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Review

Advancements in Respiratory Surgery Anesthesia: A Collaborative Approach to Perioperative Management and Recovery

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Abstract: Thoracic surgery is a highly complex field requiring collaboration between surgeons, anesthesiologists, pulmonologists, and other specialists. Successful outcomes depend on thorough preoperative evaluations that consider the patient's overall health, lifestyle habits, and surgical risks. Key elements include proper intraoperative anesthesia management, postoperative pain control, and the integration of enhanced recovery after surgery (ERAS) protocols to optimize recovery. Double-lumen tubes (DLTs) are essential for one-lung ventilation during thoracic procedures, although they can be invasive. Recent advancements, such as video-assisted laryngoscopes, have improved the success of DLTs and reduced the invasiveness of DLT intubation and extubation. Postoperative pain management is crucial for minimizing complications and enhancing recovery. Techniques like epidural analgesia, nerve blocks, and patient-controlled analgesia improve patient outcomes by allowing early mobility and deep breathing. Dexmedetomidine (DEX), a sedative with minimal respiratory impact, has shown promise in reducing delirium and aiding recovery. This review highlights the importance of teamwork, pain management, and emerging technologies in improving thoracic surgery outcomes. Advances in these areas, particularly within ERAS protocols, continue to enhance patient care and overall surgical success.

Keywords: thoracic surgery; enhanced recovery after surgery (ERAS); double-lumen tubes (DLT); postoperative pain management; dexmedetomidine (DEX)

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1. Advances in Perioperative Management for Respiratory Surgery

Respiratory surgery is highly complex and requires a collaborative approach involving the surgeon, anesthesiologist, pulmonologist, and other specialists. Together, they must determine the best treatment based on the patient's condition, underlying health issues, and risk assessment [1,2]. A thorough preoperative evaluation should include a full physical examination and an assessment of factors like exercise capacity, comorbidities, and lifestyle habits such as smoking and alcohol consumption [3]. Additionally, the type and extent of the surgery must be considered to balance the patient's perioperative risks with long-term pulmonary outcomes. Key components to ensuring optimal patient care include preoperative evaluation, intraoperative anesthesia management, postoperative pain control, and the integration of enhanced recovery after surgery (ERAS) protocols for lung resections. Thoracic surgery, which falls under the broader category of chest surgery, often involves procedures near critical blood vessels such as the superior and inferior vena cava, pulmonary artery, and aorta, necessitating careful perioperative management [4,5]. For example, effective pain management is crucial for improving postoperative comfort, reducing complications, and enhancing overall quality of life [6]. Early and effective pain control using various techniques may help prevent chronic pain syndromes, which can negatively impact a patient's daily activities [7].

Furthermore, the COVID-19 pandemic provides severe bronchopulmonary complications and the emergence of non-classical causative agents, such as viral pneumonia(s). Additionally, the standard methods, as outlined in previously recognized protocols, were found to be of low efficacy in various situations [8]. Furthermore, the spread of pathogens classified as nosocomial infections led to widespread contamination, including the infiltration of surgical equipment. As lung surgery is most affected by such infection, it may be best timing to re-evaluate the novel techniques and methods for respiratory surgery.

In this narrative review, we explore new developments in perioperative management, including (1) double-lumen tube (DLT) intubation and extubation techniques, (2) the essential role of postoperative pain management toward ERAS, (3) strategies for preventing delirium, to support ERAS, and (4) the importance of building a strong perioperative team for respiratory surgery.

2. Minimizing Double-Lumen Tube Intubation and Extubation Invasiveness: Advances in Technique and Airway Management

In most cases, thoracic surgeries, especially video-assisted thoracoscopic surgery, require a well-collapsed lung to facilitate the exposure of the surgical field. This goal can be achieved via one-lung ventilation (OLV), a technique that allows ventilation in one lung while leaving the other deflated. It is the most commonly used device for providing independent ventilation to each lung. This technique, known as OLV, allows the mechanical separation of the lungs so that only one lung is ventilated while the other passively deflates or is moved by the surgeon to improve visibility during non-cardiac chest surgeries such as thoracic, esophageal, aortic, or spinal procedures [9]. By far, the most common ventilation strategies for OLV are DLT and bronchial blockers (BB) [10]. DLT is advocated for its quick placement, easy deflation and suction from the isolated lung, and flexible application of continuous positive airway pressure [11]. BB, on the other hand, provides minor damage to the trachea, probably due to its thinner diameter and lower intra-tracheal pressure, and saves the need for the replacement of the tracheal tube to maintain postoperative mechanical ventilation after surgery [12]. At present, the choice of DLT or BB often depends on the preference of the surgeon or anesthesiologist. However, an unsolved question remains as to which is the optimal airway device for performing OLV.

A systematic review and meta-analysis indicated that DLT is quicker to place and less likely to be incorrectly positioned than BB [13]. However, reports showed smaller airway injury using BB compared to DLT [14]. A recent study has shown that BB application is associated with more severe lung infiltration (especially the surgery side) and a higher incidence of ICU admission at the early postoperative stage, which may affect the patient's early recovery [15]. In contrast, there are reports that postoperative hoarseness did not change between DLT and BB [16]. While the use of BB and its effect on patients' postoperative recovery needs further investigation, DLT intubation with minimal invasiveness has the potential for better airway outcomes.

DLTs are also utilized in minimally invasive cardiac surgeries and in conditions affecting one lung, helping prevent contamination from the opposite lung. Additionally, DLTs allow for bronchial cleaning without interrupting ventilation. However, compared to single-lumen tubes, DLTs are larger, longer, and more complex, which can make their use more invasive, especially in patients under mechanical ventilation [17]. Proper visualization of the glottis is essential during intubation to minimize trauma to the upper airway and reduce intubation time.

DLTs are currently the gold standard for managing airways during surgeries requiring one-lung ventilation. However, successfully positioning these tubes can be challenging, even for experienced anesthesiologists [18]. The high failure rate can be attributed to various factors, including the design of the DLT, the operator's experience, and anatomical variations in patients. For example, the DLT's double-barrel design increases its external diameter and reduces its flexibility compared to a similarly sized single-lumen tube, making intubation more difficult, especially in patients with unique airway structures.

Recently, video-assisted laryngoscopes have been developed to improve the success of intubations in both normal and difficult airways [19,20]. One such device, the McGRATH® MAC (McG), features a high-resolution video camera that provides both direct and indirect views of the glottis, making it particularly useful for difficult airways. The McG's blade follows the traditional Macintosh curvature, potentially addressing challenges in DLT intubation while offering the benefits of video laryngoscopy. Anesthesiologists can manipulate the DLT using both direct and indirect visualization. In a previous study, the McG demonstrated a higher success rate for intubation and reduced intubation times compared to the conventional Macintosh laryngoscope (McL) [21]. Additionally, the Cormack grade and POGO score were significantly improved in McG trials, indicating better visualization of the larynx. Furthermore, the McG's smaller blade, compared to other video laryngoscopes, may reduce the difficulty of tube manipulation and insertion. Importantly, patients in McG trials experienced less hoarseness and pharyngeal pain than those in McL trials, suggesting that DLT intubation can be performed less invasively with the McG.

Careful and gentle extubation of the DLT is equally important for managing the airway and circulatory system, particularly after lung resection, as it reduces the risk of complications like bucking or pneumothorax [22]. However, the effects of the angle of DLT extraction on extubation have not been thoroughly studied. Effective airway and circulatory management during the anesthesia recovery phase is critical, as improper timing of extubation can lead to severe complications. Premature extubation can result in laryngospasm, airway obstruction, or respiratory suppression from residual anesthetics. On the other hand, delayed extubation can cause issues like hypertension, tachycardia, or pneumothorax due to frequent manual ventilation. Achieving smooth and non-invasive extubation has long been a key objective for anesthesiologists [22].

In our previous research, we found that extubation at a 60° angle relative to the ground (forward) required less force than at 90° relative to the ground (vertical), which aligns with findings from a randomized clinical study involving single-lumen tubes. Furthermore, blood pressure fluctuations were greater when extubation was performed at 90° compared to 60°. These results suggest that extubation at 60° is less invasive for patients [23]. Further studies on the optimal techniques for both intubation and extubation of DLTs are warranted.

3. Postoperative Pain Control in Thoracic Surgery: A Critical Component of ERAS

Postoperative pain management following thoracic surgery is essential for ensuring a smooth recovery and reducing complications [24]. Thoracic surgeries often involve large incisions, which can lead to significant pain if not properly controlled. Effective pain management allows for deep breathing, which helps prevent pulmonary complications such as atelectasis and pneumonia [25]. Various methods of pain relief are commonly used in combination to optimize patient comfort and recovery outcomes.

One of the most effective techniques is epidural analgesia, where a catheter is placed in the back to administer local anesthetics or opioids. This method facilitates chest movement, making deep breathing and coughing easier, which is critical for lung function recovery. Another common approach involves nerve blocks, such as intercostal or paravertebral blocks, which provide targeted pain relief by numbing specific nerves without affecting the entire body [26,27].

Opioids, including morphine and fentanyl, are also widely used for postoperative pain control and can be administered through various routes, such as epidural, intravenous, or oral. While opioids are powerful pain relievers, they must be used cautiously due to potential side effects like nausea, constipation, and respiratory depression. Non-steroidal anti-inflammatory drugs (NSAIDs) and acetaminophen are often combined with opioids to enhance pain relief and reduce inflammation while minimizing side effects. NSAIDs must be used with care due to the risk of gastrointestinal or kidney complications.

A common strategy for patient autonomy in pain management is patient-controlled analgesia (PCA), a system that allows patients to self-administer controlled doses of pain medication, typically opioids, by pressing a button. This method enables patients to

adjust their pain relief to their needs while preventing overdose through built-in safety mechanisms.

Inadequate pain management can lead to a range of complications, including shallow breathing, which increases the risk of respiratory failure and lung issues like pneumonia. It may also contribute to chronic pain, negatively impacting the patient's quality of life. Effective pain management strategies must be individualized, taking into account the patient's overall health, surgery type, and medical history, while balancing pain relief and potential side effects [27].

Furthermore, there are discussions on opioid use in postoperative analgesia. Minimizing opioid use during surgery can improve patient outcomes by reducing the likelihood of opioid-related complications after surgery [28]. A recent study investigated the efficacy of opioid-free anesthesia in managing pain during video-assisted thoracoscopic surgery, using an analgesia index as a monitoring tool. The findings indicated that an opioid-free anesthesia approach provided comparable intraoperative pain control, as measured by the pain threshold index, to traditional opioid-based anesthesia in this type of surgery [29].

In recent years, various Enhanced Recovery After Surgery (ERAS) programs have emerged, emphasizing the importance of effective pain management and active rehabilitation to reduce complications, shorten hospital stays, and lower healthcare costs [30,31]. Within the ERAS framework, postoperative pain management plays a crucial role in facilitating early mobilization and accelerating recovery.

The success of ERAS programs hinges on advanced pain management systems, which not only improve patient comfort but also support faster recovery. The integration of these strategies into surgical care aligns with broader goals of enhancing patient outcomes and optimizing healthcare resources [32]. As evidence supporting ERAS continues to grow, the focus on evolving postoperative pain management techniques remains central to achieving these goals, ensuring both patient well-being and the efficiency of healthcare delivery.

4. Optimizing Thoracic Surgery Outcomes: The Role of ERAS and Dexmedetomidine in Perioperative Care

ERAS is designed to reduce postoperative complications, shorten hospital stays, and improve overall organ function by implementing evidence-based recommendations for patient care [33,34]. These guidelines cover every phase, from preadmission through to postoperative care, and aim to improve outcomes. The recommendations, endorsed by the Enhanced Recovery After Surgery Society and the European Society for Thoracic Surgery, include preoperative counseling, nutritional screening, smoking cessation, avoiding prolonged fasting, using preoperative carbohydrate drinks, minimizing preoperative sedatives, providing venous thromboembolism prophylaxis, preventing hypothermia, using short-acting anesthetics and regional anesthesia, opting for minimally invasive techniques, and encouraging early postoperative mobilization [34]. Many of these principles originated from colorectal surgery ERAS guidelines but have been successfully adapted to thoracic surgery, improving patient satisfaction and outcomes in this field.

One significant challenge in thoracic surgery is managing postoperative delirium, a condition marked by disturbances in consciousness, cognition, perception, and attention, along with sleep and circadian rhythm disruptions [35,36]. Delirium during the perioperative period can lead to more complications, longer hospital stays, and increased mortality [37]. Although delirium caused by pain or other easily treatable factors can often be alleviated through environmental modifications and supportive care, identifying its cause during surgery can be complex. Various elements, such as preoperative stress, anxiety about surgery, unfamiliar surroundings, and postoperative pain, all play a role, making it difficult to pinpoint a single source [38]. Thoracic surgery patients, particularly the elderly, are at a higher risk of postoperative delirium due to surgical trauma, circulatory disruptions from conditions like atrial fibrillation, and decreased oxygenation following lung resection [39].

Postoperative delirium can severely impact the early recovery phase, manifesting in behaviors such as restlessness, removing intravenous lines or central venous catheters, refusing oxygen masks, or even falling, all of which can hinder recovery [40]. In some cases, pharmacological interventions, such as antipsychotic medications, are required to manage delirium, though overuse of these drugs can lead to side effects like extrapyramidal symptoms. Preventing delirium is, therefore, a top priority, especially in thoracic surgery, where removing oxygen masks or chest drains can cause life-threatening complications. Moreover, excessive coughing or agitation can increase airway pressure, potentially leading to pneumothorax or surgical bleeding, requiring careful management.

Dexmedetomidine (DEX), an alpha-2 adrenergic agonist, has emerged as a valuable tool in intensive care units due to its ability to provide sedation with minimal respiratory depression [41,42]. It is particularly useful in postoperative management, helping reduce the need for additional analgesics while maintaining sedation. DEX is known for its ability to provide high-quality sedation, and it has a low incidence of delirium, making it a key option for postoperative care. Studies have shown that continuous low-dose administration of DEX in intensive care settings is effective not only in preventing but also in treating delirium [43]. DEX's benefits—minimal respiratory depression, analgesic effects, fewer side effects like hypotension, and its role in delirium prevention—make it particularly suitable for elderly patients recovering from thoracic surgery. Intraoperative administration of DEX may also be beneficial in lung resection surgeries for patients with a history of postoperative delirium or agitation upon waking.

DEX also contains several positive effects in OLV. It provides sedation with minimal impact on respiratory function, making it superior to traditional sedatives like propofol or benzodiazepines, which can cause respiratory depression [44]. DEX helps maintain stable oxygenation levels during OLV, ensuring safer anesthesia. Its hemodynamic-stabilizing effects, due to its alpha-2 agonist action, reduce circulatory instability, such as hypotension or tachycardia, improving patient outcomes [45]. DEX also plays a role in optimizing pulmonary blood flow, reducing circulation to the collapsed lung while improving oxygenation in the ventilated lung, which enhances gas exchange during OLV [46]. Additionally, its anti-inflammatory properties may help lower the risk of postoperative lung injury, a common concern during OLV due to mechanical stress.

As more research emerges, further evaluation of DEX's intraoperative and postoperative use is essential to understand its full potential in enhancing recovery for thoracic surgery patients.

5. Strengthening Perioperative Crisis Management in Thoracic Surgery Through Team-Based Approaches

Training perioperative crisis management in respiratory surgery is a highly complex process that demands swift decision-making and effective coordination among medical staff [40]. In thoracic surgery, resuscitation efforts are further complicated by the division of the operative field into sterile and non-sterile areas, making teamwork essential. To enhance situational awareness and procedural effectiveness, non-technical skills like communication within the medical team are crucial [47].

Even during routine procedures, close collaboration between the surgeon and the anesthesiologist is vital for managing challenges such as one-lung ventilation, lung protection strategies, extubation decisions, and postoperative pain control. In emergencies like vascular injuries or life-threatening arrhythmias, the lateral decubitus position and lack of cardiopulmonary bypass increase the difficulty of resuscitation. Training with the actual clinical team fosters a deeper understanding of each team member's role and strengthens communication, which ultimately supports patient safety. In addition to intra-department collaboration, cross-department cooperation with radiology, transfusion, and testing departments is essential for establishing effective emergency blood transfusion and testing systems. Medical staff in the operating room must be mindful of the need for collaboration between operative and non-operative field personnel [48]. Anesthesiologists, often leading

emergency responses, should take an active role in consulting with other departments, such as radiology or laboratory services, during critical situations like massive hemorrhage. The first step in preparing for perioperative emergencies is to facilitate discussions that involve multiple medical departments and specialties. These conversations, held in non-clinical environments free from immediate pressure, help build consensus and ensure smooth emergency responses [49,50].

To ensure effective emergency response protocols in respiratory surgery, it is essential to involve not only department heads and nursing directors but also the input of actively working doctors, nurses, and clinical engineers. Interprofessional training promotes better understanding and communication among medical staff. Additionally, joint seminars with educational hospital groups provide opportunities to learn from diverse hospital practices and share valuable insights gained through collaborative training, ultimately enhancing maternal and child healthcare safety.

The effectiveness of simulation-based training in improving patient safety in the operating room is well-documented. This type of training not only develops technical skills but also critical non-technical skills like situational awareness, teamwork, decision-making, leadership, and communication in emergency settings [51]. From a crisis management perspective, establishing "perioperative team" training is essential, especially for scenarios like massive intraoperative bleeding or cardiac arrest. To optimize survival rates and patient outcomes, the entire perioperative team must develop advanced non-technical skills, including both cognitive (decision-making and situational awareness) and interpersonal (communication and teamwork) competencies. Non-technical skills training is well-established in emergency medicine and rapid response teams, but the operating room presents unique challenges.

In the operating room, patients are continuously monitored, and key medical information such as weight and medical history is readily available, which aids in crisis management. Additionally, the cause of the crisis is often clear (e.g., hypovolemia from massive bleeding or hypoxia due to ventilation failure). However, one significant difference in the operating room environment is the restriction on non-verbal communication due to the use of masks and goggles. As a result, perioperative crisis management requires tailored non-technical skill assessments that reflect the specific conditions of the operating room. Crisis management roles are often divided between personnel in the operative field (e.g., surgeons, scrub nurses) and those in the non-operative field (e.g., anesthesiologists, circulating nurses, and medical engineers). These teams maintain their distinct roles during emergencies, coordinating within their designated spaces. For instance, surgeons and scrub nurses focus on controlling hemorrhage, while the non-operative team manages resuscitation and maintaining vital signs. Collaboration between these teams is critical for effective resuscitation in the operating room, and assessment methods should account for the distinct roles and interactions between operative and non-operative field personnel.

Incorporating evaluations of situational awareness and communication between these two fields will enhance the effectiveness of perioperative team management and resuscitation simulations. For example, assessments might include criteria like "shared situational awareness between operative and non-operative fields" and "effective verbal communication between teams." Continuous assessment of these factors will further improve the outcomes of simulation-based training for managing intraoperative crises [52]. To enhance non-technical skills, simulation-based discussions following a problem-based learning discussion (PBLD) format may be effective [53]. Each specialty brought different perspectives and interpretations of the same events and vital signs, leading to valuable new insights. Scenarios included managing massive hemorrhage due to pulmonary artery injury, intraoperative hypoxemia related to one-lung ventilation issues, and post-extubation hypoxemia. Future discussions could also address topics such as postoperative delirium and troubleshooting chest drains, offering further opportunities for learning and improvement.

6. Conclusions

In conclusion, thoracic surgery requires a multidisciplinary approach involving surgeons, anesthesiologists, pulmonologists, and other specialists to ensure the best patient outcomes. Preoperative evaluation, including assessments of lifestyle factors like smoking, comorbidities, and overall health, is critical for planning surgery and mitigating risks. ERAS protocols, which focus on optimizing intraoperative management and postoperative pain control, play a key role in improving recovery and reducing complications. DLTs are essential for one-lung ventilation in thoracic surgery, allowing lung isolation for better surgical visibility. However, DLTs can be invasive, and recent advancements, such as video-assisted laryngoscopes like the McGRATH® MAC, have improved the safety and success of DLT intubation. Additionally, proper extubation techniques help minimize airway trauma.

Postoperative pain control is crucial for recovery, enabling deep breathing and early mobility to prevent complications like pneumonia. Techniques such as epidural analgesia, nerve blocks, and patient-controlled analgesia help optimize pain management. DEX is particularly effective in managing pain and preventing delirium, especially in elderly patients, due to its sedative properties without respiratory depression. Overall, advancements in perioperative management, pain control, and team-based approaches continue to improve outcomes in thoracic surgery, ensuring better recovery and quality of care.

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