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Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS)

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Key question

What is the optimal perioperative management for patients undergoing lung surgery?

Key findings

Recommendations were developed for 45 ERAS items, from initial presentation through to postoperative discharge.

Take-home message

The use of a systematic multimodal perioperative care pathway has the potential to improve outcomes after lung surgery.

GUIDELINES

Abstract

Enhanced recovery after surgery is well established in specialties such as colorectal surgery. It is achieved through the introduction of multiple evidence-based perioperative measures that aim to diminish postoperative organ dysfunction while facilitating recovery. This review aims to present consensus recommendations for the optimal perioperative management of patients undergoing thoracic surgery (principally lung resection). A systematic review of meta-analyses, randomized controlled trials, large non-randomized studies and reviews was conducted for each protocol element. Smaller prospective and retrospective cohort studies were considered only when higher-level evidence was unavailable. The quality of the evidence base was graded by the authors and used to form consensus recommendations for each topic. Development of these recommendations was endorsed by the Enhanced Recovery after Surgery Society and the European Society for Thoracic Surgery. Recommendations were developed for a total of 45 enhanced recovery items covering topics related to pre-admission, admission, intraoperative care and postoperative care. Most are based on good-quality studies. In some instances, good-quality data were not available, and subsequent recommendations are generic or based on data extrapolated from other specialties. In other cases, no recommendation can currently be made because either equipoise exists or there is a lack of available evidence. Recommendations are based not only on the quality of the evidence but also on the balance between desirable and undesirable effects. Key recommendations include preoperative counselling, nutritional screening, smoking cessation, prehabilitation for high-risk patients, avoidance of fasting, carbohydrate loading, avoidance of preoperative sedatives, venous thromboembolism prophylaxis, prevention of hypothermia, short-acting anaesthetics to facilitate early emergence, regional anaesthesia, nausea and vomiting control, opioid-sparing analgesia, euvolemic fluid management, minimally invasive surgery, early chest drain removal, avoidance of urinary catheters and early mobilization after surgery. These guidelines outline recommendations for the perioperative management of patients undergoing lung surgery based on the best available evidence. As the recommendation grade for most of the elements is strong, the use of a systematic perioperative care pathway has the potential to improve outcomes after surgery.

Keywords: Enhanced recovery after surgery • Perioperative care • Thoracic surgery • Lung surgery

INTRODUCTION

There is continued interest in the development and systematic implementation of evidence-based perioperative care protocols or 'enhanced recovery after surgery' (ERAS®) pathways such as those already produced by the ERAS® Society across a range of surgical specialties [1–10]. In a meta-analysis of 38 studies, ERAS pathways were seen to be effective in reducing hospital length of stay (LOS) and postoperative complication rates [11]. Colorectal cancer surgery accounted for the majority of the studies included in this meta-analysis, and the specialty has been at the forefront of the development of ERAS pathways since their inception [3, 12–15]. The benefits described are achieved by attenuating the homeostatic disturbance and stress response associated with surgery, which is characterized by catabolism and increased oxygen demand, thereby diminishing postoperative organ dysfunction and facilitating recovery [14–16].

An enhanced recovery pathway addresses the entire patient journey from referral to discharge. Multiple small improvements and efficiencies are adopted in an evidence-based manner by a multidisciplinary team. Individual care elements may not necessarily have significant benefits when studied in isolation, but their combination with other elements of the pathway is thought to have a synergistic effect [14]. More recently, overall compliance with ERAS protocols has been shown to be associated with better patient outcomes [17–19]. At the same time, some elements (such as minimally invasive surgery and early mobilization) appear to be more influential than others [17, 19].

Fast-track multimodal protocols have previously been described in thoracic surgery and appeared to result in a reduction in postoperative complications and/or LOS [20–23]. More recently, specific ERAS pathways for thoracic surgery have been published, most of which demonstrating benefits such as reduced opiate usage, minimization of fluid overload, reduced LOS, decreased hospital costs and reduced pulmonary and cardiac complications [19, 24–30]. An initial systematic review of ERAS pathways in elective lung cancer surgery cautioned against the over-interpretation of results, as the included studies were mainly non-randomized and had methodological flaws [31]. A subsequent review and meta-analysis demonstrated that ERAS pathways in lung cancer surgery are associated with reduced complications, a shorter LOS and cost savings [32]. The authors noted significant heterogeneity between protocols and highlighted the need to develop standardized, evidence-based guidelines for thoracic surgery.

Standardized perioperative care helps to ensure that all patients receive optimal treatment. The goal of this article is to critically review existing evidence and make recommendations for elements of perioperative care in lung surgery.

METHODS

Literature search

The authors convened in May 2016 to discuss topics for inclusion. The topic list was based on the ERAS® Society guidelines for colorectal surgery [3] and gynaecological surgery [7]. After the topics were agreed upon, they were allocated among the group according to expertise. The literature search (1966–2017) used Embase and PubMed to search medical subject headings including 'thoracic surgery', 'lung cancer surgery' and all perioperative ERAS items (Table 1). Reference lists of all eligible articles were crosschecked for other relevant studies.

Study selection

Titles and abstracts were screened by individual reviewers to identify potentially relevant articles. Discrepancies in judgement were resolved by the lead (T.B.) and the senior authors (B.N., N.R. and O.L.). Meta-analyses, systematic reviews, randomized controlled studies, non-randomized controlled studies, reviews and case series were considered for each individual topic.

Table 1: Guidelines for enhanced recovery after lung surgery: recommendations of the ERAS Society and the ESTS

Recommendations	Evidence level	Recommendation grade
Preoperative phase		
Preadmission information, education and counselling		
Patients should routinely receive dedicated preoperative counselling	Low	Strong
Perioperative nutrition		
Patients should be screened preoperatively for nutritional status and weight loss	High	Strong
Oral nutritional supplements should be given to malnourished patients	Moderate	Strong
Immune-enhancing nutrition may have a role in the malnourished patient postoperatively	Low	Weak
Smoking cessation		
Smoking should be stopped at least 4 weeks before surgery	High	Strong
Alcohol dependency management		
Alcohol consumption (in alcohol abusers) should be avoided for at least 4 weeks before surgery	Moderate	Strong
Anaemia management		
Anaemia should be identified, investigated and corrected preoperatively	High	Strong
Pulmonary rehabilitation and prehabilitation		
Prehabilitation should be considered for patients with borderline lung function or exercise capacity	Low	Strong
Admission		
Preoperative fasting and carbohydrate treatment		
Clear fluids should be allowed up until 2 h before the induction of anaesthesia and solids until 6 h before induction of anaesthesia	High	Strong
Oral carbohydrate loading reduces postoperative insulin resistance and should be used routinely	Low	Strong
Preanaesthetic medication		
Routine administration of sedatives to reduce anxiety preoperatively should be avoided	Moderate	Strong
Perioperative phase		
Venous thromboembolism prophylaxis		
Patients undergoing major lung resection should be treated with pharmacological and mechanical VTE prophylaxis	Moderate	Strong
Patients at high risk of VTE may be considered for extended prophylaxis with LMWH for up to 4 weeks	Low	Weak
Antibiotic prophylaxis and skin preparation		
Routine intravenous antibiotics should be administered within 60 min of, but prior to, the skin incision	High	Strong
Hair clipping is recommended if hair removal is required	High	Strong
Chlorhexidine–alcohol is preferred to povidone-iodine solution for skin preparation	High	Strong
Preventing intraoperative hypothermia		
Maintenance of normothermia with convective active warming devices should be used perioperatively	High	Strong
Continuous measurement of core temperature for efficacy and compliance is recommended	High	Strong
Standard anaesthetic protocol		
Lung-protective strategies should be used during one-lung ventilation	Moderate	Strong
A combination of regional and general anaesthetic techniques should be used	Low	Strong
Short-acting volatile or intravenous anaesthetics, or their combination, are equivalent choices	Low	Strong
PONV control		
Non-pharmacological measures to decrease the baseline risk of PONV should be used in all patients	High	Strong
A multimodal pharmacological approach for PONV prophylaxis is indicated in patients at moderate risk or high risk	Moderate	Strong
Regional anaesthesia and pain relief		
Regional anaesthesia is recommended with the aim of reducing postoperative opioid use. Paravertebral blockade provides equivalent analgesia to epidural anaesthesia	High	Strong
A combination of acetaminophen and NSAIDs should be administered regularly to all patients unless contraindications exist	High	Strong
Ketamine should be considered for patients with pre-existing chronic pain	Moderate	Strong
Dexamethasone may be administered to prevent PONV and reduce pain	Low	Strong
Perioperative fluid management		
Very restrictive or liberal fluid regimes should be avoided in favour of euvolemia	Moderate	Strong
Balanced crystalloids are the intravenous fluid of choice and are preferred to 0.9% saline	High	Strong
Intravenous fluids should be discontinued as soon as possible and replaced with oral fluids and diet	Moderate	Strong
Atrial fibrillation prevention		
Patients taking β-blockers preoperatively should continue to take them in the postoperative period	High	Strong
Magnesium supplementation may be considered in magnesium deplete patients	Low	Weak
It is reasonable to administer diltiazem preoperatively or amiodarone postoperatively for patients at risk	Moderate	Weak
Surgical technique: thoracotomy		
If a thoracotomy is required, a muscle-sparing technique should be performed	Moderate	Strong

Continued

Table 1: Continued

Recommendations	Evidence level	Recommendation grade
Intercostal muscle- and nerve-sparing techniques are recommended	Moderate	Strong
Reapproximation of the ribs during thoracotomy closure should spare the inferior intercostal nerve	Moderate	Strong
Surgical technique: minimally invasive surgery		
A VATS approach for lung resection is recommended for early-stage lung cancer	High	Strong
Postoperative phase		
Chest drain management		
The routine application of external suction should be avoided	Low	Strong
Digital drainage systems reduce variability in decision-making and should be used	Low	Strong
Chest tubes should be removed even if the daily serous effusion is of high volume (up to 450 ml/24 h)	Moderate	Strong
A single tube should be used instead of 2 after anatomical lung resection	Moderate	Strong
Urinary drainage		
In patients with normal preoperative renal function, a transurethral catheter should not be routinely placed for the sole purpose of monitoring urine output	Moderate	Strong
It is reasonable to place a transurethral catheter in patients with thoracic epidural anaesthesia	Low	Strong
Early mobilization and adjuncts to physiotherapy		
Patients should be mobilized within 24 h of surgery	Low	Strong
Prophylactic minitracheostomy use may be considered in certain high-risk patients	Low	Weak

ERAS: Enhanced Recovery After Surgery; ESTS: European Society of Thoracic Surgeons; LMWH: low-molecular-weight heparin; NSAID: non-steroidal anti-inflammatory drugs; PONV: postoperative nausea and vomiting; VATS: video-assisted thoracoscopic surgery; VTE: venous thromboembolism.

Quality assessment and data analyses

The quality of evidence and recommendations were evaluated according to the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system (see Tables 2 and 3) [33] whereby recommendations are given as follows:

- Strong recommendations indicate that the panel is confident that the desirable effects of adherence to a recommendation outweigh the undesirable effects.
- Weak recommendations indicate that the desirable effects of adherence to a recommendation probably outweigh the undesirable effects, but the panel is less confident.

Recommendations are based not only on the quality of evidence—high, moderate, low and very low—but also on the balance between desirable and undesirable effects. As such, consistent with other ERAS® Guideline Working Groups [3, 7], in some cases strong recommendations may be reached from low-quality data and vice versa. Of note, this would be considered a modified GRADE evaluation since we did not consider resource utilization when making our recommendations [34].

RESULTS

The evidence base, recommendations, evidence level and recommendation grade are provided for each individual ERAS item below.

PREADMISSION INFORMATION, EDUCATION AND COUNSELLING

Preoperative counselling helps to set expectations about surgical and anaesthetic procedures and may diminish fear, fatigue and pain and enhance recovery and early discharge [35]. Verbalized education, leaflets and multimedia information containing explanations of the procedure and cognitive interventions may improve pain control, nausea and anxiety after surgery [36] and general anaesthesia [37]. Patient empowerment through diary keeping also appears to improve postoperative pain control but did not influence LOS in surgical cancer patients in 1 randomized controlled trial (RCT) [38]. Similar results have been demonstrated in patients provided with preoperative video information prior to lung resection [39]. Paradoxically, 1 RCT demonstrated lower levels of postoperative satisfaction following lung resection when patients were given written information [40].

It is uncertain if formal education is superior to informal education [41], but ideally patients should receive information in both written and oral form. The patient and a relative or care provider should meet with all members of the team including the surgeon, anaesthetist and nurse.

Summary and recommendations

Most studies show that counselling provides beneficial effects with no evidence of harm. In particular, pain control appears better following lung resection. It is recommended that patients should routinely receive dedicated preoperative counselling.

Evidence level: Low (conflicting data).

Recommendation grade: Strong.

PERIOPERATIVE NUTRITION

Nutritional components of ERAS include preoperative fluid and carbohydrate loading, avoidance of fasting and early recommencement of oral diet and oral nutritional supplements (ONS) [42]. Carbohydrate loading and early enteral diet are dealt with later in these guidelines.

Malnutrition is an important potentially modifiable risk factor for adverse outcomes after major surgery. In recent thoracic surgical studies, malnutrition and/or weight loss were important risk

Table 2: GRADE system for rating quality of evidence [33]

Evidence level	Definition
High quality	Further research unlikely to change confidence in estimate of effect
Moderate quality	Further research likely to have important impact on confidence in estimate of effect and may change the estimate
Low quality	Further research very likely to have important impact on confidence in estimate of effect and likely to change the estimate
Very low quality	Any estimate of effect is very uncertain

Table 3: GRADE system for rating strength of recommendations [33]

Recommendation strength	Definition
Strong	When desirable effects of intervention clearly outweigh the undesirable effects or clearly do not
Weak	When trade-offs are less certain, either because of low-quality evidence or because evidence suggests that desirable and undesirable effects are closely balanced

factors for complications after surgery [43–45]. However, it is uncertain whether modifying or optimizing perioperative nutritional state results in a reduction in complications. In rehabilitation programmes for chronic obstructive pulmonary disease (COPD), ONS is recommended and improves patient quality of life and muscle function [46]. Approximately 70% of lung cancer patients have COPD [47]. As lung cancer surgery can be considered a 'fixed exacerbation of COPD', by extrapolation a COPD-type nutrition programme may aid recovery and prevent complications after surgery. In addition, malnutrition and loss of muscle mass are frequent in cancer patients and can have a negative effect on clinical outcomes [48].

Evidence from abdominal surgery suggests that routine pre- and/or postoperative ONS may reduce postoperative weight loss, improve nutritional status and muscle strength and reduce complication rates [49–52]. A recent meta-analysis concluded no benefit of preoperative immune-enhancing nutrition (IEN) in abdominal surgery over standard ONS, although postoperative IEN may improve outcomes [42, 52, 53], particularly in patients with pre-existing malnutrition. It is not clear whether these findings are applicable following thoracic surgery as there is only 1 small study of nutritional supplementation ($n = 58$). Patients were randomized to receive either 10 days of IEN or normal diet preoperatively. There were benefits in terms of a reduced complication rate (although this was mainly due to a difference in air leak) and maintenance of postoperative plasma albumin levels [54].

Routine nutritional screening is useful. Screening tools include the Nutritional Risk Score (NRS), the Malnutrition Universal Screening Tool (MUST) and the Subjective Global Assessment (SGA) tool [42]. ESPEN guidelines recommend delaying surgery to allow for preoperative enteral nutrition in patients with at least one of the following criteria: weight loss >10–15% within 6 months, body mass index (BMI) <18.5 kg/m^2 and serum albumin <30 g/l (with no evidence of hepatic or renal dysfunction) [42]. Current general recommendations suggest administration of 5–7 days of oral supplements before surgery in patients at risk of malnutrition [42].

Summary and recommendations

Patients should be screened preoperatively for nutritional status and weight loss. If deemed at risk, they should be given active nutritional support. ONS can be used to supplement total intake. There is not enough evidence to recommend IEN over ONS preoperatively, but there may be a role in the malnourished patient postoperatively.

Evidence level:
Screening for nutritional status preoperatively: High.
ONS for malnourished patients: Moderate.
IEN: Low (extrapolated).

Recommendation grade:
Screening for nutritional status preoperatively: Strong.
ONS for malnourished patients: Strong.
IEN: Weak (postoperative only).

SMOKING CESSATION

Smoking is associated with a high risk of postoperative complications, but the pulmonary effects of smoking can be improved within 4 weeks of cessation [55]. Early studies indicated that current smokers were twice as likely to experience postoperative pulmonary complications after lung resection surgery than never smokers or those who had not smoked for more than 4 weeks [56]. Paradoxically, recent quitters (i.e. stopped smoking within 4 weeks of surgery) appeared to have an increased incidence of pulmonary complications. Further large studies could not corroborate this paradoxical effect [57, 58]. Rather, while confirming that smoking increased the risks of hospital death and pulmonary complications after lung cancer resection, these risks were mitigated slowly by preoperative cessation. More recently, smoking has not been shown to be a risk factor for pulmonary complications if patients are subjected to intense perioperative physiotherapy regimes [59]. There is also evidence that delaying surgery can result in upstaging and decreased long-term survival in lung cancer patients [60]. Nevertheless, based on the evidence available and accepting that an ideal time period has yet to be clearly defined, a delay of 4 weeks to allow smoking cessation appears reasonable.

Continued smoking at the time of lung cancer surgery is also associated with poor postoperative quality of life and fatigue [61] and reduced long-term survival [62].

While smoking cessation interventions such as behavioural support, pharmacotherapy and nicotine replacement are known to result in short-term smoking cessation and long-term abstinence rates [63, 64], there is weak evidence to show that these smoking cessation measures actively decrease postoperative morbidity. The use of varenicline is associated with an increase in long-term smoking cessation but there is no evidence of a reduction in postoperative morbidity [64, 65]. However, smoking cessation appears to be cost-effective prior to lung surgery [66].

Summary and recommendations

Smoking is associated with an increased risk of postoperative morbidity (especially pulmonary complications) and mortality and ideally should be stopped at least 4 weeks before surgery.

Evidence level:
Preoperative smoking cessation: High.

Recommendation grade:
Preoperative smoking cessation: Strong.

ALCOHOL DEPENDENCY MANAGEMENT

The effects of alcohol abuse on the liver, pancreas and neurological system are well known. In the perioperative period, the chronic effects of alcohol intake on cardiac function, blood clotting and immune function, in combination with the surgical stress response, contribute to excess morbidity. Alcohol abuse in patients undergoing lung cancer surgery is associated with increased postoperative pulmonary complications and mortality [67–69], and reduced long-term survival [70].

Prior to elective surgery, intensive preoperative interventions aimed at complete alcohol cessation, for at least 4 weeks to reduce postoperative complications, but do not significantly reduce mortality or LOS. However, only a small number of studies are available, and the mechanism by which such interventions reduce complications is unknown. Therefore, the optimal timing of such interventions has yet to be determined [71].

Summary and recommendations
Alcohol is associated with increased perioperative morbidity and mortality and should be avoided for at least 4 weeks before surgery in patients who abuse alcohol.

Evidence level:
Preoperative alcohol cessation: Moderate (small number of studies).

Recommendation grade:
Preoperative alcohol cessation: Strong.

ANAEMIA MANAGEMENT

Preoperative anaemia is associated with postoperative morbidity and mortality [72] and reduced long-term survival [73]. A comprehensive review of blood management has advocated preoperative screening for anaemia [74]. Anaemia should be identified and corrected for iron deficiency and any underlying disorder before elective surgery. Treating anaemia preoperatively helps to avoid adverse effects from anaemia and/or blood transfusion. The risks of surgery are increased with the severity of the anaemia [75]. The speed of response to iron therapy (oral or intravenous) is greater in more severe iron deficiency anaemia. Therefore, prompt identification and treatment is important in reducing the need for erythropoiesis-stimulating agents or blood transfusion. Both erythropoiesis-stimulating agents and perioperative blood transfusion have been associated with poorer outcomes for cancer patients [76, 77]. Long-term cancer survival (including survival in lung cancer patients) is also reduced following perioperative transfusion [76, 78].

Recent guidelines have shown no strong evidence of a benefit from preoperative blood transfusion to improve surgical outcomes (in cardiac surgery patients), and in the absence of other blood management measures, preoperative transfusion does not reduce total transfusion requirements. Where transfusion is considered to be unavoidable, there is no evidence to suggest advantages of pre- over intraoperative transfusion [75]. If possible, the focus should be on preventing further blood loss intraoperatively.

Summary and recommendations
Preoperative anaemia is associated with an increase in postoperative morbidity and mortality and should be identified, investigated and corrected preoperatively. Iron therapy is the preferred first-line treatment for the correction of iron deficiency anaemia. Where possible, blood transfusion or erythropoiesis-stimulating agents should not be used to correct preoperative anaemia.

Evidence level:
Correction of preoperative anaemia: High.

Recommendation grade:
Correction of preoperative anaemia: Strong.

PULMONARY REHABILITATION AND PREHABILITATION

Poorer preoperative exercise capacity is associated with worse long- and short-term clinical outcomes including postoperative complications, LOS [79, 80] and survival [81, 82] following curative lung cancer surgery. Preoperative physical conditioning, or prehabilitation, is the process of enhancing the functional and physiological capacity of an individual to enable them to withstand a stressful event and may aid recovery after surgery [83]. It is the process on the continuum of care that occurs between cancer diagnosis and surgical treatment [84]. In colorectal surgery, prehabilitation is more effective than postoperative rehabilitation in returning a patient to baseline function [85]. Patients with poor physical capacity have the most to gain from preoperative intervention [86].

Several recent systematic reviews and a meta-analysis have concluded that prehabilitation is beneficial, but, because of study heterogeneity, the exact duration, intensity, structure and patient selection to achieve maximum efficacy is uncertain [87–90]. In 21 studies (including 5 RCTs) focusing on pre- rather than postoperative rehabilitation, the intervention was delivered mainly in the outpatient setting or in a training facility [90]. Prescribed exercises included aerobic training (lower and/or upper limbs), with the addition of strength training in some studies. Respiratory exercises were also included in the majority of studies. The addition of other elements, such as relaxation techniques and educational sessions, were inconsistent. The median duration was 4 weeks (range 1–10 weeks) with a frequency of 5 sessions per week (range 2–14 weeks) of moderate to high intensity, generally tailored to the patient's tolerance.

Studies report an improvement in peak oxygen consumption or in functional capacity (measured with the 6-min walk test) from baseline to postintervention [90]. Lung function is also enhanced after prehabilitation compared with baseline.

In addition to improving preoperative fitness, prehabilitation appears to improve postoperative outcomes. Hospital LOS and morbidity were reduced in comparison with standard care in a recent meta-analysis and Cochrane review [87, 90]. Pooled estimates of effect sizes show a significant reduction in both hospital LOS and postoperative pulmonary complications. The effect on pulmonary complications seems to be specific to patients with poor preoperative lung function.

The small number of studies, and the diversity and validity of tools used, limit assessment of prehabilitation on health-related quality of life.

Summary and recommendations

A preoperative exercise rehabilitation programme can reduce hospital LOS and postoperative pulmonary complications. Because of study heterogeneity, no firm recommendations can be made on the nature of the intervention in terms of exercise modality, delivery, frequency or preoperative duration. Prehabilitation should be considered for patients with borderline lung function or exercise capacity.

Evidence level:

Prehabilitation for patients with borderline lung function or exercise capacity: Low.

Recommendation grade:

Prehabilitation for patients with borderline lung function or exercise capacity: Strong.

PREOPERATIVE FASTING AND CARBOHYDRATE TREATMENT

Evidence has shown that the intake of clear fluids up until 2 h before surgery does not increase gastric content, reduce gastric fluid pH or increase complication rates. Hence, in patients without conditions associated with delayed gastric emptying, the intake of clear fluids up until 2 h before the induction of anaesthesia, as well as limiting fasting for solid food to 6 h before induction, is now recommended [91].

To reduce postoperative insulin resistance and mitigate the associated increased risks for complications, carbohydrate loading before surgery has been advocated to achieve a metabolically fed state. In the last decades, an increasing number of original but small studies, systematic reviews and meta-analyses have shown that carbohydrate loading attenuates the increase in insulin resistance related to surgery and, therefore, should be used routinely in major abdominal surgery [3]. Carbohydrate drinks for preoperative use should be properly tested as not all carbohydrate drinks have the same effects on gastric emptying or insulin action.

Although no studies have been performed in patients undergoing thoracic surgery, these findings are considered valid for lung cancer patients given similarities in patient characteristics. Randomized studies have demonstrated that preoperative carbohydrates improve well-being and reduce nausea and vomiting [92]. No studies have specifically addressed diabetic patients, although limited data indicate that it is likely to be safe in well-controlled diabetics [93].

Summary and recommendations

Patients should be permitted to drink clear fluids up until 2 h before anaesthesia and surgery. Patients should abstain from solids for 6 h prior to induction of anaesthesia. Oral carbohydrate loading reduces postoperative insulin resistance, improves preoperative well-being and should be used routinely. Insufficient data are available for diabetic patients.

Evidence level:

Fasting guidelines for solids and fluids: High.
Carbohydrate loading: Low (extrapolated data).

Recommendation grade:

Fasting guidelines: Strong.
Carbohydrate loading: Strong.

PREANAESTHETIC MEDICATION

In general, thoracic surgical patients are older and present with compromised pulmonary function. The use of short- and long-acting benzodiazepines has been associated with over-sedation, upper airway obstruction, decreased postoperative cognitive function and delirium, especially in older frailer patients [94].

One observational trial found no association between the use of preoperative anxiolytic-sedative agents and a reduction in perceived patient anxiety [95]. A recent randomized control trial showed that the use of long-acting benzodiazepines was associated with an increased time to extubation and a decreased rate of early cognitive recovery. Additionally, premedication with lorazepam did not improve self-reported patient experience on the first postoperative day [96]. Therefore, routine administration of benzodiazepines to decrease preoperative anxiety levels should be avoided. However, small doses of short-acting narcotics may be used during preoperative placement of regional blocks or in extremely anxious patients.

Alternative strategies to reduce perioperative anxiety can be implemented. Patient education regarding perioperative goals and expectations plays an important role in reducing preoperative anxiety [36, 37]. Carbohydrate loading and the avoidance of starvation and dehydration also reduce preoperative discomfort [92]. A Cochrane review identified that melatonin administered 1–2 h before surgery is equally as effective as midazolam in reducing preoperative anxiety in adults [97]. Non-pharmacological measures, such as relaxation techniques and music interventions, may offer a substitute to standard anxiolytic medications [98].

Summary and recommendations

Routine administration of sedatives to reduce anxiety preoperatively should be avoided to hasten postoperative recovery. Alternative non-pharmacological methods to relieve preoperative anxiety should be considered in patients with severe anxiety.

Evidence level:

Avoidance of sedatives: Moderate.

Recommendation grade:

Avoidance of sedatives: Strong.

VENOUS THROMBOEMBOLISM PROPHYLAXIS

In thoracic surgery, the postoperative period carries an increased risk of venous thromboembolism (VTE) events due to both the advanced age of patients and the high frequency of this procedure being performed for lung malignancy [99]. When compared to non-cancer patients undergoing comparable surgical procedures [100, 101], the presence of cancer at least doubles the risk of a patient developing deep venous thrombosis. This risk is increased 3-fold for fatal pulmonary embolism. Moreover, postoperative VTE has been found to increase 30-day mortality after cancer surgery from 1.2% to 8.0% [102].

The incidence of postoperative VTE after thoracic surgery has been estimated at between 0.4% and 51% for deep venous thrombosis and from less than 1% to 5% for pulmonary embolism, with 2% of pulmonary embolism cases being lethal [103, 104]. Thoracic surgery patients must, therefore, be considered at high risk of postoperative VTE.

Mechanical and pharmacological venous thromboembolism prophylaxis

The evidence for using VTE prophylaxis after thoracic surgery for lung cancer is relatively limited. A recent Cochrane meta-analysis of 7 studies evaluated the use of VTE prophylaxis in thoracic surgery patients versus inactive or active control [103] and could not demonstrate any significant differences between the prophylactic regimen and the control.

The use of VTE prophylaxis is predominantly based on clinical consensus on the estimated risk of VTE and of postoperative bleeding. American College of Chest Physicians and National Institute for Health and Care Excellence (NICE) guidelines recommend that mechanical VTE prophylaxis (antiembolism stockings, intermittent pneumatic compression devices or foot impulse devices) should be started upon admission and continued until the patient has recovered full mobility [105, 106]. Pharmacological VTE prophylaxis with low-molecular-weight heparin, or unfractionated heparin for patients with renal failure, should be added in patients who have a low risk of major bleeding. For patients at high risk of bleeding, mechanical VTE prophylaxis should be used with graduated compression stocking and intermittent pneumatic compression. Once daily administration of low-molecular-weight heparin seems to be as effective as 2 daily half-dose administrations [107]. It is also recommended that epidural catheters should not be inserted or removed within 12 h of heparin administration [108, 109].

Extended pharmacological venous thromboembolism prophylaxis

Patients undergoing thoracic surgery are at risk of developing VTE after discharge [103]. In a retrospective review of 232 lung resections for cancer, the rate of VTE was 5.2% with one-third occurring after leaving hospital [110]. A recent prospective cohort study demonstrated VTE in 12.1% of 157 patients, all of whom underwent a computed tomography pulmonary angiogram and venous US Doppler 1 month postoperatively, regardless of symptoms [111]. The highest incidence of VTE appears within the first month after the surgery [112]. In patients undergoing pneumonectomy for cancer, the peak of incidence of VTE is 6–7 days post-surgery [113, 114]. Furthermore, the presence of VTE negatively impacts on long-term survival [113].

Various studies have reported that the extension of pharmacological prophylaxis up to 1 month after surgery decreases the risk of VTE in major surgery for cancer [115–118]. Despite this, the need for extended VTE prophylaxis in thoracic surgery patients remains unproven and is controversial, with practice varying widely between surgeons, centres and specialties [119]. No prospective, randomized controlled trials in thoracic surgery have been published to examine the potential benefit of extended, out-of-hospital postoperative VTE prophylaxis. However, in 1 study, extended prophylaxis was introduced based on VTE risk assessment using the Caprini model for high-risk thoracic surgery patients. Patients demonstrated an excellent adherence (97.2%) to post-discharge enoxaparin prophylaxis, and the study reported an overall VTE rate of 2.3% with no post-discharge VTE or bleeding events [120].

Currently, there is no evidence to support the use of oral pharmacological VTE prophylaxis.

Summary and recommendations

All patients undergoing major lung resection should be treated with pharmacological and mechanical VTE prophylaxis. Patients at high risk of VTE may be considered for extended prophylaxis with low-molecular-weight heparin lasting up to 4 weeks.

Evidence level:
Mechanical and pharmacological VTE prophylaxis: Moderate (extrapolated).
Extended pharmacological prophylaxis in high-risk patients: Low.

Recommendation grade:
Mechanical and pharmacological VTE prophylaxis: Strong.
Extended pharmacological prophylaxis in high-risk patients: Weak.

ANTIBIOTIC PROPHYLAXIS AND SKIN PREPARATION

In thoracic surgery, postoperative infection (pneumonia, empyema and wound infection) is an important problem [121–123], typically occurring in 7–14% of patients undergoing lung resection [124]. Lung resection without pre-existing infection is classified as a 'clean contaminated' procedure [125]. Airway colonization with bacterial pathogens has been identified as a risk factor for the development of postoperative pulmonary infectious complications [123, 126]. The incidence of bacterial airway contamination of lung cancer surgery patients has been estimated to be between 10% and 83% [127].

Antibiotic prophylaxis

Preoperative administration of prophylactic antibiotics decreases surgical site infection (SSI) after thoracic surgery but does not demonstrate any effect on the rate of postoperative pneumonia or empyema. Extended postoperative antibacterial prophylaxis is not routinely indicated. A single dose of antibiotics before incision is as effective as up to 48 h of postoperative prophylaxis [121, 122, 124, 126, 128]. Intravenous antibiotics should be given no more than 60 min prior to skin incision, usually at the time of anaesthesia induction [129]. In obese patients with a BMI of >35 kg/m^2, the dose of antibiotics should be adapted and increased [130]. Antibiotic doses during prolonged operations or when blood loss exceeds 1500 ml may be repeated according to the half-life of the chosen medication [131].

Infection caused by various organisms frequently identified in skin and respiratory flora (e.g. *Staphylococcus aureus*, coagulase-negative *Staphylococcus*, *Streptococcus pneumoniae* and Gram-negative bacilli) may be adequately prevented by cephalosporins. These are considered to be the standard for prophylaxis in pulmonary surgery due to their broad spectrum, low cost and low allergenic potential [128]. Amoxicillin–clavulanic acid is an alternative choice, and vancomycin or teicoplanin may be used in penicillin- or cephalosporin-allergic patients. Specific local guidelines should be based on the usual pattern of pulmonary flora and the potential development of antibiotic resistance [126, 127].

Skin preparation

Patients should shower or bathe the night before or the morning of surgery [132]. Using plain soap is just as effective as using chlorhexidine in decreasing SSI [133]. There is no evidence that hair removal reduces SSI, irrespective of the method chosen (shaving, hair clipping or depilatory cream). However, if hair removal is necessary, hair clipping just before surgery is associated with lower rates of SSI than other methods [134].

A 40% reduction in SSI has been reported after the use of chlorhexidine–alcohol for skin cleansing compared to a povidone-iodine solution in various clean contaminated procedures [135]. Therefore, chlorhexidine–alcohol is preferred over povidone-iodine solutions, although care must be taken to avoid fire-based and burn injuries when electrocautery is used [136].

Summary and recommendations

Routine intravenous antibiotic prophylaxis should be administered within 60 min of, but prior to, the skin incision. Routine extended prophylaxis offers no benefits, but additional doses may be given during prolonged procedures according to the half-life of the antibiotic used. Hair clipping is recommended if hair removal is required. Chlorhexidine–alcohol is preferred to povidone-iodine solution for skin preparation.

Evidence level:
Antibiotic prophylaxis: High.
Hair clipping: High.
Chlorhexidine–alcohol skin preparation: High.

Recommendation grade:
Antibiotic prophylaxis: Strong.
Hair clipping: Strong.
Chlorhexidine–alcohol skin preparation: Strong.

PREVENTING INTRAOPERATIVE HYPOTHERMIA

During anaesthesia and major surgery, hypothermia can occur as a result of prolonged exposure to cold operating room temperatures and impairment of the normal thermoregulatory response. Thoracic surgery patients are at high risk of hypothermia (estimated incidence of 35–50%) as the pleural surface of one hemithorax is exposed to dry air during surgery, leading to potentially important evaporative heat loss [137, 138].

Perioperative hypothermia (defined as a body temperature below 36°C) is associated with impaired drug metabolism, increased SSI, cardiovascular morbidity and increased bleeding secondary to impaired haemostasis [139–142]. In addition, postoperative shivering increases oxygen consumption and can worsen pain [143]. Normothermia can be maintained by different approaches: (i) procedures which decrease heat loss through redistribution (vasodilatation and prewarming); (ii) passive warming systems (room temperature and covering exposed body surfaces) and (iii) active warming systems (direct transfer of heat to the patient) [140].

Warming techniques

The most frequently used technique to prevent hypothermia is active body surface warming. Forced air-warming blankets, heating mattresses under the patient or circulating-water garment systems all achieve similar results in terms of clinical outcomes, and no system seems significantly superior to others [140]. However, convective warming systems present several advantages over conductive warming systems: blanket design, air-to-surface warming, no pressure points, single use and suitability for pre-, peri- and postoperative periods [144–146]. SSIs are significantly less common with the use of active warming compared to conventional methods, with an absolute risk reduction of 13% [143].

Before entering the operating room, prewarming patients with a forced air-warming blanket improves core temperature before surgery [147]. In a recent prospective randomized study in thoracic surgery patients, convective prewarming and additional intraoperative warming with an underbody blanket decreased the rate of postoperative hypothermia to 8% compared to 56% with conductive warming using an underbody mattress [148]. Warming intravenous and irrigation fluids to core body temperature or above has been shown to prevent heat loss and subsequent hypothermia [149].

Temperature monitoring

Temperature should be continuously monitored to guide therapy and avoid hyperthermia, which can have deleterious effects on homeostasis and increase the likelihood of a systemic inflammatory response. The most convenient site to measure core temperature during thoracic surgery is the nasopharynx. Active warming should be continued into the postoperative period until the patient's temperature is greater than 36°C.

Summary and recommendations

Monitoring of patients' temperature is mandatory to guide therapy and to avoid hypothermia and hyperthermia. Maintenance of normothermia with convective active warming devices should be used perioperatively.

Evidence level:
The use of active warming devices: High.
Continuous measurement of core temperature for efficacy and compliance: High.

Recommendation grade:
The use of active warming devices: Strong.
Continuous measurement of core temperature for efficacy and compliance: Strong.

STANDARD ANAESTHETIC PROTOCOL

Ventilation

Within the context of an ERAS programme, no single ventilation strategy during thoracic surgery has been favoured over another. However, one-lung anaesthesia with lung-protective strategies may be associated with better outcomes.

Lung isolation. The majority of procedures, whether open thoracotomy or minimally invasive techniques, employ lung isolation and one-lung ventilation to facilitate access into the operative hemithorax. The majority of thoracic procedures are performed with double-lumen tubes [150]. They tend to be more stable during surgery leading to fewer instances of repositioning of the airway device and interruption of surgery [151]. However, there is a tendency for more airway injury and an increased incidence of postoperative sore throat [152]. Bronchial blockers are useful in patients with difficult airways when intubation with a large double-lumen tube is problematic. Whether a double-lumen tube or bronchial blocker is used, it is advisable to use fibrotic bronchoscopy to position the device in the airway and avoid accidental lobar obstruction [153, 154]. The use of FiO_2 of 1.0 for ventilation immediately prior to the initiation of one-lung ventilation increases the rate of collapse of the non-ventilated lung and improves surgical access in the operative hemithorax [155].

Management of one-lung ventilation. There are 2 major complications that influence the strategy for one-lung ventilation during thoracic surgery: the risk of hypoxaemia and the possibility of injury to the ventilated lung. Over the past 3 decades, the incidence of hypoxaemia during one-lung anaesthesia has decreased, and the focus has turned towards preventing lung injury [156]. There has been a trend towards using lung-protective ventilation strategies. Decreasing the tidal volumes during one-lung anaesthesia from traditional large volumes of 10 ml/kg ideal body weight to 4–6 ml/kg is considered to be less injurious to the ventilated single lung [157], although outcomes have not been studied in large randomized controlled trials. Retrospective studies suggest that, when used without positive end-expiratory pressure (PEEP), there is no clear clinical decrease in postoperative lung injury with the smaller tidal volumes [158]. There is a trend towards a decreased incidence of hypoxaemia during one-lung ventilation with larger tidal volumes. However, when smaller tidal volumes are used with PEEP, oxygenation is equivalent [159]. The optimal level of PEEP will vary according to individual respiratory mechanics and is usually in the range of 5–10 cmH_2O [160]. An alveolar recruitment manoeuvre strategy at the onset of one-lung ventilation improves oxygenation but can be associated with a transient decrease in systemic blood pressure [161].

Although most concern has focused on preventing injury to the ventilated lung during one-lung anaesthesia, there is evidence of injury to the non-ventilated (collapsed) lung too. Avoiding complete collapse of the non-ventilated lung by the addition of continuous positive airway pressure during surgery has been shown to decrease the local intraoperative inflammatory response [162].

Non-intubated anaesthesia. There are several potential anaesthetic management strategies for thoracic surgery that do not involve intubation of the airway or positive pressure ventilation, including awake-regional anaesthesia and non-intubated general anaesthesia with spontaneous ventilation. Regional anaesthesia includes both thoracic epidural anaesthesia and paravertebral local anaesthesia, usually in combination with intravenous sedation and suppression of the cough reflex. Reported non-intubated thoracic surgical procedures include lobectomy, pneumonectomy, excision of bullae and lung volume reduction [163]. The majority of the reports of non-intubated thoracic surgery have been single-centre observational studies [164]. Most have shown trends towards equivalent or improved outcomes with non-intubated surgery compared to general anaesthesia and a trend towards shorter hospital stays [165]. One randomized controlled trial of 347 patients having a variety of video-assisted thoracoscopic surgery (VATS) procedures showed an overall decrease in postoperative complications and a shorter postoperative LOS in the non-intubated epidural group compared to the general anaesthesia double-lumen tube group, although the hospital stays were still long by fast-track standards (5.8 vs 7.7 days following bullectomy and 9.5 vs 12.7 days following lobectomy) [166]. Currently, although the technique shows potential, the routine use of non-intubated anaesthesia cannot be recommended.

Anaesthetic technique

Anaesthetic management should focus on short-acting agents that permit early extubation. This is best accomplished using a combination of regional and general anaesthetic techniques. Older volatile anaesthetics such as ether or halothane are potent inhibitors of hypoxic pulmonary vasoconstriction and are associated with a high incidence of hypoxaemia during one-lung ventilation. Modern volatile anaesthetics (isoflurane, sevoflurane and desflurane) are weak inhibitors of hypoxic pulmonary vasoconstriction, and when used in doses $\leq$1 minimal alveolar concentration, there is no clinically relevant difference in oxygenation compared to total intravenous anaesthesia (TIVA) [167]. However, there are differences between TIVA and volatile anaesthetics with respect to the local inflammatory response in the lungs. Desflurane has been shown to significantly mitigate the increase in inflammatory markers during surgery in the ventilated lung compared to TIVA with propofol [168]. Similarly, sevoflurane decreases the inflammatory response in the non-ventilated lung [169]. While volatile anaesthetics have been shown to decrease postoperative mortality and respiratory complications in cardiac surgery [170], this has not been shown to be true in thoracic surgery [171]. Dexmedetomidine, another intravenous anaesthetic/analgesic, improves oxygenation and decreases markers of oxidative stress during thoracic surgery but has not been studied in larger outcome trials [172].

Summary and recommendations

A combination of regional and general anaesthetic techniques should be used to permit early emergence from anaesthesia and extubation. Lung isolation can be provided with either a double-lumen tube or a bronchial blocker, and lung-protective ventilation strategies should be used during one-lung anaesthesia. Non-intubated anaesthesia shows potential but cannot currently be recommended for routine use. Short-acting volatile or intravenous anaesthetics, or their combination, are equivalent choices.

Evidence level:
Lung-protective strategies during one-lung ventilation: Moderate.
Non-intubated thoracic surgery: Low.
Combined regional and general anaesthesia: Low.
Short-acting volatile or intravenous anaesthetics or their combination: Low.

Recommendation grade:
Lung-protective strategies during one-lung ventilation: Strong.
Non-intubated thoracic surgery: Not recommended.
Combined regional and general anaesthesia: Strong.
Short-acting volatile or intravenous anaesthetics or their combination: Strong.

POSTOPERATIVE NAUSEA AND VOMITING CONTROL

Postoperative nausea and vomiting (PONV) remains one of the most frequent complications encountered after surgery [3, 173], impacting on the quality of early recovery and representing the leading cause of patient dissatisfaction in the immediate postoperative period. The aetiology of PONV is multifactorial. Multiple risk factors have been identified and can be divided into 3 categories: patient related, anaesthetic related and surgery related. Females, non-smokers and patients with a history of PONV or motion sickness are considered to be at highest risk [174]. The use of volatile anaesthetics is the strongest anaesthesia-related predictor [175]. In addition, nitrous oxide and postoperative opioids have been strongly associated with PONV [5]. Longer anaesthetic and surgical time has also been identified as a predictor [176], although thoracic surgery in general is not considered highly emetogenic.

Non-pharmacological control of postoperative nausea and vomiting

To risk stratify patients and develop an appropriate management plan, several scoring systems are available. The easiest to apply in clinical settings is the simplified Apfel score [173], which stratifies the patient as low risk, medium risk or high risk of PONV. The use of a multimodal approach, combining both non-pharmacological and pharmacological measures, tailored to the individual's risk score is advocated [177]. Among non-pharmacological measures, the use of preoperative carbohydrate loading with the avoidance of fasting and dehydration has been associated with a decreased incidence of PONV [178, 179]. In moderate- and high-risk patients, the intraoperative use of TIVA with propofol decreases the risk of PONV [180]. The use of peripheral nerve blocks (intercostal and paravertebral) or neuraxial anaesthesia (epidural and spinal) for the treatment of postoperative pain may reduce the need for postoperative opiates. Similarly, the use of perioperative non-steroidal anti-inflammatory drugs has a known opioid-sparing effect [181]. Electrical stimulation of the P6 acupoint has a significant impact on decreasing the rates of PONV. Acupoint stimulation is considered to be just as effective if performed either preoperatively or postoperatively [182, 183].

Pharmacological control of PONV

Pharmacological measures include administering one or a combination of antiemetic drugs, depending on the risk identified for each patient. There are several classes of recommended antiemetic drugs, all superior to a placebo in reducing PONV: 5-hydroxytryptamine (5-HT_3) receptor antagonists, neurokinin-1 (NK1) receptor antagonists, corticosteroids, phenothiazines and anticholinergics. Other effective classes (butyrophenones and antihistamines) have significant sedative effects and should be avoided, if possible. A single 8-mg preoperative dose of dexamethasone reduces PONV for the first 24 h and reduces further antiemetic needs for up to 72 h following gastrointestinal surgery [184], while high-dose methylprednisolone also reduces nausea for the first 24 h following VATS lobectomy [185]. Corticosteroid administration does raise concerns for potential blood sugar increases and postoperative infection in all patient populations [186], but it has not been associated with a higher incidence of complications following thoracic surgery [185]. The long-term immunosuppressive and oncologic effects of steroid-based antiemetic drugs are not known [3]. Nevertheless, a single dose of steroids appears to be acceptable as an adjunct to first-line therapy.

A common approach to PONV is to administer 1 drug, usually ondansetron, as prophylaxis to all patients. In patients with a moderate or high-risk profile, the most recent guidelines recommend a multimodal approach, utilizing as many non-pharmacological approaches as possible and at least 2 different classes of antiemetic drugs [177]. Treatment of PONV should be performed with a drug from a different class than the one utilized for prophylaxis [177]. Repeating the dose of a medication used for prophylaxis within 6 h of the initial dose does not provide added benefit.

Summary and recommendations

The use of non-pharmacological measures to decrease the baseline risk of PONV should be implemented in all patients undergoing thoracic surgery. A multimodal pharmacological approach for PONV prophylaxis, in combination with other measures to reduce postoperative opiate consumption, is indicated in patients at moderate or high risk.

Evidence level:
The use of non-pharmacological measures: High.
Multimodal pharmacological approach: Moderate.

Recommendation level:
The use of non-pharmacological measures: Strong.
Multimodal pharmacological approach: Strong.

REGIONAL ANAESTHESIA AND PAIN RELIEF

Pain following thoracic surgery is often severe and can be due to retraction, fracture or dislocation of ribs, injury to the intercostal nerves or irritation of the pleura or intercostal bundles by chest tubes. A standardized multimodal analgesic strategy is required to keep the patient comfortable, allow early mobilization and reduce the risk of pulmonary complications.

Inadequate provision of analgesia following thoracotomy or VATS exacerbates a compromised respiratory status. It may lead to respiratory failure secondary to splinting or pneumonia as a result of an ineffective cough and poor clearance of secretions. Pain increases immediate risks to the patient of hypoxaemia, hypercarbia, increased myocardial work, arrhythmias and ischaemia. High-intensity postoperative pain can also facilitate the development of post-thoracotomy pain syndrome. Therefore, an enhanced recovery pathway for thoracic surgery must combine multimodal enteral and parenteral analgesia with regional analgesia or local anaesthetic techniques while attempting to avoid opioids and their side effects. Patient education is also important as well-informed patients may experience less pain [35].

Pre-emptive analgesia

Pre-emptive analgesia aims to decrease acute postoperative pain, even after the analgesic effects of the pre-emptive drugs have worn off, and to inhibit the development of chronic postoperative pain. A systematic review of pre-emptive analgesia for postoperative pain relief found no evidence of benefit for the pre-emptive administration of systemic opioids, non-steroidal anti-inflammatory drugs (NSAIDs) or ketamine and little evidence of benefit with continuous epidural analgesia [187]. A subsequent meta-analysis concluded that pre-emptive thoracic epidural analgesia (TEA) was associated with a reduction in acute pain after thoracotomy but had no effect on the incidence of chronic post-thoracotomy pain [188].

Intraoperative regional analgesia

Early ERAS protocols defined epidural analgesia as an essential part of the bundle of intraoperative pain management, and it has been the gold standard technique for pain control after major thoracic surgery for some time. The risks associated with the perioperative use of epidural analgesia are becoming clearer and may be greater than previously thought [189]. Adverse effects include urinary retention, hypotension and muscular weakness. Furthermore, an increasing number of patients are taking oral anticoagulation or have renal failure, potentially increasing the risk of epidural-related complications.

Paravertebral analgesia provides a unilateral block of somatic and sympathetic nerves that lie in the paravertebral space and is particularly useful in unilateral thoracic procedures. Several randomized studies have compared outcomes after TEA or paravertebral block. The results suggest that paravertebral blocks are more effective at reducing respiratory complications than TEA and after the first few hours provide equivalent analgesia [190–192]. Percutaneous paravertebral blockade reduces the risks of developing minor complications (PONV, pruritus, hypotension and urinary retention) compared to TEA, with no difference in acute pain, 30-day mortality, major complications (cardiac and respiratory) or length of hospital stay [192, 193].

Intercostal catheters may be as effective as TEA in terms of postoperative pain. They are more cost-effective, require less time, can be placed by the surgeon at the end of the operation and may be associated with fewer complications [194]. Intercostal blocks have demonstrated reduced post-thoracotomy pain when compared to placebo [191] and do not significantly increase operative time [195].

The serratus anterior plane block [196, 197] is a novel technique with potential use in rescue analgesia. Evidence is lacking but there is a possible role in a single-port VATS or when paravertebral blockade is not appropriate (e.g. pleurectomy and decortication). Liposomal bupivacaine also shows promise when delivered as multilevel intercostal injections, potentially providing blockade of intercostal nerves for up to 96 h [198, 199]. Cryoanalgesia is not recommended as it appears to potentiate chronic pain [200, 201].

Postoperative multimodal analgesia

During the postoperative phase, a multimodal analgesic regimen should be employed with the aim of avoiding or minimizing the use of opioids. Opioids are associated with multiple side effects that may impact on a patient's ability to achieve ERAS targets such as PONV control, early mobilization and a quick return to oral diet. The concept of achieving analgesia through the additive or synergistic effects of different types of analgesics is not new and ideally allows the side effects of individual drugs to be minimized while potentiating their positive effects and reducing the use of opioids.

Acetaminophen. Acetaminophen is a vital part of postoperative pain control and can be administered either intravenously or orally [202]. A recent meta-analysis found that after major surgery, adding acetaminophen reduced morphine consumption by 20% but did not decrease the incidence of morphine-related adverse effects [203]. Acetaminophen at clinical doses has few contraindications or side effects. It is considered safe for patients at risk of renal failure [204].

Non-steroidal anti-inflammatory drugs. An NSAID in combination with acetaminophen is more effective than either drug alone [205]. NSAIDs have been used to control post-thoracotomy pain [206] and significantly improve pain control in patients receiving systemic opioids [207, 208]. NSAIDs may also be effective in controlling the ipsilateral post-thoracotomy shoulder tip pain seen in patients receiving TEA [209, 210]. Renal failure is a particular risk of NSAIDs administration in a number of groups including the elderly [211, 212], pre-existing renal failure and hypovolaemic patients. These risk factors are often present in patients scheduled for thoracic surgery. Although there is a theoretical concern that NSAID-mediated reductions in inflammation may reduce the efficacy of a surgically performed pleurodesis [213], this has not been proven in human studies [214].

N-methyl-D-aspartate (NMDA) antagonists. In a double-blinded study of patients who had undergone thoracic surgery, ketamine reduced morphine consumption and improved early postoperative lung function [215]. In another study, adding a low-dose intravenous infusion of ketamine to TEA improved early post-thoracotomy analgesia [216]. The postoperative use of ketamine should be considered for some patients, for example, those on long-term high-dose opioids.

Gabapentin. Given its mechanism of action and effectiveness in neuropathic states, gabapentin's effectiveness in preventing chronic post-surgical pain has been investigated. There is currently no clinical evidence that it reduces chronic post-surgical pain [217]. While gabapentin appears to reduce early postoperative pain scores and opioid use for patients undergoing a variety of surgical procedures [218], there is no evidence that it reduces acute or chronic pain following thoracic surgery [219, 220]. Furthermore, gabapentin does not decrease the ipsilateral shoulder tip pain seen in patients receiving TEA [221]. Therefore, on current evidence, perioperative gabapentin cannot be recommended.

Glucocorticoids. Glucocorticoids (e.g. dexamethasone and methylprednisolone) have many actions including analgesic, antiemetic, antipyretic and anti-inflammatory effects. Dexamethasone produces a dose-dependent opioid-sparing effect [222] in a general surgical setting and has been particularly effective in reducing pain scores with dynamic movement [223, 224]. These effects have been produced with a single dose of dexamethasone in the range of 10–40 mg with few reported serious side effects. Risks of glucocorticoid use include gastric irritation, impaired wound healing, impaired glucose homeostasis and sodium retention. The optimal dose that balances the advantages against these and other risks has yet to be defined. However, 1 recent trial in VATS lobectomy showed that preoperative high-dose methylprednisolone reduces postoperative pain, nausea and fatigue without increasing the risk of complications [185].

Opioids. Opioids, including patient-controlled analgesia, should be kept to a minimum or avoided entirely. If opioids are used, a balance between the beneficial effects (analgesia, enabling passive expiration and prevention of splinting) and the detrimental effects (PONV, constipation, sedation and the suppression of ventilation and coughing and sighing) must be achieved.

Summary and recommendations

A standardized multimodal approach to pain relief, including good regional anaesthesia, is recommended with the aim of reducing postoperative opioid use. Paravertebral blockade provides equivalent analgesia to TEA with evidence of a better side-effect profile. Acetaminophen and NSAIDs should be administered regularly to all patients unless contraindications exist. Dexamethasone may be administered to prevent PONV and reduce pain. Ketamine should be considered for patients with pre-existing chronic pain on long-term opiates. Gabapentin cannot currently be recommended as an adjunct to conventional analgesia.

Evidence level:
Regional anaesthesia: High.
Combination of acetaminophen and NSAIDs: High.
Ketamine: Moderate.
Dexamethasone: Low.

Recommendation grade:
Regional anaesthesia: Strong.
Combination of acetaminophen and NSAIDs: Strong.
Ketamine: Strong.
Dexamethasone: Strong.

PERIOPERATIVE FLUID MANAGEMENT

Fluid management encompasses the pre-, intra- and postoperative periods [225, 226]. Preoperatively, carbohydrate loading and the avoidance of starvation ensure that patients should not be dehydrated prior to the induction of anaesthesia [42, 49].

In lung resection surgery, fluid management is complex as patients are prone to developing interstitial and alveolar oedema. The effects of existing pulmonary disease, prior chemoradiotherapy, one-lung ventilation, direct lung manipulation by the surgeon and ischaemia–reperfusion phenomena can all damage the glycocalix and the underlying endothelial cells as well as affecting epithelial alveolar cells and surfactant. This may lead to lung injury [227, 228]. In combination with a liberal fluid regime, there is an increased risk of acute respiratory distress syndrome, atelectasis, pneumonia, empyema and death [68, 229–232]. The extent of the lung resection plays an important role, with the highest incidence of acute respiratory distress syndrome seen following extensive resection and pneumonectomy [233].

Traditionally, a volume-restrictive fluid regime of 1–2 ml/kg/h has been recommended as intraoperative and postoperative maintenance, with a perioperative positive fluid balance of <1500 ml (or 20 ml/kg/24 h). The aim is to control the amount of fluid and minimize the hydrostatic pressure in the pulmonary capillaries [234]. The concern with such restrictive fluid management is that it may produce a hypovolaemic state with impaired tissue perfusion, organ dysfunction and acute kidney injury (AKI). A retrospective analysis of 1442 patients undergoing thoracic surgery found a 5.1% incidence of AKI [235]. Subgroup analysis of patients who received less than 3 ml/kg/h showed no relationship with the development of AKI. Subsequent studies have confirmed that restrictive regimes may result in perioperative oliguria but are not associated with an increased risk of postoperative AKI [236, 237]. Similarly, setting a low perioperative urine output target (0.2 ml/kg/h) or treating oliguria with fluid boluses does not appear to affect postoperative renal function [236–238].

Goal-directed therapy (GDT) has been used in multiple specialties to improve surgical outcomes with conflicting results. A recent meta-analysis in major abdominal surgery compared outcomes between intraoperative GDT and conventional fluid therapy [239]. GDT in those patients managed in a traditional care setting was associated with significant reductions in morbidity and hospital LOS. In contrast, if patients were managed within an ERAS setting, there was little difference in outcomes. Monitoring of cardiac output (by pulse contour analysis or Doppler ultrasound), extravascular lung water (by transpulmonary thermodilution) and/or central venous oximetry may prove to be valuable adjuncts in high-risk patients and complex procedures. However, the current evidence for the use of monitoring devices to direct fluid therapy during thoracic surgery is not conclusive [240, 241].

The aim of maintaining intraoperative euvolemia with a dry lung has been discussed repeatedly [234, 242], and its efficacy has been demonstrated in a small RCT [243]. Over-restriction may eventually lead to organ dysfunction, but rates of 2–3 ml/kg/h are not associated with AKI in lung resection patients. Hypoperfusion can be avoided with the use of vasopressors and a limited amount of fluid to counteract the vasodilatory effects of anaesthetic agents and neuraxial blockade [244]. Additional fluid can be given to compensate blood or exudative loss [245]. In line with other ERAS programmes, balanced crystalloid is currently the fluid of choice over 0.9% saline [246]. In the immediate postoperative period, attention should also be paid to fluid balance and the patient's body weight. Enteral fluid should resume as soon as the patient is lucid and able to swallow [42].

Summary and recommendations

Very restrictive or liberal fluid regimes should be avoided in favour of euvoleamia. Intraoperative hypoperfusion can be avoided with the use of vasopressors and a limited amount of fluid. GDT and the use of non-invasive cardiac output monitors do not currently appear to offer benefits to the thoracic surgical patient. Balanced crystalloids are the intravenous fluid of choice and should be discontinued as soon as possible in the postoperative period to be replaced with oral fluids and diet.

Evidence level:
Euvolemic fluid management: Moderate.
Balanced crystalloids: High.
Early enteral route: Moderate (extrapolated).

Recommendation grade:
Euvolemic fluid management: Strong.
Balanced crystalloids: Strong.
Early enteral route: Strong.

ATRIAL FIBRILLATION PREVENTION

New-onset postoperative atrial fibrillation and flutter (POAF) is common after thoracic surgery with an incidence of approximately 12% following lung resection [247, 248]. Risk factors include increasing age, male sex, Caucasian race, hypertension, COPD, heart failure and valvular heart disease [247]. Following lobectomy, a VATS approach may be protective [247, 249, 250] although this is not a consistent finding [251]; however, increasing the extent of operation (e.g. pneumonectomy compared to lobectomy) increases the risk [248]. The development of postoperative complications is associated with doubling of the incidence of POAF [247]. Although POAF occurring in isolation is associated with an increased length of hospital stay and an increased risk of readmission, patients with POAF and additional complications do poorly. They are at increased risk of stroke and in-hospital death [247].

Several prevention strategies for the development of POAF have been recommended in the 2014 American Association for Thoracic Surgery (AATS) Guidelines [252]. Patients taking β-blockers prior to surgery are at risk of developing POAF if withdrawn abruptly. Therefore, β-blockers should be continued through into the postoperative period. In those patients who are magnesium deplete (either with low serum magnesium or suspected total body magnesium depletion), intravenous magnesium may be given perioperatively. Digoxin does not prevent the development of POAF and should not be used. In patients deemed at particular risk of developing POAF, it is reasonable to consider perioperative diltiazem (assuming the patient is not taking β-blockers, and cardiac function is normal) or postoperative amiodarone. However, no clinical model has been developed to identify high-risk patients after lung resection, although the $CHADS_2$ score shows promise [253]. Furthermore, there is little evidence that POAF prophylaxis improves outcomes after thoracic surgery.

Summary and recommendations

Patients taking β-blockers preoperatively should continue to take them in the postoperative period to prevent POAF secondary to acute withdrawal. Magnesium supplementation may be considered in magnesium deplete patients. The administration of diltiazem preoperatively or amiodarone postoperatively is reasonable in patients deemed at high risk, although there is little evidence that POAF prophylaxis improves outcomes.

Evidence level:
Avoid β-blocker withdrawal: High.
Replace magnesium: Low.
Diltiazem or amiodarone prophylaxis in high-risk patients: Moderate.

Recommendation grade:
Avoid β-blocker withdrawal: Strong.
Replace magnesium: Weak.
Diltiazem or amiodarone prophylaxis in high-risk patients: Weak.

SURGICAL TECHNIQUE: THORACOTOMY

Post-thoracotomy pain is one of the most common complaints of the thoracic surgical patient, adding significant morbidity, reducing patient satisfaction and increasing healthcare costs. It arises as a result of chest wall trauma, fractured ribs, damaged peripheral nerves, intercostal nerve and muscle damage and central nervous system hyperexcitability. Intercostal nerve injury appears to be the most important factor in its pathogenesis [254]. Although minimally invasive techniques such as VATS and robotic surgery are increasingly popular, the vast majority of pulmonary resections worldwide are still performed via a thoracotomy. The technique of thoracotomy has evolved with time to minimize postoperative pain.

Incision type

The type of incision made for the thoracotomy procedure depends on the type of operation being performed and the access needed as well as surgeon preference and training. The standard different access locations for thoracotomy include the traditional posterolateral approach or an anterior approach (axillary or anterolateral thoracotomy). A muscle-sparing incision (a thoracotomy that does not involve significant division of the latissimus dorsi or serratus anterior muscle fibres) is more often achieved via an anterior approach. Indeed, the anterior approaches were previously considered to be less painful, but, in a systematic review, a muscle-sparing thoracotomy did not result in less pain or preserved pulmonary function [255]. Although muscle strength and range of motion were better preserved by a muscle-sparing approach, this difference had disappeared by 1 month. A more recent meta-analysis, however, has shown that a muscle-sparing approach results in less postoperative pain up to 1 month following a thoracotomy but pulmonary function and perioperative complications are unchanged [256].

Intercostal nerve-sparing techniques

The creation of an intercostal muscle (ICM) flap, in which the muscle is separated from both ribs and then cut distally just under the serratus anterior muscle, reduces postoperative pain compared to traditional thoracotomy techniques [257, 258]. By keeping the ICM out of the surgical retractor, the intercostal bundle is protected from crush injury. An additional benefit is that the ICM can be used for bronchial or oesophageal buttressing when indicated. A non-divided ICM flap, in which the muscle is separated from both ribs and then left to dangle into the incision, is successful in further reducing pain [259].

Rib reapproximation

When closing thoracotomy incisions, techniques that spare compression of the inferior intercostal nerve during rib reapproximation are associated with less postoperative pain than conventional pericostal sutures. The intracostal suture technique involves drilling small holes through the inferior rib for passage of the rib-approximating suture [260]. The no-compression pericostal suture technique involves passage of the rib-approximating suture along the inferior bony surface of the inferior rib, avoiding compression of the associated ICM and bundle [261].

Summary and recommendations

Muscle-sparing thoracotomy incisions may reduce postoperative pain and preserve muscle function and should be performed where possible. ICM- and nerve-sparing techniques are recommended as they reduce post-thoracotomy pain. Avoiding compression of the inferior intercostal nerve when the ribs are reapproximated may further reduce pain.

Evidence level:
Muscle-sparing thoracotomy: Moderate.
ICM flap: Moderate.
Rib reapproximation avoiding nerve compression: Moderate.

Recommendation grade:
Muscle-sparing thoracotomy: Strong.
ICM flap: Strong.
Rib reapproximation avoiding nerve compression: Strong.

SURGICAL TECHNIQUE: MINIMALLY INVASIVE SURGERY

Since the introduction of VATS lobectomy almost 3 decades ago, the technique has undergone significant improvements. When compared to thoracotomy, VATS is associated with less pain, better shoulder function, earlier mobilization, shorter LOS, better preservation of pulmonary function and better quality of life [262]. An early, small randomized study demonstrated fewer complications in the VATS group but no difference in pain [263]. More recently, a larger randomized controlled trial of 206 patients undergoing lobectomy compared an anterolateral thoracotomy to a VATS approach. VATS patients had significantly less pain postoperatively and up to 52 weeks after surgery, improved quality of life and a shorter LOS, but no reduction in complications [264]. A large propensity-matched study from the European Society of Thoracic Surgeons database consisting of 28 771 patients showed a significant reduction in total postoperative complications, major cardiopulmonary complications, atelectasis requiring bronchoscopy, initial ventilation >48 h and wound infection in favour of VATS [251]. This study confirmed the findings of a previous large propensity-matched comparison from the Society of Thoracic Surgeons database [249] and a recent meta-analysis of propensity-matched patients [265]. The clinical benefits of a minimally invasive approach are particularly evident in high-risk patients with poor predicted postoperative lung function [266]. These findings form the basis for the recommendation in the most recent lung cancer guidelines of the American College of Chest Physicians that a VATS approach is preferred in the management of patients with stage I non-small-cell lung cancer [267].

No randomized trials have so far been conducted to determine whether a VATS approach impacts on long-term survival. A systematic review and meta-analysis could not demonstrate any significant difference in loco-regional recurrence, but the data suggested a reduced systemic recurrence rate and an improved 5-year mortality rate for VATS [262]. Another randomized study has shown that VATS lobectomy was associated with reduced perioperative changes in acute phase responses. The authors suggest that this finding may have implications for perioperative tumour immune surveillance in lung cancer patients [268]. Compliance with adjuvant chemotherapy seems to be facilitated by VATS surgery and thereby may also affect survival outcome [269].

In recent years, a uniportal approach has been popularized with potential benefits purported to include less pain and discomfort, but so far there has been no robust data to justify this approach over a conventional multiport approach. A recent randomized trial failed to demonstrate any difference between uniportal and multiport VATS lobectomy [270]. Postoperative pain, LOS and complications rates were equivalent. Robotic-assisted lobectomy may have advantages including 7 degrees of movement, 3-dimensional views, tremor filtration, motion scaling and improved ergonomics. Whether this will translate into improvements in clinical outcomes remains to be seen. Studies have demonstrated the feasibility and safety of the robotic approach, and morbidity rates appear equivalent to VATS [271, 272].

Summary and recommendations

A VATS approach for pulmonary resections is recommended for early-stage lung cancer. The benefits are even more marked in patients with poor respiratory reserve. The number of ports used does not appear to affect outcomes, and so, one VATS approach cannot be recommended over another. Data to support the routine use of robotic surgery are lacking.

Evidence level:
VATS lung resection for early-stage lung cancer: High.

Recommendation grade:
VATS lung resection for early-stage lung cancer: Strong.

CHEST DRAIN MANAGEMENT

Management of chest tubes remains a critical aspect in the postoperative course of patients following lung resection, influencing the recovery phase and hospital stay. Although a drain is necessary for the majority of cases, they can cause pain, reduced pulmonary function and immobility, irrespective of the surgical approach [273].

Suction versus no suction

A number of randomized clinical trials have been published comparing external suction via the chest tube versus no suction in the postoperative period. Theoretically, suction promotes pleura-pleural apposition favouring the sealing of air leak and the drainage of large air leaks. However, suction has also been shown to increase the flow through the chest tube proportional to the level of suction applied [274] and to reduce patient mobilization (if wall suction is used). No suction, on the other hand, has been shown to be effective in some circumstances at reducing the duration of air leak, presumably by decreasing the airflow [275, 276]. However, the absence of suction may be ineffective in draining large air leaks and has been associated with increased risk of other complications (particularly pneumonia and arrhythmia) [277].

The question of whether external suction or its absence has a beneficial effect on clinical outcomes has been the subject of several systematic reviews and clinical guidelines [278–281]. Although the evidence is conflicting, there does not appear to be an advantage to the routine application of external suction in terms of shortening the duration of air leak, chest drainage or LOS.

Digital drainage systems

Digital drainage systems have several advantages over a traditional water seal. They are light, compact and have a built-in suction pump, so do not need to be attached to wall suction, should suction be required, favouring early patient mobilization. They are also able to objectively quantify the volume of air leak. The ability to store information and display trends in air leak over time allows more informed decision-making about chest tube removal and reduces interobserver and clinical practice variability [282].

The objective quantification of air leak is probably the most important factor explaining the clinical benefits found in initial randomized clinical trials comparing digital versus traditional devices. Both chest tube duration and length of hospital stay were found to be shorter after lung resection [283, 284].

Modern digital chest drain devices are able to apply regulated suction to maintain the preset intrapleural pressure. A recent multicentre randomized trial [285] showed that their use reduced the duration of chest tube duration by 1.1 days and the length of hospital stay by 1 day after lobectomy. Higher levels of patient satisfaction paralleled the objective clinical benefits. Subsequent randomized studies have not found differences in chest tube duration or hospital stay with digital devices [286, 287], but conservative drain removal protocols may have influenced outcomes in 1 study [286].

Pleural fluid drainage

The amount of pleural fluid output observed daily influences the timing of chest tube removal. Traditionally, most surgeons have accepted a cut-off of approximately 200 ml/day as a threshold, below which it is safe to remove a chest tube. However, this value is based more on dogma than on scientific data or physiology.

Pleural fluid turnover is regulated by Starling forces and by the lymphatic drainage system located at the parietal level. The hourly turnover of the pleural fluid is approximately 0.2 ml/kg leading, in physiological conditions, to its complete renewal in approximately 1 h [288]. Lymphatics act as an efficient negative feedback system to regulate pleural fluid dynamics as they can markedly increase flow (20–30-fold) in response to increased filtration, as occurs after thoracic surgery due to postoperative inflammation.

Studies on more aggressive chest drain removal strategies within fast track programmes have been shown to be safe. A non-chylous fluid threshold of 450 ml/day after thoracotomy was associated with only a 0.55% readmission rate for recurrent symptomatic pleural effusion [289]. A higher threshold of 500 ml/day following VATS lobectomy resulted in an incidence of clinically relevant recurrent effusions (needing drainage or aspiration) in only 2.8% of patients [290].

Number of chest tubes

Traditionally, thoracic surgeons have used 2 chest tubes to drain the pleural space after lobectomy. Several randomized trials have demonstrated that the use of a single chest tube after lobectomy is safe and effective with no differences in residual pleural effusion or the need to reinsert a chest tube but is significantly less painful than 2 drains [291–293]. Furthermore, a single drain is associated with a reduced duration of chest drainage and a smaller volume of fluid drained [293]. The practice of using a single chest tube is supported by findings showing that the static and dynamic pain scores decrease by approximately 40% and the lung function increases by 13% after chest tube removal [273], whether surgery is performed via VATS or thoracotomy.

Summary and recommendations

Chest tubes are painful and inhibit respiratory function. Less conservative chest tube management strategies may improve patient outcomes. The routine application of external suction offers no advantages and should be avoided. The use of digital drainage systems is recommended as they remove variability in clinical decision-making and facilitate early mobilization. They may also reduce chest tube duration and hospital stay. Chest tubes can be removed safely even if the daily serous effusion is of high volume (up to 450 ml/24 h). The use of a single chest tube is associated with less pain and reduced chest tube duration without increasing the risk of recurrent effusion. Therefore, a single tube should be used instead of 2 after a routine anatomical lung resection.

Evidence level:
Avoidance of external suction: Low (conflicting data).
Digital drainage systems: Low (conflicting data).
High pleural fluid output accepted for chest tube removal (up to 450 ml/24 h): Moderate.
Single chest tube: Moderate.

Recommendation grade:
Avoidance of external suction: Strong.
Digital drainage systems: Strong.
High pleural fluid output accepted for chest tube removal (up to 450 ml/24 h): Strong.
Single chest tube: Strong.

URINARY DRAINAGE

Bladder drainage is often used during and after thoracic surgery to monitor urine output. However, the clinical value of monitoring intraoperative urine output is questionable. In patients with normal preoperative renal function, intraoperative urine output does not predict subsequent renal function or AKI [294], and targeting oliguria with fluid boluses does not appear to affect postoperative renal function [236, 238]. Similar results have been found after VATS lung resection [237], suggesting that the practice of administering fluid boluses to enhance urine output is unnecessary. Therefore, with the exception of patients with pre-existing renal impairment and those in whom fluid balance is crucial (e.g. some patients undergoing pneumonectomy and prolonged complicated surgery), the practice of placing a transurethral catheter for the sole purpose of monitoring perioperative urine output cannot be recommended.

Postoperative urinary retention (POUR) occurs commonly after surgery, but the lack of a consensus definition makes comparisons between studies difficult. POUR is associated with delayed discharge from hospital, an increased risk of urinary tract infection (UTI) and possible long-term bladder dysfunction. The cause is usually multifactorial and may include increasing age, male sex (as a result of anatomy and an increasing incidence of benign prostatic hypertrophy with age), diabetes mellitus, pain and TEA. Although the true incidence following thoracic surgery is not well documented, 1 study of 'minor' thoracic surgery, in which patients underwent a number of procedures without TEA, showed that 11.6% of patients developed POUR [295]. Currently, however, no validated system exists to identify or prophylactically manage high-risk patients.

Paravertebral blockade, in contrast to TEA, is associated with relatively few urinary side effects [192, 296]. As the incidence of POUR in patients with TEA is 26% [297], a transurethral catheter is commonly placed, normally for the duration of epidural analgesia. Prolonged urinary drainage impedes early mobilization and is associated with increasing risk of UTI [298], and so there has been interest in early removal of transurethral catheters. A systematic review of 4 studies of patients undergoing thoracotomy with TEA showed that early removal of a transurethral catheter was possible within the first 24–48 h after surgery [299]. The incidence of POUR following the removal of a transurethral catheter was acceptably low (5.9%), and the incidence of UTIs was reduced. In a recent large RCT, however, POUR occurred in 12.4% of patients who had their transurethral catheter removed within 48 h of thoracic surgery, compared to only 3.2% of patients whose catheter remained until discontinuation of TEA, without any reduction in the incidence of UTIs [300]. Another large prospective study confirmed high rates of POUR following early transurethral catheter removal (26.7% vs 12.4%) [301].

Summary and recommendations

In patients with normal preoperative renal function, monitoring of perioperative urine output does not affect renal outcomes, and a transurethral catheter is unnecessary for the sole purpose of monitoring urine output. POUR is common, but no validated system exists to identify or prophylactically manage high-risk patients. POUR is associated with TEA, and it is reasonable to insert a transurethral catheter in these patients. A recommendation on the timing of removal cannot be made.

Evidence level:

A transurethral catheter is not required if its sole purpose is monitoring perioperative urine output: Moderate.
Routine urinary drainage with TEA: Low.

Recommendation grade:

A transurethral catheter is not required if its sole purpose is monitoring perioperative urine output: Strong.
Routine urinary drainage with TEA: Strong.

EARLY MOBILIZATION AND ADJUNCTS TO PHYSIOTHERAPY

Early mobilization is an intuitive component of ERAS meant to counteract several complications related to immobilization and decrease the length of hospital stay. In contrast, bed rest is associated with several deleterious consequences, including physical deconditioning, diminished muscle mass, increased pulmonary complications (atelectasis and pneumonia) and increased risk of VTE [302, 303]. Nevertheless, 2 recent systematic reviews could not demonstrate benefits of early mobilization protocols on postoperative outcomes following thoracic surgery due to the poor quality of studies and conflicting results [89, 304]. Conflicting results on quality of life have also been reported [89, 305].

Postoperative immobility is reported as a significant risk factor for ERAS deviation and prolonged LOS following colorectal surgery [306] and is associated with increased morbidity and LOS following lung cancer resection [19]. Chest tubes, urinary catheters, continued intravenous intake of fluids and inadequate pain control are important barriers to early ambulation, underlining the importance of optimal management of these parameters. Therefore, patients should be mobilized to avoid the deleterious effects of bed rest.

Prophylactic minitracheostomy

Repeated suction via a minitracheostomy (MT) can facilitate sputum clearance. Several historical studies have shown some clinical benefits in prophylactic MT use in patients at high risk of sputum retention [307, 308]. Concerns have been raised regarding complications secondary to insertion of MTs [309], and the benefits of prophylactic MT use in high-risk patients has yet to be validated in the era of minimally invasive surgery.

Incentive spirometry

Incentive spirometry (IS) is often used as an adjunct to standard postoperative physiotherapy. However, studies have failed to demonstrate any benefits of perioperative IS in terms of recovery of lung function or reduced risk of postoperative pulmonary complications [310–313]. There may be a role for IS in high-risk patients, but further studies are required.

Non-invasive positive pressure ventilation

Non-invasive positive pressure ventilation has been widely used to prevent atelectasis following lung surgery, but studies to date have failed to demonstrate any significant clinical benefits [314].

Summary and recommendations

Patients should be mobilized within 24 h of surgery. Prophylactic MT use may be considered in certain high-risk patients. Although IS is often used as a low-risk adjunct to physiotherapy, its benefits are unclear. The routine use of postoperative non-invasive positive pressure ventilation cannot be recommended.

Evidence level:

Early mobilization: Low.
Prophylactic MT in high-risk patients: Low.

Recommendation grade:

Early mobilization: Strong (no harm).
Prophylactic MT in high-risk patients: Weak.

DISCUSSION

These guidelines outline recommendations for the perioperative management of patients undergoing thoracic surgery, based on the best available evidence. In some instances, good-quality data were not available. Consequently, some recommendations are generic or based on data extrapolated from other specialties (alcohol abuse management, preoperative anaemia management, carbohydrate treatment, VTE prophylaxis and early enteral feeding). In other cases, no recommendation can currently be made because either equipoise exists or there is a paucity of evidence (volatile versus intravenous anaesthesia, non-intubated anaesthesia, type of VATS approach, robotic surgery and timing of removal of urinary catheters). Recommendations are based not only on the quality of the evidence but also on the balance between desirable and undesirable effects. As such, strong recommendations may be reached from low-quality or conflicting data and vice versa.

The benefits of ERAS pathways are demonstrable in specialties such as colorectal surgery [11, 12], and there is emerging evidence of their efficacy in thoracic surgery [19, 26–28, 30]. It is hoped that these guidelines will help integrate existing knowledge into practice, align perioperative care and encourage future investigations to address existing knowledge gaps. As the recommendation grade for most of the included ERAS elements is strong, the use of a systematic ERAS pathway has the potential to improve outcomes after thoracic surgery.

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