthoracic esophagectomy for malignant disease experience chest wall pain months after the surgery.[5,6] Chronic pain significantly impacts the quality of life.[6–8] A common assumption is that chronic pain following a thoracotomy is a type of neuropathic pain, although a neuropathic component is not always present.[9] An alternative hypothesis would be that the pain is caused by iatrogenic chest wall abnormalities, especially thoracic fractures, resulting from the thoracotomy. However, the prevalence of chest wall abnormalities following a thoracotomy for esophageal cancer has not been investigated before.

Therefore, the primary aim of this study **was** to determine the prevalence of rib fractures and other chest wall abnormalities on postoperative imaging following a thoracotomy for esophageal cancer. The secondary aim was to compare complications, including postoperative pneumonia, long-term pain, and quality of life in patients with versus without thoracic fractures.

2 | MATERIALS AND METHODS

2.1 | Setting and study population

This retrospective cohort study included patients from two hospitals with extensive experience in upper gastrointestinal surgery. Patients ≥18 years who underwent an elective thoracotomy with the intent to cure esophageal or junctional cancer were identified from the institutional Dutch Upper GI Cancer Audit databases between January 1, 2010 and December 31, 2020. Patients were included if they had a preoperative chest computed tomography (CT) scan and a postoperative chest CT available. The CT had to be either conducted early (within 1 month) or late (minimum 6 months) postoperatively to minimize potential confusion regarding the healing status of chest wall abnormalities.

To specifically investigate the long-term effect of thoracotomy-related fractures, patients without signs of recurrent esophageal cancer or a new malignancy were invited to complete questionnaires about chest wall pain and quality of life at least 3 months after surgery. Patients were excluded from the questionnaires if symptoms could be attributed to older thoracic fractures identified on preoperative imaging, if they had an incomplete address, if there was insufficient comprehension of the Dutch language, if they had decreased sensory function due to spinal cord injury, or if they had another thoracic comorbidity. The local Medical Research Ethics Committee (MEC-2021-0129) exempted the study. Informed consent was waived for the primary objective and obtained from all participants who completed the questionnaire. The STROBE guideline was used to ensure proper reporting (Table S1).

2.2 | Data collection

Patient, tumor, and treatment characteristics were collected from the medical records. In-hospital outcomes included postoperative adverse events that occurred within 30 days after surgery. The most serious complication per patient was graded according to the Clavien–Dindo scale.[10] Pneumonia was diagnosed based on imaging, clinical, and laboratory criteria according to the Centers of Disease Control and Prevention (CDC).[11]

During the thoracic phase of the procedure, a rib spreader was used for exposure, typically through the right posterolateral fifth intercostal space with the patient in the left lateral decubitus position (n = 349, 95%).[12] In the minority of the cases, a left thoracoabdominal approach was used with transection through the costochondral arch (n = 17, 5%). The thoracotomy was conducted through the latissimus dorsi muscle preserving the serratus anterior muscle. Posterior rib osteotomy or resection was not routinely performed, nor was the costal cartilage intentionally removed. Pericostal sutures around the rib proximal and distal to the thoracic entry wound were typically used for closure. The presence of iatrogenic rib fractures generally did not result in additional surgical steps. The postoperative protocol for managing pain included paracetamol 1000 mg intravenously four times a day and epidural analgesia until postoperative day three. After removal of the epidural catheter, patients received oral oxycodone with extended release 10 mg twice a day and oxycodone 5 mg as needed with a maximum of 30 mg per day. The acute postoperative pain service was involved during the admission to guide the pain management.

Postoperative chest CTs were evaluated for chest wall abnormalities by one of two researchers (SFMVW and AB). The early CTs were assessed for new rib fractures and their classification,[13] thoracic transverse process fractures, lung herniation (defined as lung parenchyma protruding exteriorly beyond the outer cortices of the ribs), increased intercostal space, and chest wall hematoma. The late CTs were evaluated

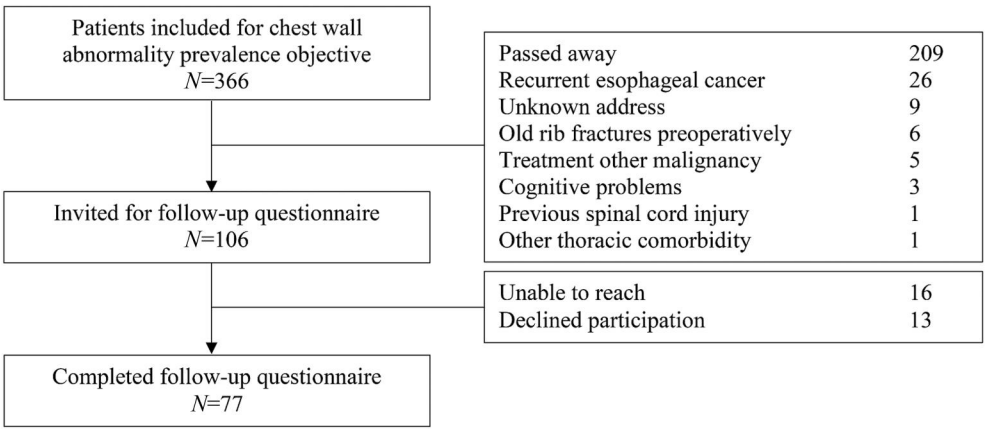

FIGURE 1 A flow diagram of patient selection for investigating the chest wall abnormalities following a thoracotomy for esophageal cancer. CT, chest tomography; m, months; *N*, number of patients.

for the presence of heterotopic ossifications, persistent lung herniation, persistent increased intercostal space, and old rib fractures. These old rib fractures were considered thoracotomy-related if they were not present on the preoperative CT and no other thoracic surgery or trauma was mentioned in the patient's medical records. Additionally, rib fracture healing was assessed. The fracture was considered healed if no fracture line was visible and as nonunion if the fracture line was still completely present. The fracture was considered healed if no fracture line was visible, as nonunion if the fracture line was still completely present, and as partial union when the line was partly visible. Delayed union was defined as incomplete healing on the first late CT combined with complete fracture healing on subsequent CT scans. Malunion was defined as an obvious angulation of the rib following fracture healing. Lastly, details were collected about the treatment of chest wall abnormalities.

2.3 | Questionnaires

Invitations for the follow-up questionnaires were mailed to eligible patients. The questionnaires included questions about other potential causes of chest wall abnormalities, analgesics, work status, and chest wall pain on the operated and contralateral side during various activities, using a Numeric Rating Scale (NRS) that ranged from zero (no pain) to ten (worst possible pain). Patients were inquired about the frequency and impact of chest wall tightness and pain around the scar on their chest, as previously detailed in the Lasting Symptoms After Esophageal Resection questionnaire.[6] The final section focused on assessing the patients' quality of life using the Short Form-36 (SF-36), consisting of eight health concepts, with scores ranging from zero (reflecting maximum disability) to 100 (indicating no disability), compared with norms from the general population of the United States.[14,15] Additionally, the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire C30 (EORTC QLQ-C30) was employed, which measures quality of life through nine multi-item scales, a Global Health Status score, and nine symptom scales specifically tailored for cancer patients.[15–18] A higher score signifies a better quality of life, except for the symptom scales, where a higher score indicates more symptoms.

2.4 | Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 28 (SPSS, Chicago, III., USA). The normality of continuous data was assessed with the Shapiro–Wilk test. Most continuous variables exhibited a nonparametric distribution and are presented as medians with 25th and 75th percentiles, while categorical variables are presented as frequencies and percentages. Missing values were not replaced. The Mann–Whitney *U*-test was used to compare continuous variables between patients with and without thoracic fractures. For categorical data, group comparisons were made using the chi-squared test or Fisher exact test, as appropriate. Spearman's rank correlation (Spearman's *r*) with 95% confidence intervals (95% CI) was used to evaluate the correlation between rib fracture classification and the occurrence of postoperative pneumonia. *p*-values below 0.05 were considered statistically significant.

3 | RESULTS

In total, 468 patients who underwent a thoracotomy for esophageal cancer were identified. Out of these, 366 (78%) patients were included based on the

TABLE 1 Patient, tumor, treatment, and hospital admission characteristics of patients with versus without thoracic fractures related to a thoracotomy for esophageal cancer.

	Total		With thoracic fractures		Without thoracic fractures		*p*-value
	*N**	(*N* = 366)	*N**	(*N* = 146)	*N**	(*N* = 220)	
Age (years)	366	66 (60–71)	146	67 (62–73)	220	65 (57–70)	**0.002**
Sex (male)	366	290 (79%)	146	127 (87%)	220	163 (74%)	**0.004**
History of diminished bone quality							
Osteopenia	37	1 (3%)	11	1 (9%)	26	0 (0%)	0.070
Osteoporosis	37	5 (14%)	11	3 (27%)	26	2 (8%)	
History of chronic pain	366	4 (1%)	146	1 (1%)	220	3 (1%)	1.000
Ttumor location							
Midesophegal	366	64 (17%)	146	27 (18%)	220	37 (17%)	0.897
Gastro-esophageal junction		299 (82%)		118 (81%)		181 (82%)	
Neo-esophagus		3 (1%)		1 (1%)		2 (1%)	
Neoadjuvant chemotherapy	366	337 (92%)	146	130 (89%)	220	207 (94%)	0.112
Neoadjuvant radiation therapy	366	249 (68%)	146	99 (68%)	220	150 (68%)	1.000
Radiation dose (Gray)	247	41 (41–41)	98	41 (41–41)	149	41 (41–41)	0.062
Pathological stage							
Stage 0	364	60 (16%)	145	24 (17%)	219	36 (16%)	0.507
Stage I	364	52 (14%)	145	24 (17%)	219	28 (13%)	
Stage II	364	113 (31%)	145	49 (34%)	219	64 (29%)	
Stage III	364	102 (28%)	145	34 (23%)	219	68 (31%)	
Stage IV	364	37 (10%)	145	14 (10%)	219	23 (11%)	
Surgical access							
Right posterolateral	366	349 (95%)	146	141 (97%)	220	208 (95%)	0.452
Left thoracoabdominal	366	17 (5%)	146	5 (3%)	220	12 (5%)	
Rib resection performed during surgery	366	5 (1%)	146	2 (1%)	220	3 (1%)	1.000
Closure thoracotomy with pericostal sutures mentioned in the operative report	366	210 (57%)	146	83 (57%)	220	127 (58%)	0.914
Intrathoracic drainage days	366	9 (6–16)	146	9 (7–17)	220	8 (6–16)	0.192
ICU LOS	366	4 (3–8)	146	4 (3–9)	220	4 (3–8)	0.779
ICU readmission	364	71 (20%)	144	26 (18%)	220	45 (20%)	0.592
Hospital LOS	366	18 (14–29)	146	17 (14–30)	220	18 (14–29)	0.910
30 days postoperative complication	366	297 (81%)	146	130 (89%)	220	167 (76%)	**0.002**
Clavien–Dindo grade							
I	297	17 (6%)	130	7 (5%)	167	10 (6%)	0.536
II		140 (47%)		64 (49%)		76 (46%)	
IIIa		46 (15%)		22 (17%)		24 (14%)	
IIIb		12 (4%)		2 (2%)		10 (6%)	
IVa		36 (12%)		14 (11%)		22 (13%)	
IVb		33 (11%)		14 (11%)		19 (11%)	
V		13 (4%)		7 (5%)		6 (4%)	

TABLE 1 (Continued)

	Total		With thoracic fractures		Without thoracic fractures		*p*-value
	*N**	(*N* = 366)	*N**	(*N* = 146)	*N**	(*N* = 220)	
OR takeback for rethoracotomy	366	27 (7%)	146	12 (8%)	220	15 (7%)	0.684
Early postoperative chest CT (<1 month)	366	256 (70%)	146	115 (79%)	220	141 (64%)	**0.004**
Days between surgery and early CT	256	7 (5–10)	115	7 (5–10)	141	6 (4–10)	0.325
Late postoperative chest CT (≥6 months)	366	245 (67%)	146	89 (61%)	220	156 (71%)	0.054
Months between surgery and late CT	245	13 (9–22)	89	12 (9–21)	156	13 (10–23)	0.287

Note: Data are presented as median (P_{25}–P_{75}) or as *N* (%). Statistically significant results are printed in bold. *N**, the number of patients for whom data were available.

Abbreviations: CT, computed tomography; ICU, intensive care unit; LOS, length of stay; Neo-esophagus, a previously reconstructed esophagus; OR, operation room.

availability of imaging (see Figure 1). One hospital contributed 314 (86%) and the other 52 (14%) patients. Rib fractures were found in 144 (39%) patients. Four patients (2%) sustained thoracic transverse process fractures related to the thoracotomy, with two of them also sustaining rib fractures. Consequently, thoracotomy-related thoracic fractures were detected in 146 (40%) patients. Patients with these were older (median 67 vs. 65 years, $p = 0.002$), and more often male ($n = 127$ (87%)) than patients without these fractures ($n = 163$ (74%), $p = 0.004$; Table 1). Other patient, tumor, and treatment characteristics did not differ. Rib fractures were noted during surgery in two (0.5%) patients, and partial rib resection was performed in five (1.4%) patients, once for a rib fracture and four times to enhance exposure.

3.1 | Prevalence of postoperative chest wall abnormalities

Of the included patients, 256 (70%) underwent an early CT, 245 (67%) a late CT scan, and 135 (37%) both (Table 2). A total of 215 rib fractures were identified, most frequently in ribs 5–7 on the posterolateral right side (Figure 2). Abnormal rib fracture healing was observed in 14 (16%) patients on the late CT (Table 2). Enlarged intercostal spaces were seen in 179 (70%) patients, irrespective of the presence of thoracic fractures ($p = 0.584$). Pulmonary herniation was detected on early CTs in nine (4%) patients, although unrelated to thoracic fractures ($p = 0.735$). This herniation was repaired in two patients. Heterotopic ossifications around the ribs were frequently detected on the late CTs, both with and without thoracic fractures ($n = 67$ (75%) versus $n = 99$ (63%), $p = 0.065$). Heterotopic ossifications forming bridges between the adjacent ribs were more common in patients with thoracic fractures ($n = 37$ (42%) versus $n = 39$ (25%), $p = 0.010$).

3.2 | Complications and long-term outcomes

Postoperative complications were more prevalent in patients with thoracic fractures than in patients without thoracic features ($n = 130$ (89%) versus $n = 167$ (76%), $p = 0.002$). Specifically, the group with thoracic fractures experienced significantly more cases of pneumonia ($n = 74$ (51%) versus $n = 86$ (39%), $p = 0.032$). Other respiratory complications did not differ statistically significantly between patients with and without thoracic fractures, including respiratory insufficiency caused by aspiration of ($n = 1$ (0%) versus $n = 0$ (0%), $p = 1.000$), pleural empyema or intrathoracic abscess ($n = 30$ (21%) versus $n = 35$ (16%), $p = 0.267$), and acute respiratory distress syndrome requiring reintubation without specified underlying cause ($n = 3$ (2%) versus $n = 0$ (0%), $p = 0.063$). No statistically significant correlation was found between rib fracture classification and postoperative pneumonia (rib fracture type $r = 0.101$ (95% CI −0.092 to 0.286) $p = 0.290$ and rib fracture dislocation $r = -0.125$ (95% CI −0.309 to 0.068) $p = 0.189$).

The severity of other complications were comparable (Table 1), and details regarding the complication type and the rate are presented in Table S2. At the time of data collection, 232 (64%) patients had passed away, with 25 (12%) succumbing to postoperative adverse events, 176 (82%) due to recurring malignant disease, and 13 (6%) due to other unrelated causes. The cause was unknown for 18 patients. During their outpatient postoperative control appointments, patient with and patients without thoracic fractures did not differ in

TABLE 2 Prevalence of chest wall abnormalities for patients with versus without thoracic fractures following a thoracotomy for esophageal cancer.

	Total		With thoracic fractures		Without thoracic fractures		
	*N**	(*N* = 366)	*N**	(*N* = 146)	*N**	(*N* = 220)	*p*-value
The number of rib fractures per patient	366	0 (0–1)	146	1 (1–2)	220	N.A.	N.A.
Findings on early CT							
Old rib fractures	256	4 (2%)	115	0 (0%)	141	4 (3%)	0.130
Rib fractures	256	109 (43%)	115	109 (95%)	N.A.	N.A.	N.A.
Type							
Simple	164[a]	135 (82%)	164[a]	135 (82%)	N.A.	N.A.	N.A.
Wedge	164[a]	24 (15%)	164[a]	24 (15%)	N.A.	N.A.	N.A.
Complex	164[a]	5 (3%)	164[a]	5 (3%)	N.A.	N.A.	N.A.
Displacement							
Undisplaced	164[a]	100 (61%)	164[a]	100 (61%)	N.A.	N.A.	N.A.
Offset	164[a]	50 (30%)	164[a]	50 (30%)	N.A.	N.A.	N.A.
Displaced	164[a]	14 (9%)	164[a]	14 (9%)	N.A.	N.A.	N.A.
Transverse process fractures	256	4 (2%)	115	4 (3%)	N.A.	N.A.	N.A.
Pulmonary herniation	256	9 (4%)	115	5 (4%)	141	4 (3%)	0.735
Enlarged intercostal space	256	179 (70%)	115	78 (68%)	141	101 (72%)	0.584
Chest wall hematoma	256	7 (3%)	115	4 (3%)	141	3 (2%)	0.704
Heterotopic ossifications	256	3 (1%)	115	1 (1%)	141	2 (1%)	1.000
Findings on late CT							
Rib fractures not identified on early postoperative CT	245	37 (15%)	89	37 (42%)	156	N.A.	N.A.
Rib fracture nonunion	245	5 (2%)	89	5 (6%)	156	N.A.	N.A.
Rib fracture partial union	245	2 (1%)	89	2 (2%)	156	N.A.	N.A.
Rib fracture delayed union	245	1 (0%)	89	1 (1%)	156	N.A.	N.A.
Rib fracture malunion	245	6 (2%)	89	6 (7%)	156	N.A.	N.A.
Heterotopic ossifications	245	166 (68%)	89	67 (75%)	156	99 (63%)	0.065
with intercostal bridges	245	76 (31%)	89	37 (42%)	156	39 (25%)	**0.010**
without intercostal bridges	245	133 (54%)	89	47 (53%)	156	86 (55%)	0.790
Involving thoracic transverse process	245	2 (1%)	89	1 (1%)	156	1 (1%)	1.000
Persistent pulmonary herniation	245	20 (8%)	89	7 (8%)	156	13 (8%)	1.000
Persistent enlarged intercostal space	245	105 (43%)	89	42 (47%)	156	63 (40%)	0.352
New unspecified rib abnormality	245	5 (2%)	89	1 (1%)	156	4 (3%)	0.656
Treatment chest wall abnormalities							
Pulmonary herniation repair	245	2 (1%)	89	0 (0%)	156	2 (1%)	0.519
Debridement deep surgical site infection with osteitis	245	1 (0%)	89	1 (1%)	156	0 (0%)	0.399
Surgical stabilization of rib fractures	245	0 (0%)	89	0 (0%)	156	N.A.	N.A.
Referral to chronic pain specialist because of severe thoracic pain >3m	204	20 (6%)	133	7 (5%)	204	13 (6%)	0.815

Note: Data are presented as median (P_{25}–P_{75}) or as *N* (%). Statistically significant results are printed in bold.

Abbreviations: CT, computed tomography; m, months. N*, number of patients for whom data were available.

[a]Represents the total number of rib fractures, not patients.

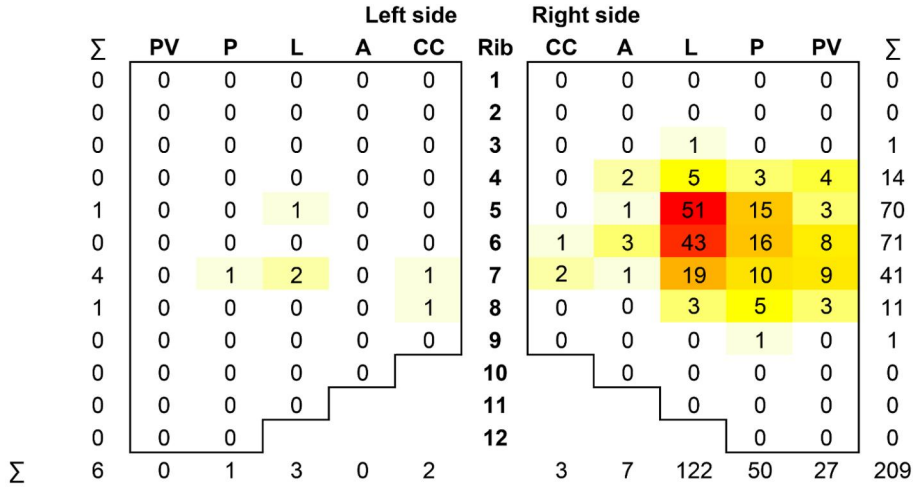

FIGURE 2 A heat map showing the number of rib fractures per anatomical sector for each rib following a thoracotomy for esophageal cancer. A, anterior; CC, costochondral; L, lateral; P, posterior; PV, paravertebral; ∑, sum.

referral rate to chronic pain specialist for severe thoracic pain ($n = 7$ (5%) versus $n = 13$ (6%), $p = 0.815$).

The long-term follow-up questionnaire was completed by 77 participants (response rate 73%) at a median of 41 (P_{25}–P_{75} 28–91) and at minimum 5 months postoperatively (Figure 1 and Table S3). Thoracic fractures were present in 33 (43%) participants. One participant sustained two traumatic rib fractures between the thoracotomy and the questionnaires. Six participants underwent additional thoracic surgery, all of which occurred at least a year before the follow-up questionnaire. Five of these surgeries were esophagectomy-related and one was unrelated, involving a pacemaker implantation.

Chest wall pain was reported by 48 (63%) participants, 22 (67%) with thoracic fractures and 26 (60%) without thoracic features ($p = 0.637$; Figure 3A). Chest wall pain was most severe during deep inspiration and household activities, although no significant differences were found between participants with and without thoracic fractures ($p > 0.100$ for all activities). Similar to pain and thoracic fractures, chest wall pain overall, pain during deep inspiration, and chest tightness did not differ statistically significantly in the presence or absence of heterotopic ossifications ($p = 0.801$, $p = 0.359$, and $p = 0.068$).

No meaningful differences in quality of life were detected by SF-36 and EORTC QLQ-C30 between participants with and without thoracic fractures following the thoracotomy (Figure 3B–E and Table S3). The median responses were comparable for all SF-36 domains to the general population, except for "'role limitations due to physical health" where the median was lower for both groups. The median responses to the EORTC QLQ-C30 scales were all within or better than the reference values.

4 | DISCUSSION

Thoracic fractures, primarily involving ribs, were detected in 40% of patients after a thoracotomy for esophageal cancer. Notably, a significant association with postoperative pneumonia risk was found in patients with thoracic fractures. Other commonly observed chest wall abnormalities included heterotopic ossifications and intercostal space enlargement around the thoracotomy site. Most patients reported chronic chest wall pain, but overall, their health-related quality of life remained within the reference values. Interestingly, no association was found between thoracic fractures and long-term pain and quality of life in disease-free patients, at a median of 3.5 years postoperatively.

Most rib fractures were localized posterolaterally around the rib spreader site. Transverse process fractures are likely caused by the momentum of rib spreading on the costotransverse articulations. However, rib or transverse process fractures during esophagectomy are rarely documented.[19] Other chest wall abnormalities, including heterotopic ossifications, are also likely linked to traumatic rib spreading, although also rarely described.[20]

In contrast, pneumonia occurs frequently following esophagectomy, presumed to result from thoracic pain impairing deep respiration, hindering mobilization, and inhibiting adequate coughing. As previously investigated, open thoracotomy for esophagectomy has a higher relative risk for pneumonia than a minimally invasive approach.[21] Unknown is whether a minimally invasive approach is associated with fewer thoracic fractures, which might explain lower pneumonia rates. The findings in this study suggest that thoracic fractures, although rarely detected, may play an important role in developing pneumonia.

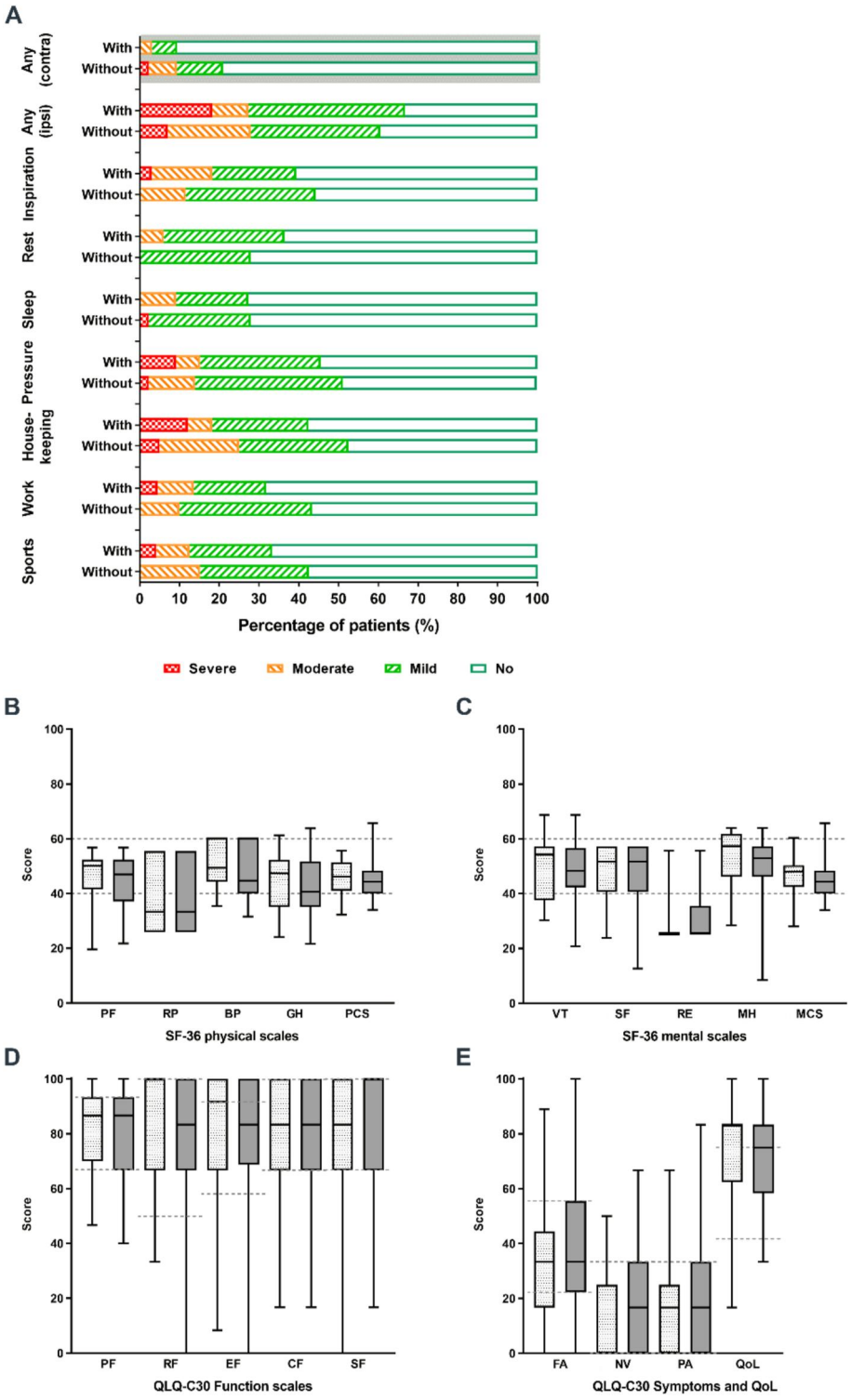

FIGURE 3 Patient-reported thoracic pain during several activities (A) and quality of life (B–E) at follow-up for patients with vs. without thoracic fractures related to a thoracotomy for esophageal cancer. (A) Mild pain is considered Numeric Rating Scale (NRS) 1–3, moderate pain NRS 4–6, and severe pain NRS 7–10. (B-E) The dotted lines represent the P_{25}–P_{75} for the reference population. The light left column represents the patients with thoracic fractures; the right dark column represents the patients without thoracic fractures. The boxes represent the median and P_{25}–P_{75}. The whiskers represent the minimum and maximum scores. Contra, contralateral side of the chest wall; ipsi, the side of the chest wall where the thoracotomy was performed. Short Form 36 (SF-36) subscales: BP, bodily pain; GH, general health perceptions; MCS, mental component summary; MH, general mental health; PCS, physical component summary; PF, physical functioning; RE, role limitations due to emotional problems; RP, role limitations due to physical health; SF, social functioning; VT, vitality, energy, or fatigue. Quality of Life Questionnaire of Cancer patients 30 (QLQ-C30) subscales: CF, cognitive functioning; EF, emotional functioning; FA, fatigue; NV, nausea/vomiting; PA, pain; PF, physical functioning; QoL, global health/quality of life; RF, role functioning; SF, social functioning.

Pulmonary care to prevent respiratory failure and pneumonia is imperative for patients with traumatic rib fractures.[22] Similarly, patients with thoracotomy-related fractures may benefit from heightened attention to pulmonary care.

Furthermore, intraoperative approaches to manage thoracotomy-related fractures are seldom described. Interest in rib fixation has been steadily growing.[23] Nevertheless, thoracotomy-related rib fractures are not routinely addressed. The only fracture stabilization method typically employed is closure using pericostal sutures.[20,24] Resection of the fractured part of the rib has been suggested to prevent the ends from rubbing against one another.[25] Others advocate prophylactically resecting 1 cm of the rib by two small osteotomies on the posterior side of the ribs to enhance intrathoracic exposure and prevent inadvertent fractures elsewhere.[26] Satisfactory results are described following thoracotomies with a prophylactic oblique osteotomy of the caudal rib, which was fixed with a metal plate at the end of the procedure.[27] Another study that randomized for thoracotomy closure between pericostal and intracostal sutures (drilled through the distal rib) found that there was significantly less pain in patients with intracostal sutures.[28] These authors noted rib fractures in 24% of patients during open lung surgeries but explicitly described not to address them, which is not uncommon in reports describing techniques to prevent post-thoracotomy pain.[29] In short, no consensus exists, even if recognized, on how to prevent or manage thoracotomy-related rib fractures.

Chronic chest wall pain was reported by 60% of patients, with a quarter experiencing moderate to severe pain, even years after surgery. This percentage aligns with previous findings on persistent pain following esophagectomy and thoracic surgery.[5,6,30,31] However, this study found no association between thoracic fractures, pain, and decreased quality of life. An explanation could be the interval between surgery and follow-up. As previously noted, pain and quality of life do not significantly differ anymore between minimally invasive and open esophagectomy after a few months, possibly explaining this study's absence of long-term differences.[32] Conversely, in the short term, minimally invasive approaches for esophagectomy have been linked to less pain and better quality of life recovery than open thoracotomy.[33,34] This disparity might be attributed to the healing of thoracotomy-related fractures after a few months, no longer causing pain thereafter. Chronic pain persisting for years post-thoracotomy is unlikely to be related to thoracic fractures. Moreover, long-term quality of life scores were comparable with or better than the reference population. The SF-36 reference values are derived from the general population, while EORTC-QLQ-C30 reference values pertain to patients with cancer. Consequently, relatively favorable scores were anticipated in the disease-free questionnaire participants.

Limitations of this study include the retrospective design and patient selection based on postoperative imaging availability. Early CTs are typically conducted when postoperative complications are suspected and late CTs are performed for suspected recurrent disease. These included patients probably have a less favorable postoperative course than patients without postoperative imaging. Nevertheless, the majority (78%) of patients who underwent a thoracotomy for esophageal cancer had postoperative imaging available. Also, direct postoperative pain could not be evaluated because of the retrospective nature of the study. Another limitation is the varying interval between surgery and the follow-up questionnaire, prohibiting the comparison of pain related to presence or absence of thoracic fractures at specific post-surgery time points. This is particularly relevant during the fracture healing period.

In conclusion, chest wall abnormalities are prevalent following a thoracotomy for esophageal cancer but are not associated with long-term pain or reduced quality of life. Rib fractures, in particular, are common and associated with an increased pneumonia risk. Proactive pain management, diligent pulmonary care, and future research to determine the best intraoperative approach toward thoracic fractures are recommended for patients who need to undergo a thoracotomy for esophageal cancer.

AUTHOR CONTRIBUTIONS

Suzanne F. M. Van Wijck: Conceptualization; Formal analysis; Investigation; Methodology; Project administration; Visualization; Writing – original draft. **Athiná Barza**: Investigation; Writing – review & editing. **Jefrey Vermeulen**: Investigation; Writing – review & editing. **Ben M. Eyck**: Resources; Writing – review & editing. **Berend J. Van der Wilk**: Resources; Writing – review & editing. **Erwin Van der Harst**: Resources; Writing – review & editing. **Michael H. J. Verhofstad**: Resources; Supervision; Writing – review & editing. **Sjoerd M. Lagarde**: Conceptualization; Resources; Supervision; Writing – review & editing. **Esther M. M. Van Lieshout**: Conceptualization; Formal analysis; Methodology; Project administration; Supervision; Validation; Visualization; Writing – review & editing. **Mathieu M. E. Wijffels**: Conceptualization; Methodology; Resources; Supervision; Writing – review & editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests.

ETHICS STATEMENT

The local Medical Research Ethics Committee (MEC-2021-0129) exempted the study.

INFORMED CONSENT

Informed consent was waived for the primary objective and obtained from all participants who completed the questionnaire.

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