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Review

Emergency Surgical Anesthesia: Rapid Sequence Induction, Hemorrhage Control and Perioperative Stabilization

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Abstract

Emergency surgical anesthesia in trauma and emergency room settings is essential, where rapid and efficient intervention is necessary to maximize patient outcomes. Three essential components of emergency surgical anesthesia are examined in this literature review: rapid sequence induction (RSI), hemorrhage control and perioperative stabilization. RSI is a fundamental technique for securing the airway in critically injured or ill patients, ensuring rapid unconsciousness and neuromuscular blockade while reducing the risk of aspiration. Common pharmacologic agents used include etomidate, ketamine, propofol, midazolam, fentanyl, and neuromuscular blockers, each with specific considerations and potential side effects. To lower mortality in trauma patients, hemorrhage control measures are crucial. Effective hemorrhage management in trauma care is advancing through innovative techniques such as viscoelastic testing, AI support, and novel hemostatic methods, including resuscitative endovascular balloon occlusion of the aorta, bioengineered clotting agents, and 3D-printed vascular grafts. To increase survival rates and avoid complications, perioperative stabilization, which includes fluid management, hemodynamic monitoring, and postoperative care, is essential. Oxygenation and ventilation strategies like protective lung ventilation, high-flow nasal cannula, and extracorporeal membrane oxygenation are essential in optimizing patient survival and extending critical care capabilities in resource-limited settings. This review highlights significant developments and challenges in trauma surgery by synthesizing current research and best practices in emergency anesthesia.

Keywords: *Anesthesia, Emergency Room, Rapid Sequence Induction, Trauma, surgical anesthesia*

Introduction

Worldwide trauma continues to be a major cause of morbidity and mortality necessitating prompt, carefully planned surgical and anesthetic intervention (1). The management of critically ill patients in need of immediate surgical care depends heavily on emergency surgical anesthesia. Emergency anesthesia, as opposed to elective procedures, entails treating patients who are unstable and have compromised physiology, which calls for quick decisions.

Rapid sequence induction (RSI) is a crucial technique in emergency anesthesia to facilitate tracheal intubation while minimizing the risk of aspiration in patients who are not fasting (2).

For emergency airway management in patients who are traumatized, critically ill, or unresponsive, rapid sequence induction (RSI) is the gold standard. A strong induction agent and a neuromuscular blocker are administered concurrently during RSI, and the airway is then secured by prompt intubation. This method reduces the chance of aspiration, especially in patients who have altered consciousness, gastrointestinal bleeding, or full stomachs. Despite its efficacy, RSI carries risks like hypotension, desaturation, and unsuccessful intubation, so anesthesiologists must possess a high level of expertise in resuscitation techniques and airway management. A major preventable cause of death in trauma situations is uncontrolled bleeding, so efficient hemorrhage control is crucial (3, 4). A major contributor to perioperative death is uncontrolled bleeding, which calls for immediate fluid resuscitation, blood transfusions, and damage control surgery. Hemorrhage control has been greatly enhanced by developments in massive transfusion protocols, thromboelastographic for coagulation assessment, and hemostatic medications like tranexamic acid. Additionally, cutting-edge methods for reducing bleeding in urgent situations include endovascular balloon occlusion of the aorta, a minimally invasive procedure. The results for patients suffering from hemorrhagic shock have greatly improved due to developments in hemostatic agents and damage control resuscitation. Perioperative stabilization, which includes ventilation techniques, fluid resuscitation, and hemodynamic monitoring, is also essential for preserving patient life and lowering the risk of complications following surgery (5, 6). Urgent intervention with vasopressors, mechanical ventilation, and targeted fluid therapy is necessary for patients undergoing emergency procedures who frequently present with hypotension, hypoxia, metabolic acidosis, and coagulopathy. The lethal triad of coagulopathy, hypothermia, and acidosis is a well-known problem in trauma anesthesia that calls for careful temperature and fluid control to avoid multi-organ failure. The use of AI-driven decision support systems, goal-directed therapy, and point-of-care ultrasound is revolutionizing emergency anesthesia procedures by enabling real-time evaluation of cardiac output, pulmonary function, and fluid status (7-9). In addition, protocols for enhanced recovery after surgery are being modified for use in emergencies to decrease complications and enhance postoperative recovery (10, 11).

With a focus on RSI in trauma and emergency room settings, hemorrhage control, and perioperative stabilization, this literature review attempts to investigate the most recent evidence-based procedures in emergency surgical anesthesia.

Review

Rapid sequence induction in emergency anesthesia

Defining RSI and its guiding principles

To facilitate intubation and reduce the risk of aspiration, RSI is a standardized airway management technique that is utilized in emergencies (6, 12, 13). It includes the administration of a strong induction agent followed by a neuromuscular blocking agent to quickly induce unconsciousness and paralysis (14). Patients with compromised airways, those at high risk of aspiration (e.g., gastrointestinal bleeding, a full stomach, or reduced consciousness), those experiencing respiratory failure necessitating immediate intubation, and those with neurological

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emergencies such as traumatic brain injury are all candidates for RSI.

Pharmaceutical substances in RSI

Etomidate, ketamine, propofol and midazolam are induction agents frequently used in RSI. Because of their distinct pharmacological characteristics, these drugs can be used in various clinical settings. Etomidate has low cardiovascular side effects, making it the preferred treatment for hemodynamically unstable patients. Because of its dissociative qualities, ketamine helps patients with trauma or hypotension by delivering both sedation and analgesia while preserving cardiovascular stability and airway reflexes (15). Because of its quick onset and brief duration of action, propofol is frequently used, although it can result in severe hypotension (16). One benzodiazepine that provides sedation and amnesia is midazolam, however its onset is slower than that of other drugs (17, 18). Neuromuscular blocking agents, including rocuronium, vecuronium, and succinylcholine, are used after induction to completely paralyze the muscles, facilitating a more seamless intubation procedure. Depolarizing muscle relaxants like succinylcholine are perfect for RSI because of their quick onset and brief duration, but they also carry risks like malignant hyperthermia and hyperkalemia (19). Non-depolarizing drugs, vecuronium and rocuronium (20), produce paralysis that lasts longer and are frequently used in situations where succinylcholine is not appropriate (21, 22). To improve intubation conditions and reduce unfavorable physiological reactions, adjunctive drugs may be given in addition to these primary agents. To avoid bradycardia brought on by airway manipulation, atropine is occasionally administered to children. In patients with reactive airway diseases in particular, lidocaine may be administered to suppress airway reflexes and lower the risk of coughing or bronchospasm. The strong opioid analgesic fentanyl helps lessen the hemodynamic reaction to intubation, especially in patients with head injuries or cardiovascular diseases where it's critical to avoid an increase in intracranial pressure. Clinicians can enhance the safety and efficacy of RSI and guarantee quick and controlled airway management in emergencies by carefully choosing and delivering these drugs. The clinical state underlying comorbidities and possible contraindications of the patient all influence the choice of agents, underscoring the significance of tailored treatment plans.

RSI complications

RSI has several potential side effects that need to be carefully managed despite its benefits (23). Hypoxia and hemodynamic instability can happen because anesthesia is induced quickly and protective airway reflexes are lost, especially in critically ill or hypotensive patients. Alternate airway management strategies such as supraglottic airway devices or surgical airway interventions may be necessary if intubation fails due to airway trauma (24). Even with proper preoxygenation and cricoid pressure, aspiration is still possible and can result in acute respiratory distress syndrome (ARDS) or aspiration pneumonia (25). Anaphylaxis, chronic paralysis, or cardiovascular instability are examples of adverse drug reactions that can result from the use of induction and neuromuscular blocking agents (18, 26, 27).

The management of bleeding during trauma surgery

Pathophysiology of hemorrhage associated with trauma

When trauma causes excessive blood loss, hemorrhagic shock occurs, a potentially fatal condition marked by cellular dysfunction, oxygen deprivation and insufficient tissue perfusion. If treatment is not received, this can quickly lead to multiple organ failure and death, coagulopathy, hypothermia, and acidosis, which exacerbate the consequences of uncontrolled bleeding (28, 29). These conditions exacerbate uncontrollable bleeding and make surgical management more difficult. To restore circulation and stop additional damage, prompt action is essential. Trauma-induced coagulopathy also poses challenges that call for prompt and accurate correction with hemostatic agents and blood products (30). Coagulopathy: Severe bleeding impairs hemostasis by interfering with normal blood clotting processes. The dilution

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caused by excessive crystalloid infusion, fibrinolysis and clotting factor consumption all contribute to trauma-induced coagulopathy which makes controlling bleeding more challenging. Hypothermia: During trauma resuscitation, blood loss and extended exposure can lower core body temperature, which can weaken platelet activity and enzymatic clotting processes and exacerbate bleeding. Lactic acidosis, which disrupts coagulation and worsens hypothermia, is the result of anaerobic metabolism brought on by inadequate perfusion and oxygen delivery.

New methods for controlling bleeding

Point-of-care viscoelastic testing is one of the latest developments in hemorrhage control, enabling quick evaluation of clotting abnormalities to direct focused interventions (31-34). Response times in trauma care are being accelerated by the combination of AI-driven decision support tools and automated bleeding detection systems (35-37). Furthermore, prehospital hemorrhage management is becoming more effective with the use of sophisticated hemostatic dressings embedded with pro-coagulant factors (38-40).

Methods for surgical hemostasis

Hemostatic dressings and topical medications like fibrin sealants and chitosan-based products help to form clots while direct pressure and tourniquets are used for bleeding in the extremities (41-43). Damage control surgery is used to temporarily close the abdomen and control bleeding in patients who have suffered severe injuries (43, 44). Resuscitative Endovascular Balloon Occlusion of the Aorta is one endovascular technique that is being used more and more for non-compressible torso hemorrhage (45, 46). Furthermore, hybrid methods that combine endovascular and open techniques have been developed to enhance results in cases of complex trauma (47). Future developments in surgical hemostasis may be possible with the use of bioengineered clotting agents and 3D-printed vascular grafts (48).

Stabilization during surgery for trauma patients

Fluid resuscitation innovations

Traditional crystalloid-heavy resuscitation is no longer preferred over whole blood transfusion protocols because overuse of crystalloids can worsen patient outcomes by causing tissue edema, dilutional coagulopathy, and inflammatory reactions. Furthermore, research is investigating new resuscitation fluids that contain hemoglobin-based oxygen carriers and oxygen-carrying nanoparticles, which may lessen the need for conventional blood products in environments with limited resources (49, 50). In critically injured patients, whole blood, which is composed of red blood cells, plasma, and platelets, provides a more balanced resuscitation strategy by preserving the patient's ability to carry oxygen and maintain hemostatic function. Beyond the whole blood transfusion, ongoing research is exploring next-generation resuscitation fluids that could revolutionize trauma care, particularly in resource-limited environments. Among these are oxygen-carrying nanoparticles and hemoglobin-based oxygen carriers (HBOCs), which both seek to improve oxygen transport while lowering dependency on conventional blood products. As artificial oxygen carriers HBOCs can be useful in pre-hospital and combat environments because they can replicate red blood cells without the need for cross-matching. Similarly, oxygen-carrying nanoparticles are being investigated for their ability to improve tissue oxygenation and mitigate ischemic damage in trauma patients. To increase survival rates, lower complications, and extend life-saving interventions to environments where traditional blood products might be limited or unavailable, these developments mark a paradigm shift in trauma stabilization. As studies proceed on the effectiveness, accessibility, and safety on a global scale.

Oxygenation and ventilation techniques

Protective lung ventilation that has low tidal volumes aids in preventing Ventilator-induced lung injury. In certain patients, non-invasive ventilation and high-flow nasal cannula are advantageous (51,

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52). Extracorporeal membrane oxygenation and prone positioning are taken into consideration in severe cases of ARDS (53-55). For the best lung protection developments in precision ventilation, such as transpulmonary pressure-guided ventilation and automated weaning procedures, are being investigated (56). There is potential for better respiratory management of critically ill trauma patients through the integration of closed-loop ventilation systems powered by real-time feedback (57).

Patient outcomes and long-term effects

Patient outcomes in the long run are greatly impacted by emergency surgical anesthesia. Although using RSI and hemorrhage control techniques correctly lowers mortality rates, it can also result in complications like psychological distress, multi-organ dysfunction, and neurocognitive impairment. Acute kidney injury, pulmonary edema, and coagulopathy are more likely to occur in patients undergoing aggressive fluid resuscitation without proper hemodynamic monitoring (58). These conditions lengthen hospital stays and raise morbidity. Recovery depends on early rehabilitation and post-anesthesia care. Ventilator-associated pneumonia and respiratory insufficiency are more common in trauma patients receiving continuous mechanical ventilation (59). Preventive lung ventilation techniques and prompt mobilization aid in reducing these hazards. Furthermore, survivors of severe trauma, especially those who experience hypotension and hypoxia during surgery, are susceptible to cognitive decline or post-traumatic stress disorder, underscoring the significance of psychological support in post-trauma care (60). Evaluation of patient-centered outcomes such as functional recovery and quality of life following major surgical procedures requires more research. Enhancing survival and reducing long-term impairments will require developments in neuroprotective anesthetic techniques, goal-directed resuscitation, and postoperative rehabilitation procedures.

Conclusion

Rapid decision-making and accurate execution are essential in the dynamic and complex field of emergency surgical anesthesia. While improvements in hemorrhage control, such as damage control resuscitation and hemostatic agents, have greatly increased trauma survival, rapid sequence induction is still the gold standard for securing the airway in critically ill patients. Goal-directed fluid resuscitation, protective ventilation, and hemodynamic monitoring are examples of perioperative stabilization techniques that are crucial for improving outcomes for trauma patients. Improving real-time resuscitation monitoring, streamlining transfusion protocols and incorporating AI-driven decision support into emergency anesthesia care should be the main areas of future research.

Disclosures

Author contributions

The author has reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Consent for publications

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Data availability

All data is provided within the manuscript.

Conflict of interest

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References

1. Raja A, Zane RD. Initial management of trauma in adults. UpToDate UpToDate, Waltham, MA(Accessed February, 2021). 2018.

2. Schrader M, Urits I. Tracheal rapid sequence intubation. 2020.

3. Rossaint R, Bouillon B, Cerny V, Coats TJ, Duranteau J, Fernández-Mondéjar E, et al. Management of bleeding following major trauma: an updated European guideline. Critical care. 2010;14:1-29.

4. Spahn DR, Bouillon B, Cerny V, Coats TJ, Duranteau J, Fernández-Mondéjar E, et al. Management of bleeding and coagulopathy following major trauma: an updated European guideline. Critical care. 2013;17:1-45.

5. Gordon D, Spiegel R. Fluid resuscitation: history, physiology, and modern fluid resuscitation strategies. Emergency Medicine Clinics. 2020;38(4):783-93.

6. Alvarado AC, Panakos P. Endotracheal tube intubation techniques. 2020.

7. Shimada K, Inokuchi R, Ohigashi T, Iwagami M, Tanaka M, Gosho M, et al. Artificial intelligence-assisted interventions for perioperative anesthetic management: a systematic review and meta-analysis. BMC anesthesiology. 2024;24(1):306.

8. Cai J, Li P, Li W, Zhu T. Outcomes of clinical decision support systems in real-world perioperative care: a systematic review and meta-analysis. International Journal of Surgery. 2024;110(12):8057-72.

9. Pham FM. Artificial intelligence-supported systems in anesthesiology and its standpoint to date—A review. Open Journal of Anesthesiology. 2023;13(7):140-68.

10. Peden CJ, Aggarwal G, Aitken RJ, Anderson ID, Bang Foss N, Cooper Z, et al. Guidelines for perioperative care for emergency laparotomy Enhanced Recovery After Surgery (ERAS) Society recommendations: part 1—preoperative: diagnosis, rapid assessment and optimization. World journal of surgery. 2021;45(5):1272-90.

11. Hajibandeh S, Hajibandeh S, Bill V, Satyadas T. Meta-analysis of enhanced recovery after surgery (ERAS) protocols in emergency abdominal surgery. World journal of surgery. 2020;44(5):1336-48.

12. Goto T, Goto Y, Hagiwara Y, Okamoto H, Watase H, Hasegawa K. Advancing emergency airway management practice and research. Acute Medicine & Surgery. 2019;6(4):336-51.

13. Acquisto NM, Mosier JM, Bittner EA, Patanwala AE, Hirsch KG, Hargwood P, et al. Society of Critical Care Medicine Clinical Practice Guidelines for Rapid Sequence Intubation in the Critically Ill Adult Patient. Critical Care Medicine. 2023;51(10):1411-30.

14. Leeuwenburg T. Airway management of the critically ill patient: modifications of traditional rapid sequence induction and intubation. Critical Care Horizons. 2015;1(1):1-10.

15. Kurdi MS, Theerth KA, Deva RS. Ketamine: Current applications in anesthesia, pain, and critical care. Anesthesia Essays and Researches. 2014;8(3):283-90.

16. Folino TB, Muco E, Safadi AO, Parks LJ. Propofol. StatPearls [Internet]: StatPearls Publishing; 2023.

17. Wan C, Hanson AC, Schulte PJ, Dong Y, Bauer PR. Propofol, ketamine, and etomidate as induction agents for intubation and outcomes in critically ill patients: a retrospective cohort study. Critical Care Explorations. 2021;3(5):e0435.

18. Scherzer D, Leder M, Tobias JD. Pro-con debate: etomidate or ketamine for rapid sequence intubation in pediatric patients. The Journal of Pediatric Pharmacology and Therapeutics. 2012;17(2):142-9.

19. Hager HH, Burns B. Succinylcholine chloride. 2018.

20. Jain A, Wermuth HR, Dua A, Singh K, Maani CV. Rocuronium. StatPearls [Internet]: StatPearls Publishing; 2024.

http://dx.doi.org/10.52533/JOHS.2025.50604

21. Cook D, Simons DJ. Neuromuscular blockade. StatPearls [Internet]: StatPearls Publishing; 2023.

22. Lundstrøm L, Duez C, Nørskov A, Rosenstock C, Thomsen J, Møller A, et al. Effects of avoidance or use of neuromuscular blocking agents on outcomes in tracheal intubation: a Cochrane systematic review. British journal of anaesthesia. 2018;120(6):1381-93.

23. Higgs A, McGrath B, Goddard C, Rangasami J, Suntharalingam G, Gale R, et al. Guidelines for the management of tracheal intubation in critically ill adults. British journal of anaesthesia. 2018;120(2):323-52.

24. Heidegger T. Management of the difficult airway. New England Journal of Medicine. 2021;384(19):1836-47.

25. Sun J, Wei G, Hu L, Liu C, Ding Z. Perioperative pulmonary aspiration and regurgitation without aspiration in adults: a retrospective observational study of 166,491 anesthesia records. Annals of Palliative Medicine. 2021;10(4):4037046-4046.

26. Li W, Lin Z, Li F, Huang K, Dou Y, Fang J. Neuromuscular Blocking Agents and Tracheal Intubation: Systematic Review and Meta-Analysis of Effects on Laryngeal Complications and Intubating Conditions. Health Science Reports. 2025;8(2):e70483.

27. Bisesi SA, Stauber SD, Hutchinson DJ, Acquisto NM. Current practices and safety of medication use during pediatric rapid sequence intubation. The Journal of Pediatric Pharmacology and Therapeutics. 2024;29(1):66-75.

28. Meza Monge K, Rosa C, Sublette C, Pratap A, Kovacs EJ, Idrovo J-P. Navigating Hemorrhagic Shock: Biomarkers, Therapies, and Challenges in Clinical Care. Biomedicines. 2024;12(12):2864.

29. Casella J, Perry M. EMS Tactical Paramedic Lethal Triad. StatPearls [Internet]: StatPearls Publishing; 2024.

30. Spahn DR, Bouillon B, Cerny V, Duranteau J, Filipescu D, Hunt BJ, et al. The European guideline on management of major bleeding and coagulopathy following trauma. Critical care. 2019;23:1-74.

31. Volod O, Bunch CM, Zackariya N, Moore EE, Moore HB, Kwaan HC, et al. Viscoelastic hemostatic assays: a primer on legacy and new generation devices. Journal of Clinical Medicine. 2022;11(3):860.

32. Lodewyks C, Heinrichs J, Grocott HP, Karkouti K, Romund G, Arora RC, et al. Point-of-care viscoelastic hemostatic testing in cardiac surgery patients: a systematic review and meta-analysis. Canadian Journal of Anesthesia. 2018;65(12):1333-47.

33. Snegovskikh D, Souza D, Walton Z, Dai F, Rachler R, Garay A, et al. Point-of-care viscoelastic testing improves the outcome of pregnancies complicated by severe postpartum hemorrhage. Journal of clinical anesthesia. 2018;44:50-6.

34. Whiting P, Al M, Westwood M, Ramos IC, Ryder S, Armstrong N, et al. Viscoelastic point-of-care testing to assist with the diagnosis, management and monitoring of haemostasis: a systematic review and cost-effectiveness analysis. Health technology assessment (Winchester, England). 2015;19(58):1.

35. Pendyala SK. Real-time Analytics and Clinical Decision Support Systems: Transforming Emergency Care. International Journal for Multidisciplinary Research (IJFMR). 2024;6(6).

36. Ouanes K, Farhah N. Effectiveness of Artificial Intelligence (AI) in clinical decision support systems and care delivery. Journal of Medical Systems. 2024;48(1):74.

37. Zia J, Kimball J, Rolfes C, Hahn J-O, Inan OT. Enabling the assessment of trauma-induced hemorrhage via smart wearable systems. Science advances. 2020;6(30):eabb1708.

38. Zhang C, Wang Y, Xue Y, Cheng J, Chi P, Wang Z, et al. Enhanced hemostatic and procoagulant efficacy of peg/zno hydrogels: a novel approach in traumatic hemorrhage management. Gels. 2024;10(2):88.

 http://dx.doi.org/10.52533/JOHS.2025.50604

39. Zou C-Y, Lei X-X, Hu J-J, Jiang Y-L, Li Q-J, Song Y-T, et al. Multi-crosslinking hydrogels with robust bio-adhesion and pro-coagulant activity for first-aid hemostasis and infected wound healing. Bioactive Materials. 2022;16:388-402.

40. Dong Y, Xu Y, Lian C, Prak K, Leo HL, Tetley TD, et al. Safe and efficacious near superhydrophobic hemostat for reduced blood loss and easy detachment in traumatic wounds. ACS Applied Materials & Interfaces. 2024;16(4):4307-20.

41. Fan P, Zeng Y, Zaldivar-Silva D, Agüero L, Wang S. Chitosan-based hemostatic hydrogels: The concept, mechanism, application, and prospects. Molecules. 2023;28(3):1473.

42. O'Donnell JS, O'Sullivan JM, Preston RJ. Advances in understanding the molecular mechanisms that maintain normal haemostasis. British journal of haematology. 2019;186(1):24-36.

43. Chiara O, Cimbanassi S, Bellanova G, Chiarugi M, Mingoli A, Olivero G, et al. A systematic review on the use of topical hemostats in trauma and emergency surgery. BMC surgery. 2018;18:1-20.

44. Risinger WB, Smith JW. Damage control surgery in emergency general surgery: what you need to know. Journal of Trauma and Acute Care Surgery. 2023;95(5):770-9.

45. Bekdache O, Paradis T, Shen YBH, Elbahrawy A, Grushka J, Deckelbaum D, et al. Resuscitative endovascular balloon occlusion of the aorta (REBOA): indications: advantages and challenges of implementation in traumatic non-compressible torso hemorrhage. Trauma surgery & acute care open. 2019;4(1):e000262.

46. Khalid S, Khatri M, Siddiqui MS, Ahmed J. Resuscitative endovascular balloon occlusion of aorta versus aortic cross-clamping by thoracotomy for noncompressible torso hemorrhage: a meta-analysis. Journal of Surgical Research. 2022;270:252-60.

47. Faulconer ER, Branco BC, Loja MN, Grayson K, Sampson J, Fabian TC, et al. Use of open and endovascular surgical techniques to manage vascular injuries in the trauma setting: A review of the American Association for the Surgery of Trauma PROspective Observational Vascular Injury Trial registry. Journal of Trauma and Acute Care Surgery. 2018;84(3):411-7.

48. Shen Y, Pan Y, Liang F, Song J, Yu X, Cui J, et al. Development of 3D printed electrospun vascular graft loaded with tetramethylpyrazine for reducing thrombosis and restraining aneurysmal dilatation. Burns & Trauma. 2024;12:tkae008.

49. Cabrales P, Intaglietta M. Blood substitutes: evolution from noncarrying to oxygen-and gas-carrying fluids. ASAIO Journal. 2013;59(4):337-54.

50. Mohanto N, Mondal H, Park Y-J, Jee J-P. Therapeutic delivery of oxygen using artificial oxygen carriers demonstrates the possibility of treating a wide range of diseases. Journal of Nanobiotechnology. 2025;23(1):25.

51. Simon M, Braune S, Frings D, Wiontzek A-K, Klose H, Kluge S. High-flow nasal cannula oxygen versus non-invasive ventilation in patients with acute hypoxaemic respiratory failure undergoing flexible bronchoscopy-a prospective randomised trial. Critical Care. 2014;18:1-9.

52. Wang Q, Peng Y, Xu S, Lin L, Chen L, Lin Y. The efficacy of high-flow nasal cannula (HFNC) versus non-invasive ventilation (NIV) in patients at high risk of extubation failure: a systematic review and meta-analysis. European Journal of Medical Research. 2023;28(1):120.

53. Schmidt M, Hajage D, Lebreton G, Dres M, Guervilly C, Richard JC, et al. Prone Positioning During Extracorporeal Membrane Oxygenation in Patients With Severe ARDS: The PRONECMO Randomized Clinical Trial. JAMA. 2023;330(24):2343-53.

54. Papazian L, Schmidt M, Hajage D, Combes A, Petit M, Lebreton G, et al. Effect of prone positioning on survival in adult patients receiving venovenous extracorporeal membrane oxygenation for acute respiratory distress syndrome: a systematic review and meta-analysis. Intensive care medicine. 2022;48(3):270-80.

http://dx.doi.org/10.52533/JOHS.2025.50604

55. Huai J, Ye X. Impact of prone positioning duration on the outcome of patients receiving venovenous extracorporeal membrane oxygenation for acute respiratory distress syndrome: A meta-analysis. Heliyon. 2022;8(12).

56. Muñoz J, Cedeño JA, Castañeda GF, Visedo LC. Personalized ventilation adjustment in ARDS: A systematic review and meta-analysis of image, driving pressure, transpulmonary pressure, and mechanical power. Heart & Lung. 2024;68:305-15.

57. Goossen RL, Schultz MJ, Tschernko E, Chew MS, Robba C, Paulus F, et al. Effects of closed loop ventilation on ventilator settings, patient outcomes and ICU staff workloads–a systematic review. European Journal of Anaesthesiology| EJA. 2024;41(6):438-46.

58. Malbrain M, Marik P, Witters I, Cordemans C, Kirkpatrick A, Roberts D, et al. Fluid overload, de-resuscitation, and outcomes in critically ill or injured patients: a systematic review with suggestions for clinical practice. Anestezjologia Intensywna Terapia. 2014;46(5):377-96.

59. Li Y, Liu C, Xiao W, Song T, Wang S. Incidence, risk factors, and outcomes of ventilator-associated pneumonia in traumatic brain injury: a meta-analysis. Neurocritical care. 2020;32(1):272-85.

60. Calsavara AJ, Costa PA, Nobre V, Teixeira AL. Prevalence and risk factors for post-traumatic stress, anxiety, and depression in sepsis survivors after ICU discharge. Brazilian Journal of Psychiatry. 2020;43(3):269-76.

http://dx.doi.org/10.52533/JOHS.2025.50604