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Anesthetic Strategies for Thymectomy: A Contemporary Systematic Review

Fitri Sepviyanti Sumardi
Fakultas Kedokteranu Universitas Pembangunan Jawa Timus
*Coresponden author: Fitri Sepviyanti Sumardi
Fakultas Kedokteran Universitas Pembangunan Jawa Timur (fitri.sepviyanti.fk@upnjatim.ac.id)

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ABSTRACT

Introduction: Thymectomy in patients with myasthenia gravis or mediastinal tumors requires a very careful anesthesia strategy due to neuromuscular sensitivity, risk of airway compression, and possible hemodynamic instability. This systematic literature review summarizes the latest evidence on anesthesia governance, including engineering innovations and their implications for facilities with limited resources.
Methodology: Literature searches were conducted through PubMed, Scopus, and Google Scholar using keywords related to "thymectomy", "anesthesia", "mediastinal mass", and "myasthenia gravis". The inclusion criteria include prospective studies, retrospectives, systematic reviews, meta-analyses, and case reports (2019–2025), as well as one 2013 case report. Out of 450 publications, 30 articles met the PRISMA criteria and were analyzed narratively. Results: Comprehensive preoperative evaluation was the main determinant of anesthesia success in patients with neuromuscular and mediastinal mass disorders. Anesthesia techniques without muscle relaxants or with propofol TCI/sevoflurane have been shown to provide better neuromuscular stability. Sugammadex produces a faster and safer reversal than neostigmine. In large mediastinal masses, special strategies such as awake intubation, spontaneous ventilation, double-lumen tube, or ECMO readiness reduce the risk of airway collapse. Minimally invasive techniques (VATS/robotics) show faster recovery and lower complications, especially when combined with advanced respiration monitoring. Discussion & Conclusion: The success of thymectomy anesthesia relies heavily on three pillars: thorough preoperative evaluation, risk-based individualized anesthesia techniques, and rigorous intraoperative monitoring. Innovations such as sugammadex, spontaneous ventilation, and advanced monitoring technology improve safety and speed up recovery. In resource-limited settings, strong clinical skills and teamwork enable effective outcomes with minimal technology.
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Keywords: Thymectomy, anesthesia, myasthenia gravis, mediastinal mass, sugammadex

Introduction

Thymectomy is a standard procedure, especially in patients with myasthenia gravis or other pathological conditions involving the thymus gland.[1-2] This procedure requires careful anesthesia planning due to the involvement of the respiratory and neuromuscular systems. The success of anesthesia management is greatly influenced by the choice of anesthesia technique, the medication used, and monitoring during and after surgery.[1-2] This article aims to provide a systematic literature review of anesthesia governance in thymectomy based on recent research.[1-3]

The thymus gland is a lymphoid organ that plays a role in the maturation of T lymphocytes, an important part of the immune system. As we age, the size and activity of the thymus decreases, so the approach to anesthesia differs between pediatric and adult patients. The presence of thymus tumors can lead to mediastinal compression syndrome that affects the respiratory and cardiovascular systems, increasing the complexity of anesthesia.[3-4] Therefore, an understanding of the anatomy and physiology of the thymus is essential to determine a safe and effective anesthesia strategy.[3-4]

Thymectomy is performed for a variety of pathological conditions, including myasthenia gravis, thymoma, and thymus hyperplasia.[1-2] Research journal publications have shown that thymus gland removal may provide long-term benefits for patients with myasthenia gravis, especially in reducing the need for immunosuppressive therapies that can have adverse side effects. For example, a 2013 journal publication of a case report found that patients who underwent thymectomy significantly improved muscle strength and quality of life after the procedure.[5]

Surgical techniques can be either open median sternotomy or minimally invasive approaches such as thoracoscopy and robotic.[6-7] The minimally invasive approach is increasingly being used because it is associated with faster recovery and lower complications than open techniques.[6-7] The selection of technique should take into account the size and location of the tumor as well as the patient's overall medical condition.[6-7]

The management of anesthesia in thymectomy has significant challenges. One of the critical challenges is neuromuscular dysfunction in patients with myasthenia gravis, which makes them more sensitive to anesthetic drugs, especially muscle relaxants.[8–9] In addition, large thymus tumors can cause mediastinal compression syndrome that interferes with pulmonary ventilation and perfusion, requiring special ventilation strategies.[3,5,10]Therefore, anesthesia should be tailored to the patient's risk and needs.[3,5,10] Removal of the thymus has been shown to provide long-term benefits for myasthenia gravis patients, especially in reducing the need for immunosuppressive therapies that have side effects.[11,12] A 2013 case report showed that patients who underwent thymectomy experienced improved muscle strength and quality of life.[5] The thymectomy procedure requires not only high surgical skills, but also special attention to the risk of anesthesia in myasthenia gravis patients.[2,8-9]

A thorough preoperative evaluation is essential.[10,13-14] The medical team must assess the patient's medical history, including neurological symptoms and muscle strength status. By understanding the patient's profile, the team can adjust anesthesia techniques, including avoiding muscle relaxants that can exacerbate weakness.[1,8-9,12] Effective communication between the surgical team and the anesthesia team is crucial.[2,15] This collaboration ensures that all aspects of the procedure, from preparation to recovery, are well managed. The anesthesiologist can recommend the most appropriate type of anesthesia, both general and regional, based on the patient's condition and the complexity of the procedure.[1,10,13] Close monitoring during and after procedures is important for detecting complications, such as reactions to anesthesia or changes in respiratory function.[16-17]

In recovery, thymectomy patients need special attention. The recovery process varies depending on age, health conditions, and surgical techniques.[6-7,11] Patients with a minimally invasive approach tend to recover faster than open procedures.[6-7,18] Therefore, the medical team should provide clear information about the recovery process, side effects and signs of complications to look out for.[12,17] Integrating a 2013 case report journal publication[5] with the latest literature will provide valuable insights and help develop better guidelines for the management of anesthesia in thymectomy, ultimately improving the quality of life of patients undergoing this procedure

Methodology

The methodology used in this study involved a comprehensive literature review on the anesthesia management of patients undergoing thymectomy. Data was obtained from a variety of sources, including scientific journals, case reports, and retrospective studies. This study examines anesthesia methods and preoperative assessment strategies to reduce complications in patients with thymoma and myasthenia gravis.

The analysis was conducted by collecting data from relevant articles, including the publication of a 2013 case report journal,[5] which emphasized the importance of pre-operative evaluation. Recent studies discussing the safer use of anesthetic drugs and modern anesthesia techniques are also reviewed. The data collected is analyzed to find patterns that can be used as guidelines in clinical practice.

The literature search was conducted using inclusion criteria for publications from 2019 to 2025 that discussed anesthetic management in thymectomy, accessed through databases such as PubMed, Scopus, and Google Scholar. The keywords used included "thymectomy," "anesthesia," "thymoma," "myasthenia gravis," and "perioperative management." Eligible studies included case reports, clinical trials, systematic reviews, and meta-analyses. All articles were critically evaluated based on methodology, data quality, and the relevance of their findings to the topic.

Table 1. PRISMA Stages

PRISMA Stages	Process Description	Number of Articles
Identification	Literature searches were performed across multiple sources relevant to anesthesia and thymectomy. Duplicate articles were removed to ensure data uniqueness	450 articles identified, 122 duplicates removed
Screening	Articles were screened based on titles and abstracts to assess their initial relevance to the research question. Irrelevant studies were excluded	328 articles screened, 241 excluded
Eligibility	Full-text articles that passed the screening stage were assessed to determine compliance with inclusion and exclusion criteria	87 full-text articles assessed, 53 excluded
Included in Final Review	Articles that met all criteria were included in the final systematic review or meta-analysis	30 articles included in the final review
Inclusion Criteria	• Prospective studies, retrospective studies, meta-analyses, literature reviews, case reports. • Focus on anesthesia for thymectomy, anesthetic management strategies, and intraoperative/postoperative monitoring.	22
Exclusion Criteria	• Articles not discussing anesthesia. • Articles focusing solely on surgical aspects without relevance to anesthesia or MG patient management	18

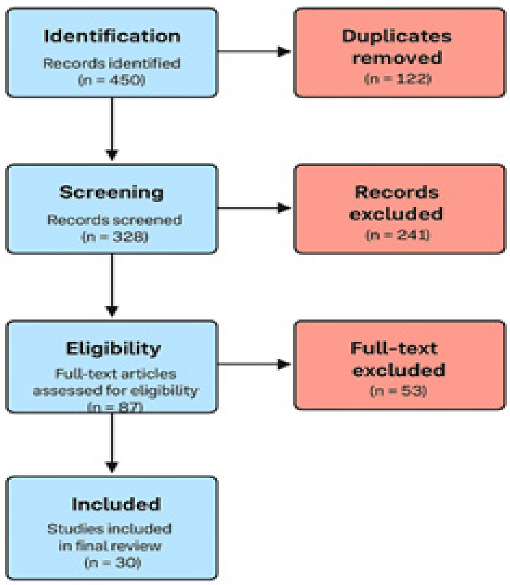

Figure 1. Diagram PRISMA

Results and Discussion

This systematic literature review highlights the important role of comprehensive preoperative evaluation in determining the success of thymectomy, especially in patients with comorbid conditions such as myasthenia gravis or thymoma.[1-3] A thorough preoperative evaluation, including a comprehensive physical examination and assessment of lung and cardiac function, is essential to identify potential perioperative risks and implement effective mitigation strategies.[4,19]

Research journal publications highlight that thorough physical examination and assessment of respiratory and cardiovascular function are crucial components in anesthesia planning, especially in patients with anterior mediastinal mass.[3,10,19] This strategy allows the medical team to anticipate possible airway or large vessel compression, as well as determine whether additional interventions such as Extracorporeal Membrane Oxygenation (ECMO) are needed as backup governance.[19-20]

For myasthenia gravis patients, preoperative evaluation primarily focuses on neuromuscular assessment and muscle strength. The literature suggests that these patients have a high sensitivity to muscle relaxants, so the choice of anesthesia technique should consider the use of agents such as sevoflurane or propofol target controlled infusion (TCI) without muscle relaxants.[1,5,8] Several research journal publications have also highlighted the benefits of using sugammadex in safely reversing neuromuscular blocks in myasthenia gravis patients, compared to neostigmine.[17,21-24] This supports faster post-anesthesia recovery and reduces the risk of myasthenia crisis.

In addition, follow-up respiratory monitoring during and after the procedure is highly recommended to detect changes in lung function and hemodynamics in real-time.[14,16] Technologies such as dynamic monitoring and machine learning-based early warning systems have been developed to improve perioperative safety in high-risk patients. In the context of surgical techniques, robotic and thoracoscopy approaches show better results in terms of recovery and complications compared to open sternotomy.[6-7,11,18] In several journal publications, comparative research showed that patients who underwent thymectomy with a minimally invasive approach experienced shorter hospitalization times and better quality of life postoperatively.[6,11]

Overall, the integration between thorough preoperative evaluation, selection of appropriate anesthesia techniques, and advanced perioperative monitoring is key to the success of thymectomy, especially in patients with myasthenia gravis or large mediastinal masses. Multidisciplinary collaboration between surgeons, anesthesiologists, and intensive care teams is essential to optimize clinical outcomes and reduce the risk of complications.[2,10,15]

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Challenges and Strategies for Airway Governance in Large Mediastinum Masses

One of the most critical and challenging aspects of anesthesia for thymectomy is airway management in patients with large anterior mediastinal masses. A large tumor can cause external compression of the trachea or primary bronchi, which risks causing complete airway collapse during anesthesia induction or muscle relaxant administration.[3-5,14]

In a 2022 prospective observational

research journal publication, it emphasized that patients with symptoms of airway compression require very careful anesthesia planning, often maintaining spontaneous ventilation for as long as possible or securing the airway before the patient is fully conscious (awake intubation).[14] Modern preoperative evaluations now also utilize ultrasound parameters to predict laryngoscopic and intubation difficulties, providing an additional layer of safety in planning.[26]

In extreme cases where airway compression is particularly significant, innovative techniques are required. A 2024 case report demonstrates the successful use of bronchial occluders placed outside the tracheal tube to address complex airway compression during tumor resection, highlighting the need for a highly individualistic strategy in this high-risk scenario.[13]

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Anesthesia Management for Thymectomy with Specific Conditions

Discussions about thymectomy and the management of anesthesia in patients with thymoma and myasthenia gravis involve many important factors. A 2021 journal publication emphasized the importance of thoroughly understanding a patient's medical history and response to prior therapy in determining the appropriate anesthesia strategy.[2] In myasthenia gravis, identifying the severity of the disease and evaluating previous therapies (e.g., acetylcholinesterase inhibitors, immunosuppressive therapies) helps anticipate the patient's response to anesthesia and reduces the risk of complications.[2,9]

The literature suggests that patients with myasthenia gravis have a high sensitivity to muscle relaxants, so an anesthetic approach without the use of relaxants, such as with sevoflurane or propofol TCI, may be a safer option.[1,8] The use of sugammadex as a neuromuscular block reversal agent has been shown to be more effective and safe than neostigmine, especially in patients with neuromuscular disorders such as myasthenia gravis.[17,21-24]

Anesthetic planning for patients with large mediastinal masses, including thymomas, requires careful consideration of the potential for airway and major vascular compression. Such anatomical distortion may predispose patients to critical respiratory or hemodynamic compromise during induction and positive-pressure ventilation. Consequently, a comprehensive preoperative assessment—encompassing imaging, functional respiratory evaluation, and risk stratification—is imperative to anticipate perioperative instability. Tailored ventilation strategies, including maintenance of spontaneous breathing, gradual titration of anesthetic depth, and preparation for alternative airway management techniques, are essential to mitigate the risk of intraoperative airway obstruction and ventilation failure. These principles are consistently emphasized across contemporary literature addressing the anesthetic management of anterior mediastinal masses.[3,10,19]

Case reports and observational studies have demonstrated that the use of adjunctive devices such as bronchial blockers can provide substantial benefit in managing airway compression during mediastinal tumor resection. Several published studies highlight that positioning the bronchial blocker extraluminally, rather than within the tracheal tube, offers a practical and effective method to maintain adequate ventilation in patients experiencing significant mediastinal compression. This technique enables selective airway control while reducing the risk of further luminal narrowing caused by instrumentation. These observations align with a growing body of evidence underscoring the need for individualized ventilation strategies in patients with large anterior mediastinal masses, where the risks of dynamic airway obstruction, impaired venous return, and hemodynamic instability are markedly elevated. Such tailored approaches are essential to optimize perioperative safety in anatomically and physiologically complex cases.[10,14]

In patients without symptoms of myasthenia gravis, the anesthesia approach should still consider the potential for latent neuromuscular disorders. In a 2013 journal publication of a case report on thymoma without neurological symptoms, it was emphasized that even if the patient does not show clinical signs of myasthenia gravis, sensitivity to anesthetic agents still needs to be anticipated. This is important because latent neuromuscular disorders can trigger postoperative muscle weakness or prolong neuromuscular recovery if anesthesia strategies are not adjusted.[5]

In recent journal publications, the literature also emphasizes that patients with latent neuromuscular disorders have an unpredictable response to muscle relaxants. Therefore, safe anesthesia strategies include avoiding non-depolarizing muscle relaxants, using inhaling agents such as sevoflurane or TCI propopol, and considering the use of sugammadex as a more effective reversal agent.[8,17,21-24]

Overall, current evidence consistently demonstrates that anesthesia management for both patients with mediastinal compression and those with thymoma without symptomatic myasthenia gravis must be tailored to individual risk profiles. Individualized anesthetic strategies—guided by comprehensive preoperative assessment, imaging findings, and functional evaluation—have been shown to enhance intraoperative safety and facilitate smoother postoperative recovery.[5,8,10,13–14,17]

Moreover, optimal anesthetic care in thymectomy requires a patient-specific approach that integrates clinical status, prior treatments, and tumor characteristics into perioperative planning. Effective management is best achieved through close multidisciplinary collaboration among anesthesiologists, surgeons, and intensive care teams, ensuring coordinated decision-making and improving overall procedural outcomes.[2,10,15]

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Pre-Operation Evaluation and Risk Governance

Preoperative evaluation is a crucial stage in determining the success of anesthesia and surgery, especially in patients with neuromuscular conditions or paraneoplastic syndrome.[2,9] A comprehensive preoperative examination includes an in-depth anamnesis, a thorough physical examination, and an evaluation of lung and cardiac function to identify potential perioperative risks.[10,14]

In a 2013 publication of a case report, it emphasized that early detection of neuromuscular disorders is helpful in determining safer and more effective anesthesia strategies.[5] Early identification of conditions such as myasthenia gravis, Eaton-Lambert syndrome, or peripheral neuropathy is essential to avoid anesthesia complications that can prolong the patient's recovery.[2,9,12]

Patients with neuromuscular disorders often have a higher sensitivity to muscle relaxants and general anesthesia, so the approach to anesthesia should be more individualized. The literature suggests that the use of sevoflurane may provide additional muscle relaxant effects that are at risk of worsening weakness in patients with myasthenia gravis. Therefore, safe anesthesia strategies include avoiding non-depolarizing muscle relaxants, using short-acting agents when needed, and considering sugammadex as a more effective reversal agent than neostigmine.[17,21-24]

In addition to the neuromuscular aspect, patients with large mediastinal masses such as thymoma also require an evaluation of the risk of compression of the airway and large blood vessels.[3,4,10,19] Several recent research journal publications have shown that specific ventilation strategies, including the use of double-lumen tubes (DLTs) or bronchial occluders, may help maintain adequate ventilation in patients with mediastinal compression.[13-14]

A thorough preoperative evaluation should also consider risk factors for postoperative myasthenia crisis, which can increase morbidity and prolong the length of hospitalization. Therefore, optimizing the patient's condition before surgery, including the arrangement of immunosuppressive or corticosteroid therapy, becomes an integral part of risk management.[2,9]

Preoperative evaluation and risk management in thymectomy demands a multidisciplinary approach involving anesthesiologists, surgeons, and intensive care teams. With early detection of neuromuscular disorders, adjustment of anesthesia strategies, and strict monitoring of respiratory and hemodynamic risks, patient safety can be significantly improved.[2,5,8-10,12-14]

Neuromuscular Blockade Optimization: The Crucial Role of Sugammadex

.The management of muscle relaxants (neuromuscular blockade/NMB) in myasthenia gravis patients undergoing thymectomy requires a very precise balance. Patients with myasthenia gravis have an altered sensitivity to NMB agents, thereby increasing the risk of residual muscle weakness and postoperative respiratory complications.[12,23]This condition demands a careful anesthesia strategy, with strict neuromuscular monitoring and the selection of appropriate reversal agents.

The greatest pharmacological innovation in this field is the use of sugammadex, a selective binding reversal drug for rocuronium and vecuronium. Recent narrative and systematic reviews consistently show that sugammadex offers much faster and predictable reversal of neuromuscular blockades compared to traditional agents such as neostigmine, even in patients with neuromuscular disease.[21,23-24]

In a 2025 meta-analysis research journal publication, it concluded that sugammadex significantly reduced recovery time in the post-anesthesia recovery room (PACU) as well as decreased the incidence of residual muscle weakness.[22] Furthermore, a 2024 publication of a research journal showed that the use of sugammadex was shown to improve the overall quality of recovery after general anesthesia and reduce patient morbidity.[17]

The availability of these reversal drugs also allows anesthesiologists to maintain a deep enough neuromuscular blockade during surgery that is often required in thoracoscopic or robotic procedures, with the belief that a quick and complete recovery can be achieved at the end of the procedure. [11,25] This provides greater flexibility in anesthesia management, while improving the safety of patients with neuromuscular disorders.

Recent evidence confirms that sugammadex is an important breakthrough in the optimization of neuromuscular blockade, especially in myasthenia gravis patients undergoing thymectomy. With its fast, safe, and predictable reversal capabilities, sugammadex not only reduces respiratory complications, but also improves the quality of recovery and long-term clinical outcomes.[17,21-25]

Advancements and Innovations in Anesthesia Techniques

Technological and pharmacological innovations in anesthesia have significantly improved perioperative safety, particularly in complex thoracic procedures such as thymectomy.[1,2,8] Key developments include the introduction of more selective anesthetic agents, individualized ventilation strategies, minimally invasive airway approaches, and sophisticated real-time physiological monitoring systems that collectively enhance clinical outcomes.[1,8,16] One major advancement is the increased utilization of central nervous system–friendly agents such as propofol and remifentanil. These drugs offer rapid-onset sedation and analgesia with predictable pharmacokinetics, allowing precise titration of anesthetic depth and improved hemodynamic stability. Their short duration of action facilitates smoother emergence and reduces postoperative recovery time, making them highly advantageous in minimally invasive thymectomy.[1,8,28]

As a short-acting opioid, remifentanil also ensures effective intraoperative analgesia without prolonging postoperative respiratory support. The combined use of propofol–remifentanil has become standard in many centers due to its stability profile and reduced need for prolonged mechanical ventilation.[8,28] Another notable advancement is the adoption of sugammadex for neuromuscular block reversal. Acting selectively on rocuronium and vecuronium, sugammadex offers faster, more predictable reversal than neostigmine, particularly in patients with neuromuscular disorders such as myasthenia gravis.[21–24] A 2025 meta-analysis further confirmed that sugammadex significantly accelerates recovery from anesthesia and lowers the incidence of postoperative respiratory complications.[22]

In parallel, perioperative monitoring technologies have also evolved. Advanced respiratory monitoring systems and machine-learning–based early warning platforms are increasingly implemented to detect

Table 2. Summary of Innovations in Anesthesia Techniques

Innovation Category	Key Strategies / Technologies	References
Modern Anesthetic Agents	Propofol TCI and sevoflurane without muscle relaxants; remifentanil for rapid analgesia	[1,8,28]
Neuromuscular Management	Avoid non-depolarizing muscle relaxants; use sugammadex for neuromuscular block reversal	[17,21–24]
Ventilation Techniques	Spontaneous ventilation using SLT/DLT; non-intubated VATS with DEX infusion	[16,30]
Advanced Monitoring	Advanced respiratory monitoring; machine-learning–based early warning systems	[16,29]
Minimally Invasive Surgical Approaches	Robot-assisted thymectomy; VATS; subxiphoid single-port techniques	[6,7,11,18]
Postoperative Recovery Optimization	Sugammadex-enhanced rapid recovery; shorter recovery with minimally invasive techniques	[17,22]

Table 3. Comparison of Intubated vs Non-Intubated VATS Techniques in Thymectomy

Aspect	Intubated VATS	Non-Intubated VATS
Indications	• Patients with suboptimal pulmonary function • Complex procedures requiring full airway control	• Patients with good pulmonary function • Mild or asymptomatic myasthenia gravis • To minimize airway trauma
Advantages	• Deep and stable anesthesia • Maximum airway control • Optimal surgical conditions	• Spontaneous ventilation • Faster recovery • Minimal airway trauma[2,30]
Risks	• Residual postoperative muscle weakness • Longer recovery time in PACU	• Risk of conversion to intubation • Airway management challenges • Limited to selected patients
Clinical Outcomes	• Slower recovery due to full neuromuscular blockade • Highly effective for complex surgical procedures	• Faster recovery • Lower pulmonary complications when combined with DEX and spontaneous ventilation
References	Furák et al. (2023)	Daum et al. (2021), Luo et al. (2025)

hemodynamic or ventilatory instability in real time during high-risk procedures such as thymectomy. These systems support earlier clinical intervention and enhance intraoperative decision-making accuracy.[16,29]

Minimally invasive airway and ventilation techniques have also transformed anesthetic practice. The non-intubated VATS (NI-VATS) approach has emerged as a promising alternative for selected thymectomy cases. By avoiding endotracheal intubation, NI-VATS reduces airway trauma, preserves spontaneous ventilation, and accelerates postoperative recovery.[28] Several publications report that NI-VATS lowers the risk of respiratory complications and improves patient comfort—benefits that are especially relevant for individuals with myasthenia gravis, who are vulnerable to prolonged neuromuscular blockade and postoperative weakness.[2,9]

Further supporting this approach, a 2023 study demonstrated that spontaneous ventilation with a double-lumen tube (DLT) can be safely applied during thoracoscopic thymectomy, maintaining more physiological respiratory mechanics and minimizing the need for muscle relaxants.[28] NI-VATS is often complemented by dexmedetomidine (DEX) infusions, which provide cooperative sedation, analgesia, and hemodynamic stability while preserving spontaneous breathing. Studies

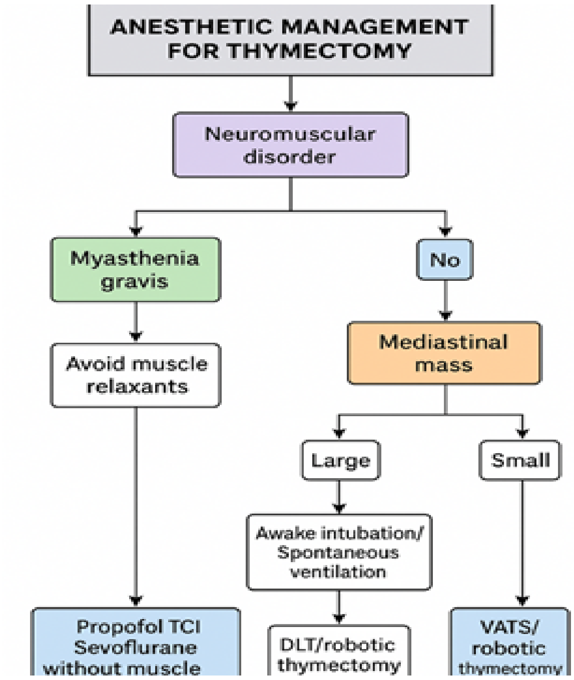

Figure 2. Anesthesia Management Flow in Patients with Neuromuscular Disorder

indicate that the combination of DEX with NI-VATS enhances patient comfort and reduces the workload of additional anesthetic interventions.[14,28,30] Collectively, the integration of selective anesthetic agents, neuromuscular management innovations, advanced monitoring systems, and non-intubated thoracoscopic techniques is reshaping modern anesthesia practice. These advancements not only improve safety and comfort for patients undergoing thymectomy but also broaden the spectrum of perioperative strategies that can be tailored to individual clinical profiles. The ongoing evolution of minimally invasive and patient-centered anesthesia approaches represents a pivotal foundation for future perioperative governance.[1,8,21–30]

Advancements and Innovations in Intraoperative Monitoring

Intraoperative monitoring technologies have evolved rapidly over the past decade, particularly in neuromuscular transmission assessment and non-invasive physiological monitoring. These advancements enable real-time adjustment of anesthetic dosing and continuous evaluation of neuromuscular function during thymectomy, thereby reducing the risk of postoperative muscle weakness, respiratory depression, and delayed neuromuscular recovery.[8,16,17]

A key innovation is the widespread adoption of quantitative neuromuscular monitoring, including Train-of-Four (TOF) and electromyography (EMG)-based systems. These modalities provide precise measurements of neuromuscular blockade and guide appropriate titration of anesthetic agents and reversal drugs. This is especially crucial in patients with myasthenia gravis, where sensitivity to anesthetic and neuromuscular-blocking agents varies significantly and cannot be reliably predicted based solely on clinical assessment.[2,9]

Recent evidence highlights the clinical importance of rigorous monitoring. A 2024 study demonstrated that sevoflurane may potentiate the effects of neuromuscular blockers, increasing the risk of residual paralysis if monitoring is inadequate.[8] Similarly, advanced respiratory monitoring has been shown to detect early changes in lung mechanics and hemodynamics during major thoracic procedures, offering a critical safety margin during thymectomy.[16] In addition, intraoperative monitoring plays a central role in detecting abnormal or unexpected responses to anesthesia—such as incomplete reversal or rapid onset of neuromuscular blockade. A 2024 meta-analysis confirmed that sugammadex administration guided by quantitative neuromuscular monitoring significantly accelerates recovery while reducing postoperative respiratory complications.[17]

For patients with mediastinal masses, especially those causing airway or vascular compression, continuous monitoring of airway pressures and perfusion dynamics is essential to prevent ventilation collapse and maintain adequate gas exchange. Techniques such as bronchial occlusion or directional ventilation require dynamic, real-time monitoring to adjust ventilatory strategies according to evolving intraoperative conditions.[13] Overall, precise and continuous intraoperative monitoring constitutes a central pillar of modern anesthetic practice. Its integration with individualized anesthesia techniques has consistently been shown to enhance perioperative safety, optimize physiological stability, and accelerate postoperative recovery—particularly in patients with neuromuscular disorders or large mediastinal tumors.[8,13,16,17]

Managing Complex Cases and Anticipating Post-Operative Crises

While the majority of thymectomy procedures can be safely managed using standard anesthetic strategies, a subset of patients with giant anterior mediastinal tumors present profound physiological challenges. Tumors of this size may cause severe compression of the tracheobronchial tree and major vascular structures, predisposing patients to acute airway obstruction or sudden hemodynamic collapse during induction, positioning, or surgical manipulation.[3] These high-risk cases demand meticulous preoperative planning and individualized anesthetic strategies.

In such life-threatening scenarios, advanced extracorporeal support modalities may be necessary. A 2023 systematic review underscored the critical role of Extracorporeal Membrane Oxygenation (ECMO) as a rescue strategy in patients undergoing surgery for giant mediastinal tumors when conventional ventilation and oxygenation strategies are insufficient.[19] The implementation of ECMO requires thorough multidisciplinary coordination involving anesthesiology, thoracic surgery, perfusion teams, and critical care specialists to ensure appropriate timing, cannulation planning, and perioperative support. Postoperative complications must also be carefully anticipated, particularly in patients with myasthenia gravis (MG). One of the most serious risks is the development of a myasthenic crisis, characterized by a rapid deterioration in neuromuscular function leading to respiratory failure requiring mechanical ventilation. A meta-analysis has identified several perioperative factors associated with increased risk of crisis after thymectomy, including advanced MG classification, poor preoperative respiratory function, high preoperative pyridostigmine dose, and extended surgical duration.[12] Recognizing and stratifying these risks is essential for determining the appropriate postoperative care pathway—such as proactive ICU admission, prolonged observation in high-dependency units, or intensified neuromuscular monitoring. Early identification of warning signs enables prompt intervention and significantly reduces morbidity. The management of complex thymectomy cases requires an integrated approach that combines advanced life-support planning, individualized anesthetic strategies, and vigilant postoperative surveillance to ensure optimal outcomes in this high-risk population

Optimizing Clinical Outcomes Through Modern Anesthesia Techniques

A growing body of evidence demonstrates that clinical outcomes in thymectomy are significantly enhanced when comprehensive preoperative evaluation, individualized anesthetic planning, and advanced intraoperative monitoring are integrated into perioperative care.[1,2,8,16–17] This combination allows clinicians to tailor anesthetic strategies to each patient's physiological and pathological profile, thereby improving safety, reducing complications, and accelerating postoperative recovery. Patients who undergo thymectomy with a structured preoperative evaluation—incorporating respiratory function testing, neuromuscular assessment, and detailed imaging—consistently demonstrate faster postoperative recovery, shorter hospital stays, and lower incidence of complications such as respiratory insufficiency and neuromuscular weakness.[2,9,12] Thorough preoperative assessment also facilitates early identification of patients with heightened sensitivity to neuromuscular-blocking agents, enabling modification of anesthetic plans to prevent prolonged postoperative weakness.[5,8]

The adoption of modern anesthetic techniques, including propofol TCI or sevoflurane without muscle relaxants, has been shown to be safe and effective for patients with myasthenia gravis, minimizing the risk of exacerbated neuromuscular blockade.[1,8] When combined with ultra–short-acting opioids such as remifentanil, these approaches provide precise intraoperative analgesia without prolonging postoperative mechanical ventilation requirements.[1,8] Innovations in neuromuscular management also contribute significantly to improved outcomes. Sugammadex, a selective reversal agent for rocuronium and vecuronium, has demonstrated superior safety and efficacy compared to neostigmine, particularly in patients with underlying neuromuscular disorders. Meta-analytic data confirm that sugammadex markedly accelerates neuromuscular recovery and reduces the incidence of postoperative respiratory complications.[17,21–24]

Intraoperative safety is further enhanced by advanced monitoring modalities, including sophisticated respiratory monitoring systems and machine learning–assisted early warning technologies, which facilitate real-time detection of hemodynamic or ventilatory instability.[16,29] These innovations support more rapid intervention, reduce the likelihood of intraoperative crises, and improve decision-making during critical phases of surgery. Additionally, minimally invasive surgical approaches—such as robotic thymectomy and video-assisted thoracoscopic surgery (VATS)—have been strongly associated with superior postoperative outcomes. Comparative studies demonstrate that these techniques lead to shorter hospital stays, reduced postoperative pain, faster return to usual activities, and improved quality of life compared with open procedures.[6,7,11,18]

The integration of detailed preoperative risk stratification, modern anesthesia techniques, advanced monitoring technologies, and minimally invasive surgical approaches yields a demonstrable improvement in the clinical outcomes of thymectomy patients. This coordinated, multidisciplinary framework not only minimizes perioperative complications but also enhances recovery trajectories and overall patient well-being.[1,2,5–8,11,12,16–18,21–24,28,29]

Practical Implementation in Indonesia: Bridging Technological Gaps and Resource Limitations

In many regions of Indonesia, the application of modern anesthetic innovations is constrained by disparities in technological availability, healthcare infrastructure, and access to advanced pharmacological agents. While technologies such as robotic surgery, advanced neuromonitoring, and novel reversal agents offer substantial improvements in perioperative safety, the realities of regional hospitals often necessitate adaptable strategies tailored to local resource capabilities. Not all facilities have immediate access to sugammadex, quantitative neuromuscular monitoring, or extracorporeal membrane oxygenation (ECMO).

In resource-limited settings, fundamental patient safety principles remain the primary focus. A 2013 Indonesian case report demonstrated that less complex thymectomy cases—such as non–myasthenic thymomas—can still achieve favorable outcomes when managed with meticulous adherence to standard anesthetic techniques.[5] This underscores the principle that core clinical skills, vigilance, and sound decision-making by the anesthesiologist are the most critical "monitoring tools" when technology is limited.

A "low-tech, high-skill" approach becomes essential. For example, when advanced videolaryngoscopes are unavailable, portable ultrasonography—which is increasingly accessible in district hospitals—can serve as an effective tool to evaluate airway anatomy before intubation.[26] Similarly, for thoracoscopic procedures (VATS) performed in resource-constrained environments, a solid understanding of basic anesthetic principles for lung isolation—such as the use of conventional double-lumen tubes or simple bronchial blockers guided by basic fiberoptic bronchoscopy—is crucial for intraoperative success.[27]

One of the most significant challenges in these facilities is the limited availability of high-cost medications such as sugammadex. In its absence, reliance on traditional reversal agents like neostigmine requires heightened vigilance, slow and controlled reversal, and stringent clinical assessment. Ideally, even in low-resource settings, a simple peripheral nerve stimulator should be used to ensure adequate neuromuscular recovery before extubation, thereby preventing postoperative respiratory complications in vulnerable patients.

Ultimately, anesthetic management for thymectomy in Indonesia requires a dual-strategy framework: incorporating cutting-edge technologies in major referral centers for complex cases, while simultaneously strengthening core clinical competencies, context-appropriate adaptations, and safe low-resource practices in district and regional hospitals. This balanced approach ensures equitable and safe perioperative care across diverse healthcare settings.

Anesthesia in Remote Areas of Indonesia: Challenges and Solutions

Anesthesia services in remote areas of Indonesia face significant challenges. One of the main obstacles is the lack of trained medical personnel in the field of anesthesia. Many rural health centers still rely on general practitioners or paramedics with limited anesthesia training, increasing the risk of intraoperative complications.[17,25] This creates an additional burden for healthcare workers who must make critical decisions without adequate anesthesia specialist support.[15,25] In addition to limited human resources, access to anesthesia drugs and essential equipment is also often limited. Ventilators, hemodynamic monitors, as well as advanced respiratory monitoring devices are not always available in rural health facilities. This makes anesthesia procedures riskier, especially in patients with complex conditions such as myasthenia gravis or mediastinal masses.[16-17]

Several research journal publications show that equipment limitations can have a direct impact on the morbidity and quality of patient recovery. A 2024 research journal publication emphasized that the use of modern reversal anesthetic drugs such as sugammadex can improve the quality of recovery, but access to these drugs in remote areas is still very limited.[17] Similarly, a 2022 research journal publication highlighted the importance of deep neuromuscular block in minimally invasive procedures, but its implementation is difficult to do without adequate technological and drug support.[25] To overcome the challenges of anesthesia services in remote areas of Indonesia, several solutions can be implemented systematically. First, it is necessary to increase the capacity of local health workers through basic anesthesia training and a short certification program, so that general practitioners and paramedics have adequate skills in handling anesthesia procedures.[17,25] Second, there is a need for a more equitable distribution of essential medicines and anesthesia equipment, including portable ventilators and simple respiration monitors, in order for rural health facilities to provide safer services.

In addition, collaboration with referral hospitals is an important step in providing telemedical support, so that medical personnel in remote areas can consult with anesthesia specialists in real-time in critical decision-making. Finally, the development of technology-based early warning systems to detect hemodynamic instability can assist medical personnel in conducting quick and appropriate interventions, while improving patient safety.[16,29] With the implementation of this solution, anesthesia services in remote areas are expected to be safer, more effective, and able to reduce the risk of intraoperative and postoperative complications, despite facing limited resources.[15,17,25]

Limitations of Systematic Literature Review

This systematic literature review has several limitations that need to be considered. Variations in the study methodology used, including prospective studies, retrospectives, literature reviews, and meta-analyses, lead to heterogeneity in the interpretation of results and limit the generalization of findings. In addition, the lack of detailed patient data, including demographic characteristics and disease severity, can jeopardize the validity of conclusions and limit the application of results in broader clinical practice. Most studies focus more on anesthesia strategies without integrating the surgical aspects that also play a role in the clinical outcomes of thymectomy. The lack of long-term studies is also an obstacle in assessing the impact of anesthesia strategies on patients' quality of life after surgery. In addition, the application of intraoperative monitoring technology and artificial intelligence (AI) in clinical practice is still limited and has not been widely tested on a large scale. Inequities in population representation are also challenging, as most research comes from specific medical centers or geographic regions, which may not reflect global populations. Finally, the potential for publication bias, where studies with positive results are more likely to be published than studies with negative or insignificant results, can lead to distortions in the conclusions drawn from these reviews.

Suggestions for Future Research

Future research should involve prospective studies with a larger and more diverse sample of patients, taking into account factors such as age, comorbidities, and severity of myasthenia gravis. This will increase the validity of findings related to anesthesia strategies and patient recovery. Longitudinal studies are also needed to examine the long-term effects of anesthesia on post-thymectomy quality of life, with a focus on neuromuscular recovery and the risk of complications, such as respiratory insufficiency and muscle weakness. In future studies, it is critical to integrate surgical and anesthesia approaches to understand how different techniques affect outcomes. Comparative research on minimally invasive methods (such as VATS and robotic surgery) versus traditional open procedures can reveal insights into anesthesia requirements and remediation.

Larger studies should investigate the effectiveness and safety of various intraoperative monitoring methods, including AI in anesthesia management. The study should assess the accuracy of AI in real-time dose adjustment and its effect on patient stability and complication rates. Exploring the application of the Enhanced Recovery After Surgery (ERAS) principle in thymectomy is essential, especially in terms of pain management and length of hospital stay. Studies can examine the impact of multimodal analgesia on opioid dependence, patient mobilization, and risk of complications. Finally, a comprehensive meta-analysis that includes a diverse patient population and an extended follow-up period is needed to draw stronger conclusions about thymus anesthesia strategies. This study should evaluate clinical variables that affect respiratory and neuromuscular function. Overall, broader evidence-based studies are needed to optimize anesthesia practices in thymectomy and provide clearer clinical guidelines for healthcare professionals managing complex neuromuscular conditions.

Conclusion

The management of anesthesia in thymectomy requires a highly individualized and risk-based approach, especially in patients with myasthenia gravis or large mediastinal masses. Comprehensive preoperative evaluation, anesthesia strategies without muscle relaxants or with rigorous neuromuscular monitoring, as well as the use of sugammadex as a superior reversal agent consistently improve clinical outcomes and accelerate recovery. Engineering innovations such as spontaneous ventilation, non-intubated VATS, and advanced respiration monitoring strengthen perioperative safety, while ECMO readiness is key in extreme cases. In resource-constrained facilities, success can still be achieved through strengthening clinical skills, optimal use of simple technologies, and multidisciplinary collaboration. This integrated approach provides a solid foundation for the development of safer, more effective, and adaptive thymectomy anesthesia guidelines at various levels of healthcare

References

1. Van HV, Huu TN, Dang TN. Propofol TCI or sevoflurane anesthesia without muscle relaxant for thoracoscopic thymectomy in myasthenia gravis patients: a prospective, observational study. BMC Anesthesiology, 2023; 23: 349. https://doi.org/10.1186/s12871-023-02296-6
2. Daum P, Smelt J, Ibrahim IR. Perioperative management of myasthenia gravis. BJA Education, 2021; 21(11): 414e419. doi: 10.1016/j.bjae.2021.07.001
3. Tani K, Kimura D, Matsuo T, Sasaki T, Kimura S, Muto C, Minakawa M. Perioperative strategies and management of giant anterior mediastinal tumors: a narrative

review. Mediastinum, 2024; 8: 34. https://dx.doi.org/10.21037/med-23-40
4. Sarkiss M, Jimenez CA. The evolution of anesthesia management of patients with anterior mediastinal mass. Mediastinum, 2023; 7: 16. https://dx.doi.org/10.21037/med-22-37
5. Sumardi FS, Tavianto D, Kaswiyan U. Prosedur anestesi timektomi pada kasus timoma tanpa gejala myasthenia gravis. J Anestesi Perioperatif. 2013;11:51–57. https://journal.fk.unpad.ac.id/index.php/jap/article/view/160
6. Jiang B, Tan QY, Deng B, Mei LY, Lin YD, Zhu LF. Robot-assisted thymectomy in large anterior mediastinal tumors: A comparative study with video-assisted thymectomy and open surgery. Thorac Cancer, 2023; 14: 267–273. doi: 10.1111/1759-7714.14744
7. Kang CH, Na KJ, Park S, Park IK, Kim YT. Long-Term Outcomes of Robotic Thymectomy in Patients With Thymic Epithelial Tumors. Ann Thorac Surg, 2021; 112: 430-5. https://doi.org/10.1016/j.athoracsur.2020.09.018
8. Fabris M, Orso D, Poldini F, Bove T. Muscle relaxant effect induced by sevoflurane during thymectomy surgery in patients with myasthenia gravis: A systematic review. JCA Advances, 2024; 100011: 1-8. http://dx.doi.org/10.1016/j.jcadva.2024.100011
9. Bhat A, Jason Dean J, Aboussouan LS. Perioperative Management in Neuromuscular Diseases: A Narrative Review. J. Clin. Med, 2024; 13: 2963. https://doi.org/ 10.3390/jcm13102963
10. Tan JC, Lin PS, He LX, Lin Y, Yao YT, the Evidence in Cardiovascular Anesthesia(EICA) Group. Anesthetic management of patients undergoing mediastinal mass operation. Front. Surg, 2022; 9: 1033349. doi: 10.3389/fsurg.2022.1033349
11. Raza B, Dhamija A, Abbas G, Toker A. Robotic thymectomy for myasthenia gravis surgical techniques and outcomes. J Thorac Dis, 2021; 13(10): 6187-6194. http://dx.doi.org/10.21037/jtd-2019-rts-10
12. Geng Y, Zhang H, Wang Y. Risk factors of myasthenia crisis after thymectomy among myasthenia gravis patients A meta-analysis. Medicine, 2019; 99:1. http://dx.doi.org/10.1097/MD.0000000000018622
13. Zhou Y, Jiang Y, Ding Y, Gu L, Tan J. Placement of bronchial occluder outside the tracheal tube in a patient combined with airway compression undergoing mediastinal tumors resection: a case report. BMC Anesthesiology, 2024; 24: 100. https://doi.org/10.1186/s12871-024-02480-2
14. Hartigan PM, Karamnov S, Gill RR, Ng JM, Yacoubian S, Tsukada H, Swanson J, et al. Mediastinal Masses, Anesthetic Interventions, and Airway Compression in Adults: A Prospective Observational Study. Anesthesiology, 2022; 136: 104–14. doi: 10.1097/ALN.0000000000004011
15. Scheriau G, Weng R, Lassnigg A, Maleczek M, Zimprich F, Matilla J, et al. Perioperative Management of Patients With Myasthenia Gravis Undergoing Robotic-Assisted Thymectomy—A Retrospective Analysis and Clinical Evaluation. J Cardiothorac Vasc Anesth, 2022 ; 36(10): 3806-3813. doi: 10.1053/j.jvca.2022.05.024
16. Jimenez Santana JD, Spadaro S, Navarro MPA, Mazzinari G. Advanced Respiratory Monitoring in the Perioperative Setting. Current Anesthesiology Reports, 2024; 14: 551–566. https://doi.org/10.1007/s40140-024-00646-9
17. Olesnicky BL, Farrell C, Clare P, Wen S, Leslie K, Delaney A. The effect of sugammadex on patient morbidity and quality of recovery after general anaesthesia: a systematic review and metaanalysis. British Journal of Anaesthesia, 2024; 132 (1): 107e115 doi: 10.1016/j.bja.2023.10.032
18. Lee JH, Hwang J, Park TH, Gu BM, Jung Y, Yi E, Lee S, et al. Subxiphoid Single-Port Robotic Thymectomy Using the Single-Port Robotic System versus VATS: A Multi-Institutional, Retrospective, and Propensity Score-Matched Study. Cancers, 2024; 16: 2856. https:// doi.org/10.3390/cancers16162856
19. Bertini P, Marabotti A. The anesthetic management and the role of extracorporeal membrane oxygenation for giant mediastinal tumor surgery. Mediastinum, 2023; 7: 2. https://dx.doi.org/10.21037/med-

22-35
20. Pladet L, Luijken K, Fresiello L, Miranda DDR, Hermens JA, van Smeden M, Cremer O, et al. Clinical decision support for ExtraCorporeal Membrane Oxygenation: Will we fly by wire?. Perfusion, 2023; 38(1S): 68–81. doi: 10.1177/02676591231163688
21. Ravindranath S, Backfish-White K, Wolfe J, Ranganath YS. Sugammadex for Neuromuscular Blockade Reversal: A Narrative Review. J. Clin. Med, 2025; 14: 4128. https://doi.org/10.3390/ jcm14124128
22. Zhu N, Li Y. Sugammadex vs neostigmine in post-anesthesia recovery: A systematic review and meta-analysis. Biomolecules and Biomedicine, 2025; 26 (2): 295–306. doi: 10.17305/bb.2025.12689
23. Schneider A, Tramer MR, Keli-Barcelos G, Elia N. Sugammadex and neuromuscular disease: a systematic review with assessment of reporting quality and content validity. British Journal of Anaesthesia, 2024; 133 (4): 752e758. doi: 10.1016/j.bja.2024.05.015
24. Carron M, De Cassai A, Linassi F. Sugammadex in the management of myasthenic patients undergoing surgery: beyond expectations. Ann Transl Med, 2019; 7 (8): S307. http://dx.doi.org/10.21037/atm.2019.10.35
25. Zheng J, Du L, Deng X, Zhang L, Wang J, Chen G. Deep neuromuscular block for minimally invasive lung surgery: a protocol for a systematic review with meta-analysis and trial sequential analysis. BMJ Open, 2022; 12: e056816. doi:10.1136/bmjopen-2021-056816
26. Udayakumar GS, Priya L, Narayanan V. Comparison of Ultrasound Parameters and Clinical Parameters in Airway Assessment for Prediction of Difficult Laryngoscopy and Intubation: An Observational Study. Cureus, 2023; 15(7): e41392. doi: 10.7759/cureus.41392
27. Sharma VK, Singh CP. Anaesthetic Considerations in the Video-assisted Thoracoscopic Excision of Pulmonary Aspergilloma: A Case Report. Journal of Clinical and Diagnostic Research, 2024; 18(4): UD08-UD10. doi: 10.7860/JCDR/2024/69061.19328
28. Furák J, Németh T, Budai K, Farkas A, Lantos J, Glenz JR, Fabó C, et al. Spontaneous ventilation with double-lumen tube intubation for video-assisted thoracic surgery thymectomy: a pilot study. Video-assist Thorac Surg, 2023; 8: 37. https://dx.doi.org/10.21037/vats-23-37
29. Luo T, Zhang Y, Xu BW, Zhang CC, Zhang LW, Ran XQ, Fu MY. Non-intubated vs. intubated video-assisted thoracoscopic surgery for the treatment of thoracic diseases: a systematic review and meta-analysis of propensity score-matched cohorts. Front. Surg, 2025; 12: 1661466. doi: 10.3389/fsurg.2025.1661466
30. Chiang DH, Jiang Z, Tian C, Wang CY. Development and validation of a dynamic early warning system with time-varying machine learning models for predicting hemodynamic instability in critical care: a multicohort study. Critical Care, 2025; 29: 318. https://doi.org/10.1186/s13054-025-05553-x