Review Article

Enhanced recovery after chest wall resection and reconstruction: a clinical practice review

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Abstract: Since the late 1990s, and Henrik Kehlet's hypothesis that a reduction of the body's stress response to major surgeries could decrease postoperative morbidity, "Enhanced Recovery After Surgery" (ERAS) care pathways have been streamlined. They are now well accepted and considered standard in many surgical disciplines. Yet, to this day, there is no specific ERAS protocol for chest wall resections (CWRs), the removal of a full-thickness portion of the chest wall, including muscle, bone and possibly skin. This is most unfortunate because these are high-risk surgeries, which carry high morbidity rates. In this review, we propose an overview of the current key elements of the ERAS guidelines for thoracic surgery that might apply to CWRs. A successful ERAS pathway for CWR patients would entail, as is the standard approach, three parts: pre-, peri- and postoperative elements. Preoperative items would include specific information, targeted patient education, involvement of all members of the team, including the plastic surgeons, smoking cessation, dedicated nutrition and carbohydrate loading. Perioperative items would likely be standard for thoracotomy patients, namely carefully selective pre-anesthesia sedative medication only in some rare instances, low-molecular-weight heparin throughout, antibiotic prophylaxis, minimization of postoperative nausea and vomiting, avoidance of fluid overload and of urinary drainage. Postoperative elements would include early mobilization and feeding, swift discontinuation of intravenous fluid supply and chest tube removal as soon as safe. Optimal pain management throughout also appears to be critical to minimize the risk of respiratory complications. Together, all these items are achievable and may hold the key to successful introduction of ERAS pathways to the benefit of CWR patients.

Keywords: Enhanced Recovery After Surgery (ERAS); chest wall resection (CWR); chest wall reconstruction

Submitted Jun 07, 2023. Accepted for publication Jan 29, 2024. Published online Apr 01, 2024.
doi: 10.21037/jtd-23-911
View this article at: https://dx.doi.org/10.21037/jtd-23-911

Introduction

In the late 1990s, Henrik Kehlet established the hypothesis that by reducing the body's stress response to major surgeries, surgical teams could decrease postoperative morbidity (1). The main finding was that, barring basic surgical or anesthetic technical mistakes, it was the surgical procedure itself that imposed increased demands on organ functions. This in turn inflicted such a stress situation on the patient that only a detailed understanding of the mechanisms generating that stress would allow its minimization. Kehlet went on to posit that no single intervention would achieve that goal alone, but that a set of interventions was warranted to reduce the unwanted side-effects of surgery and improve or accelerate post-surgical recovery. Finally, he understood that the key element to support his approach was a fine understanding of each trigger of the stress reaction. This was the first formal initiation of what became known as "Enhanced Recovery After Surgery" (ERAS) care pathways.

Since then, these multimodal protocols have been streamlined. Their effectiveness on postoperative outcomes in various surgical specialties has been described. This includes their introduction in the practice of thoracic surgery (2,3), which reported decreased postoperative complications, shorter hospital stays and decreased overall costs for non-small cell lung cancer (NSCLC) patients included in an ERAS pathway (4). Thus, the enthusiasm garnered by ERAS care pathways is growing and extended to new surgeries on a regular basis.

Chest wall resections (CWRs) are major surgical procedures indicated for the resection of lung tumours, primary chest wall malignancies as well as other pathologies. The procedure entails a removal of a part of the chest wall, which significantly affects respiratory mechanics. By way of consequence, this procedure is associated with increased risks of pulmonary atelectasis and pneumonia and consequent postoperative morbidity (24–46%) and mortality (2.3–7%) (5-7).

Although other surgical specialties developed ERAS protocols for abdominal wall, breast or head and neck reconstructions (8-10) and pectus deformity repair (11), there is yet no specific ERAS protocol described for CWRs in the literature to this day. In this review, we will give an overview of the current key elements of the ERAS guidelines for thoracic surgery that might apply to CWRs and chest wall reconstructions.

ERAS

The protocols known as ERAS are multimodal, evidenced-based, perioperative care pathways, which were developed to improve and accelerate post-surgical recovery (2). The principle underlying ERAS pathways is the combined effect of various individual elements that act synergistically from patient referral to discharge. The objective is to reduce surgical stress on organs' function (12,13). Traditionally, ERAS programs are described as, and sub-divided in three distinct phases: pre-, peri- and postoperative (*Table 1*).

During the preoperative phase, it is critical that patients meet the entire multidisciplinary team. This includes the surgeon, anesthesiologist, clinical nurse, and nutritionist if necessary. The goal of this phase is to formally educate the patient about every facet of the ERAS protocols, surgery and anesthesia. This step is central to ensure the highest possible compliance to the protocol, an element described to impact postoperative morbidity (13,15). All surgical patients are routinely encouraged to quit tobacco usage and receive pre-surgical carbohydrate loading to minimize postoperative insulin resistance. The perioperative phase encompasses various elements deemed central for surgery: venous thromboembolic prophylaxis, antibiotic prophylaxis at induction, normothermia during surgery, avoidance of fluid overload and multimodal analgesia. Finally, the postoperative phase focuses on early mobilization, respiratory physiotherapy, early oral fluids and removal of chest tubes as soon as there is no air leak and the amount of pleural fluid is <400 mL over 24 hours. All these elements are evidenced-based and were validated by the ERAS Society in 2019 (3).

Since then, various studies demonstrated the efficacy of ERAS protocols on postoperative outcomes following surgery of the thorax (4,14,16). Our first series included 50 patients following an ERAS protocol after anatomical pulmonary resections. Compared to 50 patients undergoing a similar surgery before ERAS introduction, they showed a significantly shorter median postoperative length of stay (4 *vs.* 7 days, P<0.0001), decreased postoperative complication rate (24% *vs.* 48%, P=0.03) and lower hospitalization costs (€15,945 *vs.* €20,360, P<0.0001) (16). A subsequent, propensity-matched series of 307 patients undergoing Video-assisted thoracoscopic (VATS) lobectomy for NSCLC demonstrated that the patients included in the ERAS pathway stayed in hospital for a shorter time (−1.4 days, P=0.034) and presented fewer postoperative cardiopulmonary complications (−13%, P=0.044) (14). A recent meta-analysis including 6,480 anatomical pulmonary resections for NSCLC confirmed the benefits brought about by ERAS pathways, showing a significantly lower rate of postoperative complications [risk ratio (RR): 0.64, 95% confidence interval (CI): 0.52 to 0.78], shortened postoperative length of stay [standard mean difference (SMD) =−1.58, 95% CI: −2.38 to −0.79] and decreased hospitalization costs in the ERAS group (4).

However, it is established that patient compliance is a necessary part of maximizing positive results and it plays a central role on postoperative outcomes (15,17). Rogers *et al.* reviewed 422 patients undergoing anatomical pulmonary resections for NSCLC and included in an ERAS

Table 1 ERAS elements important for chest wall resection and reconstruction surgery

Variables	ERAS
Preoperative consultation	Information by ERAS team members including thoracic surgeon, plastic surgeon (if necessary), anaesthesiologist, clinical nurse, dietician
ERAS education	Information by clinical nurse: information booklet with daily goals, smoking cessation, nutritional advice, preoperative incentive spirometer instruction
Carbohydrate drink	Two packs of 50 g of Resource Preload (Nestlé, Switzerland) with 400 mL of water the day before the operation, one pack two hours before surgery and three pack per day during post-operative hospitalization
Preoperative sedation	No
VTE prophylaxis	LMWH from the day before surgery until discharge
Antibiotic prophylaxis	Induction
Anaesthesia	Epidural catheter with NSAIDs and paracetamol. Propofol or halogenated anaesthetic gases
Intraoperative warming	Yes
Avoidance of fluid overload	Yes
Chest drainage	Early removal of the chest tubes if no air leak over 6 hours and <400 mL/24 h
Postoperative analgesia	Paracetamol, NSAIDs, epidural catheter, morphine s.c. (after chest tube removal), tramadol
PONV	Prophylaxis with ondansetron, dexamethasone 21-phosphate disodium
Feeding	Early
Mobilization	Within 24 hours after surgery and daily with physical therapists

This table was adapted from Forster *et al.* (14) and used with permission. ERAS, Enhanced Recovery After Surgery; VTE, venous thromboembolism; LMWH, low molecular weight heparin; NSAIDs, non-steroidal anti-inflammatory drugs; PONV, postoperative nausea and vomiting.

protocol (17). They found a significant correlation between compliance to the protocol and postoperative complications [odds ratio (OR): 0.72, 95% CI: 0.57 to 0.91, P<0.01]. We also published a recent series of 192 patients with NSCLC undergoing VATS anatomical pulmonary resection who presented an overall ERAS compliance rate of 76% (15). Patients with a high compliance (>75%) presented fewer postoperative complications (18% *vs.* 48%, P<0.0001) and a lower rate of delayed discharge (>4 days) (37% *vs.* 60%, P=0.0013). Several elements critical to compliance optimization were identified. The most important is patient education and follow-up by a dedicated clinical nurse (13). Indeed, with formal and informal education about the program, the patient becomes an actor of the process and this will maximize compliance. The role of the clinical nurse is also to maintain the motivation and rigor among the team members, and coordinate regular team meetings to discuss results, barriers and project developments (13).

In spite of being now widely accepted for thoracic surgery interventions, ERAS pathways are still missing for some aspects of our specialty. One such aspect pertains to CWRs. This is most unfortunate because, since these procedures are high-risk surgeries, which carry rather high morbidity rates, they might be prime candidates for a much-needed improvement.

CWR

CWR involves the removal of a full-thickness portion of the chest wall, including muscle, bone and possibly skin (5). Indications for CWRs vary and span from primary or metastatic tumours (NSCLC infiltrating chest wall, primary chest wall tumours, metastases, sarcomas) to non-oncological pathologies such as infectious processes from osteomyelitis, post-radiotherapeutic necrosis, traumatic injuries or congenital defects (5,7,18-21).

When CWRs are performed for an oncological indication, the extent of the resection is determined by two elements pulling in opposite directions: radical resection (R0) is critical to ensure positive oncological outcomes but removing a part of the chest wall significantly affects respiratory mechanics, thus increasing the risk of pulmonary atelectasis and pneumonia (6,18,20,21).

Various improvements have allowed extensive CWRs to be performed with acceptable morbidity and mortality: surgical and anesthetic techniques; improved understanding of R0 resection; critical care units; use of antibiotics; development and refinements in reconstruction techniques; advent of positron emission tomography-computed tomography (PET-CT) allowing a more precise oncological staging of the disease; improvements in neo-adjuvant/adjuvant therapies (6,7). The location, the size and the type of resection depend on the underlying pathology. Whereas wide *en-bloc* resections with free margin are key to successful primary malignant chest wall tumours management, the mere extent of the resection may be an obstacle for reconstruction.

Resections of the anterior chest wall are considered particularly challenging because of the associated sternal resection, ensuing instability of that thoracic region and exposure to patients for increased cardio-pulmonary complications (18). The pulmonary status of the patient should also be evaluated to anticipate postoperative complications, predict the need for ventilatory support, and maximize the patient's pulmonary capabilities. Indeed, if a concomitant lung resection has to be performed, the morbidity outcomes appear to be higher (22).

Chest wall reconstruction

The need for reconstruction after surgery depends on various factors influencing the propensity of the defect to induce paradoxical chest wall motion, on sternal involvement and on defect size (5,6,23). The most commonly resected ribs are the anterior and lateral ribs (7,21) and studies report that on average, 2.4 ribs are resected in each patient (24). There is some degree of disagreement as to whether the number of resected ribs is a predictive factor of postoperative morbidity (25).

When it comes to postoperative reconstructions, various techniques and various materials can be considered, depending on the size and localization of the defect, as well as on the surgeon's experience (20,23,26,27). Generally, defects smaller than 5 cm anywhere on the thorax, or defects smaller than 10 cm in the posterior part of the thorax can be left to heal without reconstruction (22,23). Conversely, all other defects, accounting for some 40–50% of defects need to be assessed for optimal reconstruction (6,20,23).

Defects in the thoracic cage can be reconstructed in many different ways, using many different synthetic or biological prosthetic materials. Generally, the materials used can be separated into two broad categories: rigid and non-rigid materials (22,23,27). Rigid prosthetic materials tend to offer higher thoracic stability but are reported to induce higher rates of mechanical complications (displacements or ruptures; infections) and can be more difficult to manipulate intraoperatively (23).

Conversely, non-rigid prosthetic materials are easier to use for the surgeon and tend to be more acceptable for the patient (lower risk of infections and general foreign-body reactions), but the protection that they afford to the internal organs is less strict than that of rigid prosthetic materials and they tend to carry higher costs (23,28). Complications, however, are clearly reported as functions of the extent of resection rather than the material used for reconstruction (21,23,29). However, Nayak *et al.* have reported that the use of rigid reconstruction materials was associated with lower mortality rate (0% *vs.* 4.5%), lower complication rates (5.2% *vs.* 24%), and decreased length of hospital stay (10 *vs.* 13.3 days) (22).

The additional use of muscle flaps for chest wall reconstruction (originating mainly from pectoralis major, latissimus dorsi, serratus anterior and rectus abdominis muscles) may in addition increase the risk of chest wall instability and associated cardio-pulmonary complications. By way of conclusion, there is no standard of care for chest wall reconstruction. Rather, this step should be carefully designed to consider the specifics of the patient, of the chest wall defect and of the surgeon's expertise.

Postoperative morbidity after CWR

Postoperative complications after CWRs can be of various natures (pneumonia, atelectasis, arrhythmia, pleural effusion/hemothorax) and may at times require re-interventions (6). Complications tend to occur in a non-negligible fraction of patients (37–46%) (6,22), but few of these evolve into life-threatening situations (0–7% mortality at 30 days) (6,19,22,25,26) (*Table 2*). This, however, represents twice the mortality rate of patients undergoing operations for similar indications but without CWR (25). Interestingly, even this relatively high rate of complications is an improvement over complication rates reported previously (46–69%) (21), which confirms that even for high-risk surgical interventions, technical improvements yield large benefits to patients.

Table 2 Morbidity and mortality rates after chest wall resection and reconstruction

Author, year	N	Indications for chest wall resection	Length of hospitalization (d)	Morbidity (overall, 30-d) (%)	Respiratory complications (%)	Mortality (30-d) (%)
Mansour *et al.*, 2002 (7)	200	Primary chest wall tumour, NSCLC invading chest wall, breast tumour, severe pectus deformity	Mean 14±14	23.5	19	7
Weyant *et al.*, 2006 (21)	262	Primary chest wall tumour, NSCLC invading chest wall, breast tumour, metastasis, radiation necrosis, infection	Median 7 (range, 1–67)	33.2	11.1	3.8
Hameed *et al.*, 2008 (30)	20	Primary chest wall tumour, breast tumour, chest wall defect, radiation necrosis	NA	25	0	0
Wouters *et al.*, 2008 (24)	127	Sarcoma	Median 9–12	20–23	10	0
Bosc *et al.*, 2011 (31)	22	Primary chest wall tumour, breast tumour, radiation necrosis	NA	54.5	NA	4.5
Miller *et al.*, 2013 (28)	25	Primary chest wall tumour, NSCLC invading chest wall, metastasis	Median 4 (range, 2–41)	24	NA	0
Rocco *et al.*, 2014 (32)	86	Primary chest wall tumour, NSCLC invading chest wall, breast tumour, metastasis, radiation necrosis, infection, benign lesion	NA	16.3	NA	2.3
Spicer *et al.*, 2016 (29)	427	Primary chest wall tumour, NSCLC invading chest wall metastatic lesion, malignant pleural disease	NA	NA	23.9	1
Scarnecchia *et al.*, 2018 (20)	71	Primary chest wall tumour, NSCLC invading chest wall	NA	NA	14.1	NA
Wald *et al.*, 2020 (19)	25	Primary chest wall tumour	NA	18	0	0
Schroeder-Finckh *et al.*, 2020 (26)	34	Primary chest wall tumour, NSCLC invading chest wall, breast tumour, metastasis, radiation necrosis	NA	23.5	5.9	0
Towe *et al.*, 2022 (25)	306	NSCLC invading chest wall	Median 6	55.6	NA	2.9
Elahi *et al.*, 2022 (6)	93	Primary chest wall tumour, breast tumour, metastasis	Mean 16±10	49.5	NA	3.2

d, days; NSCLC, non-small cell lung cancer; NA, not available.

Pulmonary complications are frequent after CWRs (22) because the operation sparks a cascade of disruptions (pain, loss of rigidity, paradoxical respiration, impaired mechanisms of lung cleaning, increased risks of pulmonary issues). Elahi *et al.* report that the defect size above 114 cm^2 is a good discriminant for pneumonia (OR: 4.29, 95% CI: 1.32 to 15.41, P=0.02 on univariable and OR: 3.67, 95% CI: 1.01 to 14.63, P=0.05 on multivariable analysis) (6). Studies also report that sternal involvement is significantly associated to postoperative atelectasis (OR: 78.92, 95% CI: 4.01 to 9,005.94, P=0.02 on multivariable analysis) (6,33). Other studies report that age, concomitant lobectomy or pneumonectomy, and size of the chest wall defect are associated with increased odds ratios for a complication (22,27,29), predominantly of pulmonary nature or wound-related issues (up to 20% of patients), especially if the defect is larger than 60 cm^2 (7% of patients *vs.* 0% developing infectious complications if the defect is smaller than this threshold) (22). More generally, it is reported that procedure duration, type of reconstruction and location of the resection have no statistically significant impact on patient outcome (6,21,27,29). In addition, the authors do not identify a correlation between the type of reconstructive material and perioperative pulmonary or infectious wound complications (29).

Benefits of ERAS on CWR surgery

Today, the benefits of ERAS pathways in various surgical disciplines leave it beyond any kind of doubt that these are useful management steps for any postoperative course (4). Although CWRs carry a very high rate of complications and general morbidity, no such proposal exists for this specific type of surgery. As mentioned above, CWR surgeries include a wide variety of procedures from minor to major resections, anterior or posterior, with or without associated lung resections, etc. Thus, developing a standardized ERAS protocol is not an easy task, since postoperative outcomes are not similar between these groups and specific adaptations of the protocol might be interesting. However, ERAS programs are based on several simple interventions and thus can be easily standardized for all kind of CWRs. A specific mention should be made for CWRs associated with concomitant pulmonary resections. Indeed, removing a part of the lung changes postoperative outcomes by exposing patients to other complications, such as air leak or bronchopleural fistula. Consequently, a mix between ERAS protocols for CWRs and lung resections should be introduced, although the two look alike.

Just like for any other surgical discipline, a successful ERAS pathway for CWR patients would entail three parts: pre-, peri- and postoperative items. Preoperative items would likely span the various items encountered for other thoracic surgery patients and described above: specific information, review of schedules, good communication with all members of the multidisciplinary team (including the plastic surgeons, in this specific case) and review of general procedure. Of critical importance are the notions of smoking cessation, of dedicated nutrition and carbohydrate loading (2,3,17) and explanations on achievable goals in terms of outcomes and discharge (14). It might also be noted that for an operation with a relatively high morbidity profile such as CWR, the benefits might well be higher than for other disciplines. It has been shown that the introduction of an ERAS pathway was associated with more clinical benefit after thoracotomy than thoracoscopy (34,35). Indeed, the study by van Haren *et al.* found a lower reduction of morbidity and length of hospitalization in patients undergoing VATS as compared to those undergoing open approaches (34). Another group did the same observations (35). This can be explained by the minimal invasive surgery inducing less surgical trauma and thus provoking less postoperative pain and morbidity. Thus, introduction of ERAS pathways for this type of surgery shows less impressive results than open approaches.

For the perioperative phase, most elements would be reminiscent of the management of a standard thoracotomy. No pre-anaesthesia sedative medication seems necessary nowadays, except perhaps in cases of important anxiety. On the other hand, low-molecular-weight heparin the day before surgery and once daily during the entire hospital stay is part of the normal routine in our center, as is antibiotic prophylaxis immediately before surgical incision. The use of propofol by total intravenous anesthesia is generally associated with reduced postoperative nausea and vomiting. Fluid overload (defined as intraoperative hydration of >1,000 mL of balanced fluid) and urinary drainage are best avoided. Postoperatively, all patients should be extubated and transferred to the continuous care unit for 24 h. As is the case for other surgical disciplines, early mobilization is highly important (17), as is early feeding and swift discontinuation of intravenous fluid supply as soon as patients can drink by themselves. Daily early mobilization, in the form of two short walks in the ward with the help of a nurse, should start on the day of the operation as soon as patients are fully awake, and continue twice daily until discharge. The chest tube(s) can be removed as soon as there is no air leak over 6 hours and the amount of pleural fluid is <400 mL over 24 hours.

One of the most frequent complaints of patients who underwent a thoracic surgical intervention is pain. It is clear that a painful postoperative course adds significant costs and morbidity and decreases patient quality of life and satisfaction. This is of course frequent in CWR patients due to the extent of chest wall trauma, encompassing bones, peripheral nerves and muscular layers. It is to be noted that inadequate pain gestion after CWR increases the risk of respiratory complications, such as pneumonia and pulmonary atelectasis. Thus, ERAS protocols including multimodal pain management might be useful in this context. It should combine local analgesia with an epidural catheter or paravertebral block and systemic medication [non-steroidal anti-inflammatory drugs (NSAIDs) associated with paracetamol], with the aim of reducing postoperative opioid use (3,14).

More generally, since postoperative pain may amplify endocrine metabolic responses, autonomic reflexes, nausea, ileus and muscle spasm, and thereby delay restoration of function, optimal postoperative analgesia is central to enhance recovery and reduce morbidity (1).

In our experience, postoperative multimodal analgesia is centered primarily around epidural catheter, NSAIDs and paracetamol. Once the chest tubes are removed, epidural catheter can be removed and replaced by oral strong opioids (e.g., morphine). Finally, weak opioids or derivatives (e.g., tramadol) are introduced (14). In parallel, it is also critical to initiate full physiotherapeutic management, to quickly gain respiratory and mobility autonomy.

Obviously, our prior experiences with the ERAS introduction covered various types of operations, including VATS surgeries, which would be, by definition, excluded from the population of patients considered here. In addition, because several of the proposed elements are already in place in our center, it is quite possible that the initial results might not be as spectacular as they could be if we were to start from a fully non-ERAS practice. However, and this is a central message, the proper identification of patients with the highest risk for complications could direct our initial efforts to reinforce pre- and postoperative physical therapy protocols as well as optimize pre-, peri- and postoperative steps to minimize the risk of complications (6). Prior results in patients undergoing open thoracotomy also corroborate this view (12).

Conclusions

In conclusion, CWR/reconstruction is a traumatic and stressful procedure that can potentially induce increased cardio-pulmonary complications. Particular care should be given to patients with larger resection sizes or involving the sternum to minimize the risk of pneumonia/atelectasis. ERAS pathway with emphasis on optimal pain management is the cornerstone after CWR. Early mobilization (within the first 24 hours) is critical to any ERAS course and has been identified as a factor in reducing postoperative complication rates (17). Various other elements of the ERAS pathway are likely to be applicable to CWR patients, namely: controlled nutrition, targeted postoperative nausea and vomiting control, standardized multimodal analgesia regimen and avoidance of fluid overload (17). ERAS elements such as the ones suggested in this paper may lead to a major reduction in the undesirable sequelae of surgical injury with improved recovery and reduction in postoperative morbidity and overall costs in CWR patients (1,6,13-15). As was the case for other surgical specialties, optimal results are likely to be achieved with a profound "cultural" change in the surgical wards, whereby the focus is dedicated to multidisciplinary actions, patient compliance and cross-specialty items (counselling, preoperative nutrition, early rehabilitation, and pain relief), with special attention on recovery-limiting procedures (intravenous fluids, drains, tubes, etc.). None of these elements in unsurmountable, and this observation may hold the key to successful introduction of ERAS pathways to the benefit of CWR patients.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Erik de Loos, José Ribas de Campos and Jean Daemen) for the series "Chest Wall Resections and Reconstructions" published in *Journal of Thoracic Disease*. The article has undergone external peer review.

Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-911/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-911/coif). The series "Chest Wall Resections and Reconstructions" was commissioned by the editorial office without any funding or sponsorship. M.G. serves as an unpaid editorial board member of *Journal of Thoracic Disease* from February 2023 to January 2025. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Kehlet H. Multimodal approach to control postoperative pathophysiology and rehabilitation. Br J Anaesth 1997;78:606-17.
2. Melnyk M, Casey RG, Black P, et al. Enhanced recovery after surgery (ERAS) protocols: Time to change practice? Can Urol Assoc J 2011;5:342-8.
3. Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, et al. Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS). Eur J Cardiothorac Surg 2019;55:91-115.
4. Li R, Wang K, Qu C, et al. The effect of the enhanced recovery after surgery program on lung cancer surgery: a systematic review and meta-analysis. J Thorac Dis 2021;13:3566-86.
5. Hazel K, Weyant MJ. Chest Wall Resection and Reconstruction: Management of Complications. Thorac Surg Clin 2015;25:517-21.
6. Elahi L, Zellweger M, Abdelnour-Berchtold E, et al. The size and sternal involvement of chest wall resections for malignant disease predict postoperative morbidity. Transl Cancer Res 2022;11:1162-72.
7. Mansour KA, Thourani VH, Losken A, et al. Chest wall resections and reconstruction: a 25-year experience. Ann Thorac Surg 2002;73:1720-5; discussion 1725-6.
8. Sartori A, Botteri E, Agresta F, et al. Should enhanced recovery after surgery (ERAS) pathways be preferred over standard practice for patients undergoing abdominal wall reconstruction? A systematic review and meta-analysis. Hernia 2021;25:501-21.
9. Tan YY, Liaw F, Warner R, et al. Enhanced Recovery Pathways for Flap-Based Reconstruction: Systematic Review and Meta-Analysis. Aesthetic Plast Surg 2021;45:2096-115.
10. Bertelsen C, Hur K, Nurimba M, et al. Enhanced Recovery After Surgery-Based Perioperative Protocol for Head and Neck Free Flap Reconstruction. OTO Open 2020;4:2473974X20931037.
11. Mangat S, Hance L, Ricketts KJ, et al. The impact of an enhanced recovery perioperative pathway for pediatric pectus deformity repair. Pediatr Surg Int 2020;36:1035-45.
12. Madani A, Fiore JF Jr, Wang Y, et al. An enhanced recovery pathway reduces duration of stay and complications after open pulmonary lobectomy. Surgery 2015;158:899-908; discussion 908-10.
13. Forster C, Gonzalez M. Enhanced recovery after surgery (ERAS): philosophy, theory and practice. J Thorac Dis 2022;14:3684-7.
14. Forster C, Doucet V, Perentes JY, et al. Impact of Compliance With Components of an ERAS Pathway on the Outcomes of Anatomic VATS Pulmonary Resections. J Cardiothorac Vasc Anesth 2020;34:1858-66.
15. Gonzalez M, Abdelnour-Berchtold E, Perentes JY, et al. An enhanced recovery after surgery program for video-assisted thoracoscopic surgery anatomical lung resections is cost-effective. J Thorac Dis 2018;10:5879-88.
16. Forster C, Doucet V, Perentes JY, et al. Impact of an enhanced recovery after surgery pathway on thoracoscopic lobectomy outcomes in non-small cell lung cancer patients: a propensity score-matched study. Transl Lung Cancer Res 2021;10:93-103.
17. Rogers LJ, Bleetman D, Messenger DE, et al. The impact of enhanced recovery after surgery (ERAS) protocol compliance on morbidity from resection for primary lung cancer. J Thorac Cardiovasc Surg 2018;155:1843-52.
18. Scarnecchia E, Liparulo V, Pica A, et al. Multidisciplinary approach to chest wall resection and reconstruction for chest wall tumors, a single center experience. J Thorac Dis 2017;9:5093-100.
19. Wald O, Islam I, Amit K, et al. 11-year experience with Chest Wall resection and reconstruction for primary Chest Wall sarcomas. J Cardiothorac Surg 2020;15:29.
20. Scarnecchia E, Liparulo V, Capozzi R, et al. Chest wall resection and reconstruction for tumors: analysis of oncological and functional outcome. J Thorac Dis 2018;10:S1855-63.
21. Weyant MJ, Bains MS, Venkatraman E, et al. Results of chest wall resection and reconstruction with and without rigid prosthesis. Ann Thorac Surg 2006;81:279-85.
22. Nayak R, Choe SI, Shargall Y. Complications of Chest Wall Resection in Conjunction with Pulmonary Resection. Thorac Surg Clin 2021;31:393-8.
23. Colella S, Brandimarte A, Marra R, et al. Chest wall reconstruction in benign and malignant tumors with non-rigid materials: An overview. Front Surg 2022;9:976463.
24. Wouters MW, van Geel AN, Nieuwenhuis L, et al. Outcome after surgical resections of recurrent chest wall sarcomas. J Clin Oncol 2008;26:5113-8.
25. Towe CW, Servais EL, Grau-Sepulveda M, et al. Impact of Chest Wall Resection on Mortality After Lung Resection for Non-Small Cell Lung Cancer. Ann Thorac Surg 2022;114:2023-31.
26. Schroeder-Finckh A, Lopez-Pastorini A, Galetin T, et al.

Anterior Chest Wall Reconstruction Using Polypropylene Mesh: A Retrospective Study. Thorac Cardiovasc Surg 2020;68:341-51.
27. Khullar OV, Fernandez FG. Prosthetic Reconstruction of the Chest Wall. Thorac Surg Clin 2017;27:201-8.
28. Miller DL, Force SD, Pickens A, et al. Chest wall reconstruction using biomaterials. Ann Thorac Surg 2013;95:1050-6.
29. Spicer JD, Shewale JB, Antonoff MB, et al. The Influence of Reconstructive Technique on Perioperative Pulmonary and Infectious Outcomes Following Chest Wall Resection. Ann Thorac Surg 2016;102:1653-9.
30. Hameed A, Akhtar S, Naqvi A, et al. Reconstruction of complex chest wall defects by using polypropylene mesh and a pedicled latissimus dorsi flap: a 6-year experience. J Plast Reconstr Aesthet Surg 2008;61:628-35.
31. Bosc R, Lepage C, Hamou C, et al. Management of chest wall reconstruction after resection for cancer: a retrospective study of 22 consecutive patients. Ann Plast Surg 2011;67:263-8.
32. Rocco G, Martucci N, La Rocca A, et al. Postoperative local morbidity and the use of vacuum-assisted closure after complex chest wall reconstructions with new and conventional materials. Ann Thorac Surg 2014;98:291-6.
33. Hennon MW, Dexter EU, Huang M, et al. Does Thoracoscopic Surgery Decrease the Morbidity of Combined Lung and Chest Wall Resection? Ann Thorac Surg 2015;99:1929-34; discussion 1934-5.
34. Van Haren RM, Mehran RJ, Mena GE, et al. Enhanced Recovery Decreases Pulmonary and Cardiac Complications After Thoracotomy for Lung Cancer. Ann Thorac Surg 2018;106:272-9.
35. Martin LW, Sarosiek BM, Harrison MA, et al. Implementing a Thoracic Enhanced Recovery Program: Lessons Learned in the First Year. Ann Thorac Surg 2018;105:1597-604.

Cite this article as: Forster C, Jacques V, Abdelnour-Berchtold E, Krueger T, Perentes JY, Zellweger M, Gonzalez M. Enhanced recovery after chest wall resection and reconstruction: a clinical practice review. J Thorac Dis 2024;16(4):2604-2612. doi: 10.21037/jtd-23-911

