JEVTM
Journal of ENDOVASCULAR RESUSCITATION and Trauma Management
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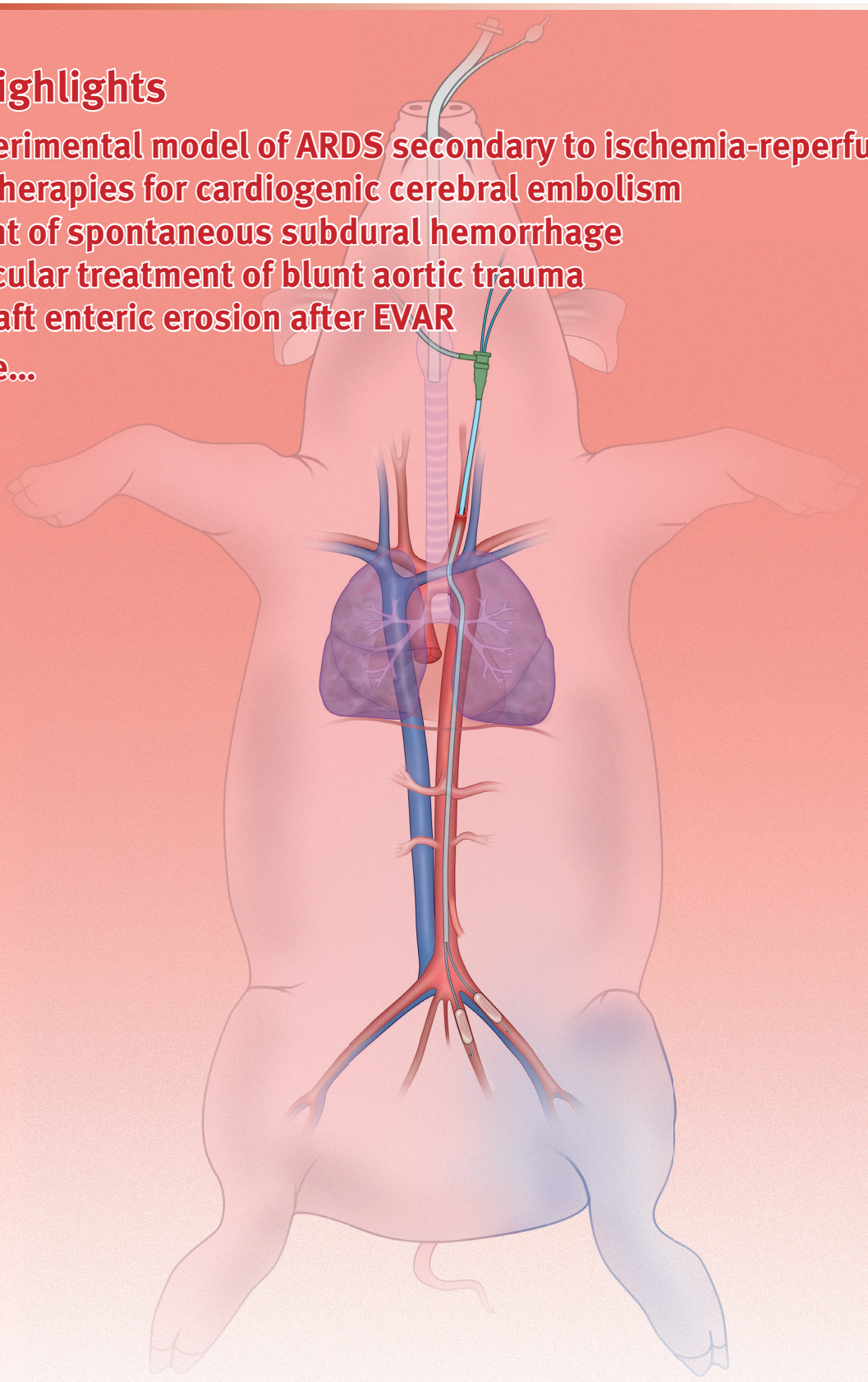
Issue Highlights

New experimental model of ARDS secondary to ischemia-reperfusion
Current therapies for cardiogenic cerebral embolism
Treatment of spontaneous subdural hemorrhage
Endovascular treatment of blunt aortic trauma
Aortic graft enteric erosion after EVAR
And more...



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To achieve this, we do not wish to be bound by medical discipline, country, resource or even the conventional rules of medical publishing. To achieve this goal, we have assembled an Editorial Board of clinicians and scientists who are experts within the field. This project is generously supported by a grant from the Department of Cardiothoracic and Vascular Surgery, Örebro University Hospital, Sweden.

We are keen to receive manuscript submissions that present new original findings, review important topics or educate our readers on any aspect of hemorrhage control, where an endovascular technique has been employed. This can either be in isolation or in combination with open surgical techniques (hybrid surgery). For further information for authors, please see *https://publicera.kb.se/jevtm*.

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Submissions should preferably be produced using Microsoft Word, although other formats will be considered. Submissions should be anonymized.

The submission process requires three discreet documents:

1. Cover Letter
2. Title Page
3. Manuscript (including Abstract, Tables and Figures)

Please ensure that the names and contact details of **all** authors are entered on the online submission system.

Cover Letter

This should be written by the corresponding author and must contain the following:

1. The type of manuscript submission (Original Article, Review Article, etc).
2. A sentence or two on the subject of the study.
3. Confirmation that the study is not under consideration for publication by another journal.
4. Confirmation that all of the authors have made a substantial contribution to the manuscript and that they have seen and approved the submission draft.
5. A conflict-of-interest statement regarding the authors. Where there is none, this should be clearly stated. More information about the Journal's publication ethics can be found on the journal webpage https://publicera.kb.se/jevtm/policies.
6. A clear statement that the authors follow the ethical guidelines as stated on the Journal webpage.

Title Page

This should consist of the following:

- Title: This should be concise and reflect the type and purpose of the study.
- Authors: These should be listed in order for publication, with first name, initials and surname.
- Affiliations: The institution(s) that the authors are affiliated with should be listed. Ensure that sufficient information is included to identify the authors (full addresses are not required).
- Corresponding Author: This individual should be clearly identified, along with one full institutional address and email address.
- Presentation: The meeting where any of the submitted data was presented should be listed.
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- Author Contributions (Optional): All authors are expected to have substantially contributed to the study and manuscript writing (see https://publicera.kb.se/jevtm/policies).

Main Body

This should consist of text in 12 pts, double spaced with a justified margin, written in US English. While each article type has specified headings, the use of sub-headings is encouraged to aid clarity. These should be formatted as follows:

Main Heading **BOLD, FULL CAPITALS**
Sub-Heading ***Bold and Italicized, Title Case***
Sub-sub-heading *Italicized, sentence case*

Abstract
The abstract should be a maximum of 250 words and consist of the following headings (but see specific manuscript types below for exceptions):

- Background
- Methods
- Results
- Conclusions

Keywords
Three to six appropriate keywords should be included.

References

References should follow the Vancouver Style and should be noted in the text numerically in sequence within the text, using square brackets, e.g.: [1] or [1,2] or [1–3].

Example references:

Stannard W, Rutman A, Wallis C, O'Callaghan C. Central microtubular agenesis causing primary ciliary dyskinesia. Am J Respir Crit Care Med. 2004;169:634–7.

Tang AL, Diven C, Zangbar B, et al. The elimination of anastomosis in open trauma vascular reconstruction. J Trauma Acute Care Surg. 2015; *In Press*. doi: XXXXXXXXXX.

Rasmussen TE, Tai NRM. Rich's Vascular Trauma. 3rd ed. Philidelphia: Elsevier; 2015.

Thamm DH. Miscellaneous tumors. In: Withrow S, Vail D, editors. Small Animal Clinical Oncology. 5th ed. St. Louis: Elsevier; 2013. pp. 679–88.

Where there are more than six authors, the first three should be included followed by et al.

Figures/Tables

All figures/tables must be cited within the text, presented as Figure 1, Figure 2*a*,*b*, Figures 1 and 2, and Table 1.

Figure captions should be styled as follows.
Figure 1 Title of figure.
Details of figure described below. (**a**) First sub item. (**b**) Second sub-item.

Table captions are styled similarly.

Supplementary Digital Content

Where manuscripts would benefit from additional content (datasets, images, video) that does not necessarily need to be included in the published article, supplementary digital content (SDC) can be hosted. This includes, but is not limited to, tables, figures, or video. Authors should include in their cover letter a description of this content and its purpose. All supplementary digital content should be cited within the text, presented as e.g. Supplementary Video 1, Supplementary Dataset 1, Supplementary Image 1 etc.

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The below guidance only refers to the writing process, and not to the use of artificial intelligence (AI) tools to analyze and draw insights from data as part of the research process. We strongly recommend not to use AI in any analysis and any so should be reported if used. Not reporting use of AI can cause direct rejection of the submission.

Where authors use generative AI and AI-assisted technologies in the writing process, authors should only use these technologies to improve readability and language. Applying the technology should be done with human oversight and control, and authors should carefully review and edit the result. AI and AI-assisted technologies should not be listed as an author or co-author, or be cited as an author.

Authors must disclose in their manuscript the use of AI and AI-assisted technologies in the writing process by adding a statement at the end of their manuscript in the core manuscript file, before the References list. The statement should be placed in a new section entitled 'DECLARATION OF THE USE OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS'. This declaration does not apply to the use of basic tools for checking grammar, spelling, references etc. If there is nothing to disclose, there is no need to add a statement.

STATEMENT: During the preparation of this work the author(s) used [NAME TOOL / SERVICE] in order to [REASON]. After using this tool/ service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

The statement will appear in the published work. Please note that authors are ultimately responsible and accountable for the contents of the work. The Journal of Endovascular Resuscitation and Trauma Management is using dedicated tools for analysis of use of AI in submitted articles.

TYPES OF ARTICLES

All of the following article types are peer reviewed.

Original Articles

This is a report of a formal basic science or clinical research study. Manuscripts reporting unique scientific studies should be no longer than 5000 words for the main body of the text (from introduction to conclusion, and excluding abstract, references, tables and legends). They should consist of the following sections:

- *Introduction*: This should concisely present the background to the problem that the study hopes to answer. A hypothesis should be clearly stated.
- *Methods*: This section should be suitably detailed to permit replication of the study. The regulatory permissions for the study should also be detailed, e.g. Institutional Review Board, ethical committee etc, including a protocol/registration number. Where animal research has been undertaken, the institutional animal care and use guidelines that have been followed should be clearly stated.
- *Results*: These should involve the reporting of the salient positive and negative findings of the study in clear language. The use of images, figures and tables are encouraged, of which the data should not be duplicated in the prose. There is no maximum number of figures or tables, but these should be appropriate to the study. Numerical results and *P* values should be reported to three decimal places.
- *Discussion*: This should place the reported study findings in the context of the literature. Limitations and future direction should also be discussed. Authors must be careful to ensure that conclusions are not overstated and are supported by data.

They should contain a structured abstract with a maximum of 250 words.

Editorials

Short, focused Editorials on an important aspect of endovascular hemorrhage control are welcomed. These should endeavor to bring attention to an important topic, or accompany an article published within the Journal. The latter will be invited by the Editor. Submitted manuscripts should be no longer than 1500 words. Abstracts are not included.

Narrative Reviews

This style of article can afford the author considerable latitude in examining a pertinent topic in endovascular hemorrhage control. The literature should be examined objectively and presented to the reader in the context of current understanding. The author should be able to synthesize a narrative, which leaves the reader with a good understanding of an emerging or controversial topic. The author is welcome (and encouraged) to express an opinion, but where this is the case, it should be clearly stated.

The submitted manuscript should be no longer than 5000 words for the main body of the text (from introduction to conclusion, and excluding abstract, references, tables and legends). There is no formal structure; however, the use of logical headings/ sub-headings is important to enable readers to follow the article easily. The abstract should also be unstructured and be a maximum of 150 words.

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Systemic Reviews and Meta-Analyses

Where there is a topic within the subject area of endovascular hemorrhage control that has a substantial evidence base, a Systematic Review with/without a Meta-Analysis is considered more appropriate than a narrative review article. These articles should follow the methodology established by PRISMA. The overall aim is to provide a pooled analysis that enables firm conclusions to be drawn on a particular subject.

Submitted manuscripts should be no longer than 5000 words for the main body of the text (from introduction to conclusion, and excluding abstract, references, tables and legends). Authors should include a PRISMA checklist in their submission. The abstract should be no longer than 250 words.

Tips and Techniques

In the evolving world of endovascular hemorrhage control, the advice and opinion of actively practicing clinicians is of great importance. Both solicited and unsolicited submissions are reviewed, both on major and minor components of endovascular techniques. This can be presented in the context of "evidence" or just as an opinion. The use of quality images and diagrams is encouraged. This type of article permits the author to write from experience, rather than from the published literature. Articles explaining how to approach certain problems or how to accomplish certain maneuvers are welcomed.

The submitted manuscript should be no longer than 1500 words for the main body of the text (from introduction to conclusion, and excluding abstract, references, tables and legends). The abstract should be unstructured and be a maximum of 150 words.

Images of Interest

The Journal accepts images of interest accompanied by a short commentary. The aim of this section is to demonstrate and illustrate an educational message, rather than just to demonstrate dramatic pathology. Images can be submitted as a multi-panel with a series of scans/photographs in order to support the message presented in the narrative.

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These are short case reports including current literature reviews.

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The EVTM-ST Section will be a section of each JEVTM edition geared towards residents/fellows and education. The editors will invite one trainee to submit an interesting case report, and invite a reviewer to review and add a brief editorial. The editors should not be authors nor reviewers. The components of the section will include a standard case report presentation with figures of CT or angio or anything interesting and pertinent. The discussion should finish with a "what I learned" summary/bullet points for education purposes. The brief editorial by the reviewer is the final paragraph.

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The EVTM Society is a non profit organization that aims to share information on advanced methods for bleeding control and endovascular resuscitation, exchange of data, and cooperation and education. It is also designed to serve as a professional platform for the multidisciplinary approach.

By joining the EVTM Society you will be part of this global development.

To join, please visit jevtm.com/evtm-society.

The Membership fee is 50 USD biannually (25 USD per year).
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Vision and Mission:
Our mission is to promote optimal treatment and new methods for bleeding control in trauma and non-trauma patients, and state-of-the-art endovascular resuscitation. This will be achieved by a joint international body that will support the following:

- A web-based free platform for EVTM issues (jevtm.com).
- JEVTM – the Journal of Endoascular Resuscitation and Trauma Management, an open access peer-reviewed journal.
- The EVTM round table symposium, a platform for continuous debate and data exchange.
- Educational opportunities in the form of manuals (Top Stent), courses, workshops, and web seminars.
- Promoting open dialogue and cooperation between societies, organizations and the industry.
- Promoting new guidelines and recommendations for EVTM-related issues and protocols.
- Promoting research in EVTM-related areas, both human and animal.
- Promoting PR for EVTM issues, grants, and collaboration with industry.
- Encouraging residents and young colleagues to carry out research on EVTM issues.
- Promoting cooperation and data exchange with other medical instances.

Structure:
The EVTM council, led by the society chair, will change membership periodically (i.e., after two years). The council aims to have one or two representatives from each participating country and discipline.

The EVTM Society is supported at this stage by Örebro University Hospital in all financial respects (as part of EVTM research group support). This support has been granted for the forthcoming five years.

The main task of the council is to pave the way for the EVTM venture, and promote the JEVTM/EVTM symposium, EVTM-related courses, cooperation, and free exchange of information.

Members will obtain free access to all JEVTM information and discussions as well as regular updates on EVTM-related activities, education, and developments. Members will also be offered a reduced fee for the EVTM round table symposium.

The EVTM Society is registered in Sweden, and is managed in collaboration with the EVTM program at Örebro University Hospital, the JEVTM journal and web platform, and other institutes.

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Please consider joining by filling out the form at:
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Systematic Reviews and Meta-Analyses

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Safety of Current Therapies for Cardiogenic Cerebral Embolism: A Systematic Review

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Background: Cardiogenic cerebral embolism (CCE) accounts for approximately 20% of ischemic strokes and presents with severe neurological deficits and high mortality rates. The safety and effectiveness of current therapeutic strategies remain under evaluation. This systematic review aims to assess the safety profiles of current therapies, including thrombolysis, endovascular thrombectomy, anticoagulants, and antiplatelets, in patients with CCE.
Methods: A systematic search was conducted in Web of Science, Scopus, and PubMed for studies published up to May 2024. Articles were screened using the Rayyan intelligence tool, and their quality was assessed using the JBI critical appraisal tool. The review included randomized controlled trials (RCTs) and observational studies evaluating the safety and outcomes of different CCE treatment modalities.
Results: Ten studies met the inclusion criteria. Endovascular thrombectomy demonstrated improved functional outcomes with a reduced risk of mortality, although symptomatic intracranial hemorrhage (sICH) rates were comparable to other therapies. Intravenous thrombolysis with alteplase was associated with increased sICH risk but reduced 90-day mortality. Direct oral anticoagulants (DOACs), including apixaban and edoxaban, showed a favorable safety profile with no significant increase in intracranial bleeding. Antiplatelet therapy, particularly low-dose tirofiban, demonstrated reduced in-hospital mortality without increasing hemorrhagic risk.
Conclusion: While current therapies for CCE improve outcomes, their safety profiles vary. Endovascular thrombectomy appears effective for severe cases, whereas DOACs provide a safe alternative for long-term anticoagulation. Further large-scale trials are needed to refine treatment guidelines and minimize hemorrhagic risks.

Keywords: *Cardiogenic Cerebral Embolism; Stroke; Anticoagulants; Thrombolysis; Endovascular Thrombectomy; Antiplatelets*

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INTRODUCTION

Cerebral embolism, defined as the displacement of diverse emboli (including mural thrombi, atherosclerotic plaques, fat, tumor cells, fibrocartilage, or air) into cerebral arteries, may result in ischemic necrosis of brain tissue and localized neurological impairments. Cerebral embolism primarily occurs inside the internal carotid

artery system. Cerebral embolism constitutes roughly 15–20% of all ischemic strokes.

Cerebral embolism can be classified as cardiogenic or non-cardiogenic, depending on the origin of the emboli. Cardiogenic cerebral embolism (CCE) transpires when a thrombus or other substance from the heart migrates to the brain, resulting in an obstruction of the cerebral blood arteries. Emboli may present as white (non-hemorrhagic) or red (hemorrhagic) and frequently result in abrupt localized neurological impairments [1]. Cardiogenic cerebral embolism accounts for approximately 15% of all strokes and is considered one of the more preventable types of strokes [2].

Risk factors linked to cardiogenic cerebral embolism encompass several cardiac disorders, including atrial fibrillation (AF), ischemic heart disease, rheumatic mitral stenosis, and prosthetic heart valves. Atrial fibrillation, specifically, is pivotal, accounting for almost 75% of cardiogenic cerebral embolism cases. The pathogenesis entails emboli originating from the left atrium or left atrial appendage, traveling through the vascular system to obstruct brain arteries. The resultant neurological impairments can be catastrophic, impacting patients' quality of life and placing significant strains on families and healthcare systems [3,4].

Cardiogenic cerebral embolism presents with abrupt and frequently severe symptoms. These encompass hemiplegia (weakness or paralysis on one side of the body), sensory impairment, facial weakness, cognitive deficiencies, speech disturbances, nausea, vomiting, abrupt headache, and diminished eyesight [5,6]. Management of cardiogenic cerebral embolism entails multiple treatment strategies. Thrombolysis utilizing tissue plasminogen activator (tPA) can effectively dissolve blood clots when delivered within hours of stroke start, enhancing short-term and three-month outcomes by reinstating cerebral blood flow.

For individuals unable to undergo thrombolysis within 4.5 hours, anticoagulant treatment represents a safe and efficacious alternative. The combination of anticoagulant and antiplatelet treatment is advised. Approximately 41.2% of patients attain a favorable functional outcome (modified Rankin Scale score <2) at three months, and mortality rates exhibited variability but were not significantly different among therapy groups [2,4,7,8].

Cardiogenic cerebral embolism presents significant problems, requiring thorough assessment of existing treatments to improve safety and optimize patient care. The major aim of this systematic review is to evaluate the effectiveness of current treatments for cardiogenic cerebral embolism and to offer recommendations for innovative therapeutic strategies. Our objective is to enhance patient outcomes for this intricate disorder through a rigorous evaluation of the existing data.

METHODS

This systematic review adheres to the standards of the Preferred PRISMA2020 statement for Reporting Items in Systematic Reviews and Meta-Analyses. The research protocol has been documented in the Open Science Framework (OSF; registration doi: 10.17605/OSF.IO/KGPMQ).

Search Strategy

We collected original articles in this field by searching PubMed, Google Scholar, Web of Science, and Scopus databases for English-language literature published up to May 2024. The search was conducted based on ("cardiogenic cerebral embolism") or ("CCE"), AND ("therapy") or ("treatment") and a combination of a list of drugs and treatment modalities related to cardiogenic cerebral embolism as keywords. The full search strategy is reported in (Supplementary Table 1; Supplementary Digital Content is available online at https://doi.org/10.26676/ jevtm.40591).

Furthermore, duplicate records were omitted using EndNote version 21 and the Rayyan intelligence tool for systematic reviews. To identify other suitable studies, we also reviewed the references of relevant papers and reviews on the topic of safety of current therapies for cardiogenic cerebral embolism (Supplementary Table 1).

Eligibility criteria

Following the exclusion of animal research, the remaining studies were incorporated into the review if they adhered to the PICOS criteria:

P (Population): Patients with cardiogenic cerebral embolism.

I (Intervention): Current therapies.

C (Control group): Patients with cardiogenic cerebral embolism who have undergone sham trials or placebo trials.

O (Outcome): Patient's progression-free survival and responsiveness to treatment.

S (Study design): English-language randomized controlled trials (RCTs).

Study Selection and Quality Assessment

Two reviewers (MA, AM) employed the Rayyan intelligence tool for systematic reviews to evaluate and filter titles and abstracts in a blinded manner, identifying analogous works. The texts were acquired to evaluate the qualifications of the "Yes" and "Maybe" groups. In the event of conflicts, a third reviewer was engaged to facilitate consensus and resolve discrepancies. Conflicts were addressed by dialogue between the parties. Quality assessment and risk of bias for each included study were conducted utilizing JBI's critical appraisal methods.

RESULTS

Study Characteristics

A total of 14,236 studies were found in the screening database search, 5,740 of which were duplicate records. Two reviewers (MA, SH) examined article titles and/or abstracts. After screening 8,496 records (Figure 1), we excluded 8,443. In total, 53 studies were selected for full-text review. Forty-three reports were not retrieved due to the unavailability of full text. Ten studies met the inclusion criteria and were included in this review.

Results of Systematic Analysis of Current Therapies

Endovascular therapy

In this Chinese study from 2016, a total of 17 patients had thrombectomy with Solitaire stent [9]. Ten of these patients had intravenous recombinant tissue plasminogen activator (IV rtPA) thrombolysis with bridging arterial embolectomy, while seven of them had just undergone thrombectomy. The 16 patients in the control group only underwent IV rtPA thrombolysis. National Institutes of Health (NIH) Stroke Scale scores, Glasgow Coma Scale

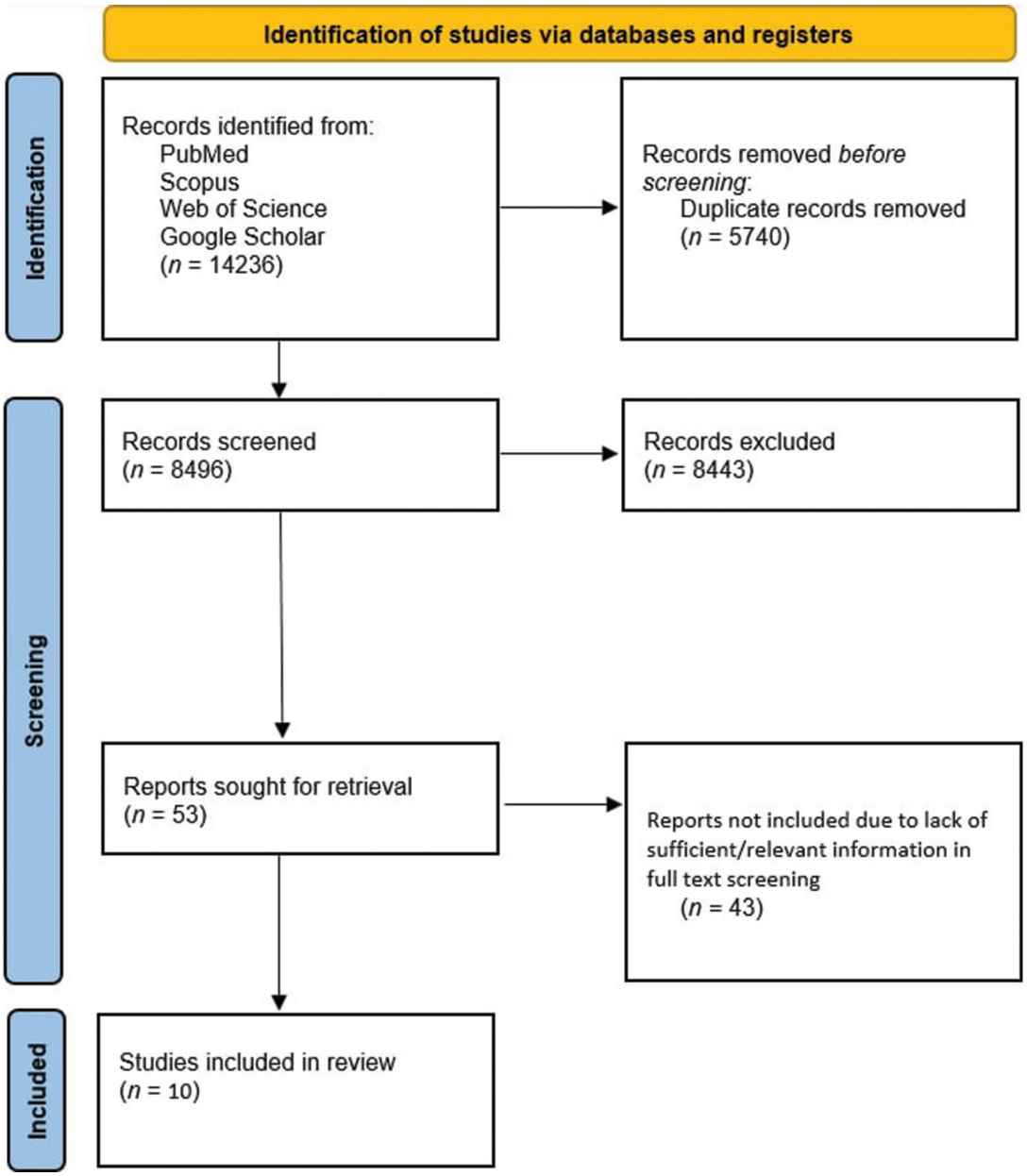

Figure 1 PRISMA flow diagram of the study selection procedure.

(GCS), symptomatic intracerebral hemorrhage, incidence of hernia, high perfusion encephalopathy, or mortality between the two groups were assessed [9].

In this Japanese study from 2019, a total of 555 patients were examined [10]. Among them, 374 patients underwent endovascular treatment (EVT), while 181 did not receive this treatment. The median age was 73 years (66–77 years). The main result was delayed hemorrhage. Any intracranial hemorrhage, symptomatic intracranial hemorrhage indicating neurological deterioration of >4 points on the NIH Stroke Scale (NIHSS) within 72 hours of stroke onset, and transient ischemic attack (TIA) or stroke recurrence within 90 days were the secondary outcomes [10].

Intravenous thrombolysis

The study by Cao et al. took place in China in 2022 [11]. In this study, 290 patients with cardioembolic (CE) stroke from the DIRECT-MT trial were included. Of these, 146 patients received direct mechanical thrombectomy (MT), and 144 received a combination therapy (endovascular thrombectomy with intravenous alteplase; bridging therapy group).

The primary outcome was the 90-day modified Rankin Scale (mRS) score [11].

In this study from 2021, they pooled data from stroke registries at eight comprehensive stroke centers across the US [12]. They retrospectively analyzed 1,367 patients (72.4%) who did not receive MT and 522 patients (27.6%) who received MT. They sought to determine whether alteplase treatment was related to 90-day mortality and the rate of hemorrhagic transformation [12].

In this study (2018), they analyzed data on patients treated with rtPA from the Safe Implementation of Treatments in Stroke–Eastern Europe (SITS-EAST) register of Central and Eastern Europe [13]. Thirty percent of all strokes were cardioembolic strokes (n = 4,131). Three-month mortality, symptomatic intracerebral hemorrhage (SICH) rate, excellent clinical outcome (mRS score 0–1) at three months following a stroke, and NIHSS score were reported as outcomes [13].

Direct oral anticoagulants (DOAC)

In this Italian study from 2020, 75 patients (median age: 78.3 years; 48 females, 27 males) were enrolled in the Prospective Observational Study of Safety of Early Treatment with Edoxaban at therapeutic dosage (60 mg/day) within five days of cardioembolic stroke onset [14]. NIHSS scores were evaluated upon admission and following revascularization, and were assessed at discharge. GCS, mRS score, intracranial bleeding, major and minor bleeding, and mortality were also reported [14].

In this US study from 2021, a total of 47 patients were randomized to the warfarin arm, and 41 patients received apixaban [15]. Early use of apixaban was started at days 0–3 for TIA, days 3–5 for small-sized acute ischemic stroke (AIS) (<1.5 cm), and days 7–9 for medium-sized AIS (≥1.5 cm, excluding entire cortical territory), while warfarin was started one week after TIA, or two weeks after AIS. The study participants' mean age (SD) was 73.5 (±12.7) years, with 56% of them being female. The incidence of the mRS score, NIHSS, and the primary composite safety outcome (fatal stroke, recurrent ischemic stroke, or TIA) were reported [15].

In this Italian study from 2016, 147 patients started DOAC within seven days of stroke onset [16]. Out of these, 97 (66%) started DOAC after 1–3 days, and 50 (34%) started DOAC after 4–7 days. The outcome variables on the follow-up were post-DOAC intracranial hemorrhage and post-DOAC recurrent ischemic stroke (any new ischemic infarct) [16].

Antiplatelets

In this study from 2000, they analyzed data from 449 patients at 45 Norwegian centers [17]. The patients were divided into two groups and given either dalteparin 100 IU/kg (low-molecular-weight-heparin; LMWH) subcutaneously twice a day along with placebo tablets daily or aspirin tablets 160 mg daily and placebo ampoules subcutaneously twice daily. The frequency of recurrent ischemic stroke and symptomatic cerebral hemorrhage during the first 14 days, mRS score, The International Stroke Trial scale, and deaths were reported as outcomes [17].

In this study from 2021, conducted at a stroke center in China, they included 288 cardioembolic stroke patients treated with endovascular therapy [18]. Out of these, 117 patients received tirofiban, whereas 171 patients did not. The primary outcome was sICH prior to discharge. The secondary outcomes included re-occlusion, in-hospital mortality, and three-month functional outcomes [18].

Effects of Interventions

Fu et al. demonstrated that patients undergoing embolectomy, either alone or in conjunction with thrombolytic therapy, had superior short- and long-term functional outcomes compared to patients receiving IV rtPA therapy alone [9]. Compared to the group that received thrombolytic treatment alone, the NIHSS score improvement for the Solitaire stent embolectomy group was noticeably more significant. The group with embolectomy showed a significantly higher GCS improvement than the group that received IV rtPA therapy alone. The long-term outcome that was assessed by measuring the mRS score was determined to be significantly better in stent patients [9]. The GCS is typically

performed upon arrival at the emergency department to assess the patient's initial level of consciousness. This is a crucial early evaluation to determine the severity of neurological impairment and guide immediate treatment decisions.

Matsukawa et al. demonstrated noticeably lower NIHSS scores in the EVT group [10]. Patients in the EVT group had a better clinical course (mRS score 0–2) than those in the no-EVT group. The EVT group had a significantly lower mortality rate within 90 days than the no-EVT group. The proportions of any intracranial bleeding and symptomatic intracranial bleeding within 72 hours and recurrence of stroke or transient ischemic attack within 90 days were similar between the two groups [10].

According to Cao et al., direct mechanical thrombectomy may be more beneficial for individuals with mild to moderate cardioembolic stroke than bridging therapy [11]. There were no significant differences in the outcome and mortality rate of CE stroke patients with an NIHSS >15 between the two treatment groups, but patients with an NIHSS ≤15 in the direct MT group were linked to better outcomes and lower mortality than those in the bridging therapy group.

The results from Zhao et al. showed that patients who received tirofiban experienced fewer decompressive craniotomies and cerebral hernia than those who did not [18]. There was a significant difference in the three-month mortality rates between patients who received tirofiban (20.5%) and those who did not (31.6%).

Yaghi et al. discovered that individuals with AIS in the context of AF who were not treated with MT had a lower mortality rate when they received IV alteplase [12]. Among patients undergoing MT, there was a non-significant reduction in the number of passes and deaths in subjects treated with intravenous alteplase compared to those who did not receive intravenous alteplase. Alteplase-treated patients were more likely to have an initial NIHSS score with a higher median (interquartile range) (8 [4–15] versus 6 [2–14], $P = 0.002$).

According to Vaclavik et al., there is no association between cardioembolic strokes (CS) and higher mortality rates [13]. After intravenous thrombolysis (IVT), patients with CS had better outcomes and were less likely to have sICH [13].

Frisullo et al. found that 53 (70.7%) of the 75 patients had excellent functional outcomes at three months (defined as mRS score 0–1), two (2.7%) patients had gastrointestinal bleeding, and 11 (14.7%) patients had minor bleeding (five epistaxis, three gingival bleedings, and three cutaneous hematomas) [14]. None of the 75 patients had significant intracranial hemorrhage at three months.

Cappellari found no correlation between the early introduction of DOAC and intracranial bleeding [16]. No patients experienced recurrent ischemic stroke.

The study conducted by Berge provides no evidence that high-dose LMWH is superior to aspirin for the prevention of recurrent ischemic stroke during the first 14 days [17]. The study showed no significant increase in sICH or improved outcome on LWMH compared with aspirin.

According to Labovitz et al., the early use of the DOAC apixaban did not increase the number of intracranial hemorrhages, including hemorrhagic transformation (HT) and intracranial hemorrhages (ICH) [15].

The summary of the outcomes is shown in Table 1.

DISCUSSION

This systematic review summarizes the safety and effectiveness of available therapies in treating cardiogenic cerebral embolism using actual patient data.

Cardiogenic cerebral embolism is a highly hazardous condition with a high rate of occurrence, disability, death, and recurrence [28,29]. It can cause immediate and critical neurological symptoms, and the high risk of bleeding and poor rate of recanalization might reduce the effectiveness of even very timely therapy [9].

Mechanical Thrombectomy

Endovascular mechanical recanalization technology is rapidly being used as a first-line treatment for acute cerebral infarction since the development of catheter and neural intervention techniques, especially in patients with occluded major cerebral arteries. Large intracranial vessels, such as the basilar artery, the middle cerebral artery, the anterior cerebral artery, and the end of the internal carotid artery, frequently become blocked due to cardioembolisms. The recanalization rate of such occluded arteries is relatively low, about 10%, when rtPA thrombolytic therapy is the only treatment used. Furthermore, the bleeding conversion rate is estimated to be 10.23%. Using IV rtPA thrombolysis alone to treat cerebral embolism often does not achieve satisfactory results [28,30].

The MR-CLEAN trial [31] revealed the first indication that mechanical thrombectomy performed within six hours of symptom onset improved 90-day clinical outcomes (mRS score) compared to a group receiving standard medical care, with 90.6% receiving IV rtPA within 4.5 hours. According to the Fu et al. study, the stent group had significantly higher NIHSS and GCS scores during admission and discharge than the group that received drug therapy alone. In addition, the group that underwent mechanical thrombectomy had considerably better long-term clinical outcomes [9].

For the first time, a sub-analysis of an extensive prospective registry indicated that EVT could reduce the incidence of delayed hemorrhage and had no influence on neither any intracranial hemorrhage nor on symptomatic intracranial hemorrhage within 72 hours

Table 1 Summary of study characteristics and findings.

Author	*Year*	*Country*	*Participants*	*Age*	*Treatment*	*Efficacy*	*Outcome*	*Conclusion*
Maolin Fu [19]	2016	China	Embolectomy group = 17, Control = 16	Case = 55.24 ± 12.55 years, Control = 63.31 ± 13.40 years	7 thrombectomy and 10 IV rtPA thrombolysis with bridging arterial embolectomy (Solitaire stent embolectomy), Control = IV rtPA thrombolysis	–	• Reduction of NIHSS score • Better GCS at discharge • Low score of modified rankin scale	Embolectomy has better short-term and long-term outcomes compare to rtPA
Giovanni Frisullo [20]	2020	Italy	75 patients	78.3 years median	Edoxaban at therapeutic dose (60 mg/day) within five days from cardioembolic stroke onset in 90 days	–	• Reduction of NIHSS SCORE • Significant reduction of intracranial bleeding	Looks eligible in acute phase, but required large group study
Shadi Yaghi [21]	2021	The United States	1,889 patients, Study group = 1,367 patients (72.4%) alteplase, Control = 522 patients (27.6%) received MT	77.2 ± 11.8 years	Alteplase	Reduced risk of 90-day mortality = 14.3% (43/300)	Alteplase increases risk of hemorrhagic transformation, but reduced 90 days mortality risk	Alteplase without MT reduced risk of mortality
Daniel Vaclavik [22]	2018	Czech Republic and Central and Eastern Europe	13,772 patients, 4,131 CCE (30%)	70.8 ± 11.49 years	Intravenous thrombolysis (IVT)	No significant difference in mortality rate	• The risk of sICH is reduced • Higher chance of getting better within 24 h	Improves patient outcome
Wenbo Zhao [23]	2021	China	288 patients, Study group = 117, Control = 171	Case = 70.1 ± 11.0 years Control = 69.6 ± 11.0 years	Tirofiban therapy = 5 mg diluted with 100 ml NL saline at standard rate 1 mL/min (doses ranging from 0.25 mg to 0.5 mg). Tirofiban IV administered at a rate of 4–8 mL/h (i.e., 0.2 to 0.4 mg/h) for 12–24 h	Mortality rate significantly reduced	• Re-canalizations time onset gets faster • No difference in ICH risk • Reduced risk of hernia and decompressive craniectomy • Small difference in mRS scores	Tirofiban reduced mortality death, but no difference in ICH risk
Eivind Berge [24]	2000	Norway	449 patients, 224 dalteparin, 225 aspirin	80 years median	LMWH, dalteparin (100 IU/kg subcutaneously twice a day), aspirin (160 mg every day)	Dalteparin increases risk of mortality rate	• No difference in the rate of recurrent ischemic stroke within 14 days • No significant difference in symptomatic and asymptomatic ICH • ICH more severe in dalteparin • Dalteparin increases risk of mortality rate in 14 days but no difference after three months	No difference in functional outcomes between dalteparin and aspirin

Arthur J Labovitz [25]	2021	The United States	88 randomized, warfarin = 47, apixaban = 41	73.5 ± 12.7 years	Apixaban	Rate of death is reduced	Rates of fatal stroke, recurrent ischemic stroke, symptomatic ICH, and death reduced but rate of symptomatic HT increased	Apixaban seems secure and eligible for early anticoagulant therapy
Manuel Cappellari [26]	2016	Italy	147 patients, DOAC between 1 and 3 days (n = 97), Control = 4–7 days (n = 50)	Case = 78.8 ± 9.1 years, Control = 79.3 ± 6.5 years	DOAC within the first three days of stroke onset		• Reduced mean stroke onset • Lower NIHSS score • Rate of intracranial bleeding reduced in small infarct but increases in large infarct • No correlation between early DOAC and risk of intracranial bleeding after DOAC administration	• Safe and eligible early applying DOAC for nVAF patients with small and medium sized infarct • The only factor for prediction of intracranial bleeding is large infarct
Hidetoshi Matsukawa [10]	2019	Japan	562 patients, Study group (EVT) = 374, Control = 188	Case = 73 (66–77) years, Control = 72 (66–7) years	Endovascular treatment	Significant reduction of mortality rate	• Lower NIHSS score • Lower mRS score • More likely to require IV rtPA • Less chance of decompressive hemicraniectom • Same ICH risk	Reduce the risk of DH with no change in ICH risk
Jie Cao [27]	2022	China	290 patients, 146 received direct MT, 144 combination therapy with intravenous alteplase and endovascular thrombectomy (bridging therapy group)	18–60 years 73 years median	Direct mechanical thrombectomy, Control = alteplase and MT	No significant difference in mortality rate	No significant difference between the two groups in primary outcome (modified Rankin scale)	No difference of mRS scores in MT with and without alteplase within 90 days
			100/290 NIHSS ≤ 15 (47 MT/53 BT)			Reduced mortality risk	Primary and secondary outcomes (Functional independence, mRS (mRS 0–3) at 90 days, NIHSS after 24 h, NIHSS at 5–7 days or discharge) are better with MT only	Direct MT has better outcome for low risk CCE
			190/290 NIHSS > 15 (99 MT/91 BT)			No significant difference in mortality rate	No significant difference between the two groups in primary and secondary outcomes	Only slight difference in outcomes for high risk CCE

BT, bridging therapy (combination of intravenous alteplase and endovascular thrombectomy); CCE, cardioembolic stroke; DH, delayed hemorrhage; DOAC, direct oral anticoagulant; EVT, endovascular treatment; GCS, Glasgow Coma Scale; HT, hemorrhagic transformation; ICH, intracranial hemorrhage; IV rtPA, intravenous recombinant tissue plasminogen activator; IVT, intravenous thrombolysis; LMWH, low molecular weight heparin; mRS, modified Rankin Scale (a measure of functional outcome after stroke); MT, mechanical thrombectomy; NIHSS, National Institutes of Health Stroke Scale (a measure of stroke severity); NVAF, non-valvular atrial fibrillation; rtPA, recombinant tissue plasminogen activator; sICH, symptomatic intracranial hemorrhage.

in patients with cardioembolic proximal intracranial occlusion in the anterior circulation [10].

Intravenous Thrombolysis

The question of whether individuals with acute ischemic stroke and atrial fibrillation should be treated with heparin as an anticoagulant has long been debated [32–34].

The results of the study by Berge et al. provide no evidence that high-dose LMWH is better than aspirin for improving outcomes at 14 days or three months, or in preventing recurrent ischemic stroke or any other event during the first 14 days [17].

Yaghi et al. discovered that patients with acute ischemic stroke in the setting of AF who were not treated with MT had a lower 90-day mortality rate when they received intravenous alteplase medication [21]. These results support the findings of the previous extensive cohort studies [21].

When MT patients received IV alteplase treatment as opposed to those who did not, there was a non-significant reduction in the number of passes and deaths among the former group [12]. This aligns with the pivotal thrombectomy trials, which showed no impact on mortality or outcome [35,36]. This is also consistent with recent trials demonstrating no substantial additional benefit of alteplase usage in patients with proximal blockage undergoing MT [34,37,38]. These findings may be attributable to alteplase's poor ability to achieve reperfusion in patients with proximal large-artery occlusion successfully. However, our results emphasize the need for more research on this matter.

In addition, based on the RCT by Cao et al., patients with mild and moderate cardioembolic stroke may benefit more from direct mechanical thrombectomy than from bridging therapy [11].

DOCA

For individuals with nonvalvular AF, DOACs such as apixaban, dabigatran, edoxaban, and rivaroxaban are now the main treatment option for preventing stroke [39]. One in six stroke patients who are eligible for IVT are expected to have been administered DOACs after the switch from vitamin K antagonists (VKAs) to DOACs. In situations of ischemic stroke, the recommendation suggests against administering IVT to patients who have recently administered DOACs (within the last 48 hours). This advice is based on the assumption that there is a higher risk of sICH. Nevertheless, there is not much data on when oral anticoagulation should be started following an acute stroke [40].

A prospective, non-randomized study found that early initiation of edoxaban, within five days, does not seem to lead to any symptomatic intracranial bleeding or recurrent stroke after three months. However, two gastrointestinal major bleedings and 11 minor bleedings were reported [14]. A prospective analysis showed no association between early initiation of DOAC (1–3 days after stroke onset) and intracranial bleeding in stroke patients with non-valvular atrial fibrillation [16]. However, the major weakness in these studies was the absence of a control group with delayed anticoagulant treatment.

Based on our review, a randomized controlled trial was done comparing the safety of early use of apixaban versus warfarin in a 1:1 ratio. It revealed that apixaban had numerically smaller but statistically comparable rates of death, fatal stroke, recurrent strokes/TIA, and symptomatic hemorrhages. Early anticoagulant initiation following TIA or small- or medium-sized AIS from AF does not seem to impair patient safety [15]. However, more extensive pivotal trials are necessary to ascertain the possible effectiveness of the early initiation of DOCA.

Antiplatelets

The standard treatment for patients with AIS due to large-vessel obstruction is EVT [41–43]. Conversely, endothelial damage might be an unavoidable consequence that results in early re-occlusion and infarction extension [44]. Significant interest has been shown in the adjunctive administration of antiplatelet medications to reduce the rate of ischemia complications and increase the rate of favorable reperfusion.

Earlier research demonstrated that tirofiban was linked to a greater possibility of functional independence in AIS patients receiving EVT. It was also associated with a decreased risk of re-occlusion and an improved rate of favorable reperfusion [45,46].

However, a prospective study of 288 cardioembolic stroke patients found no correlation between the administration of low-dose tirofiban and three-month mortality. Additionally, there was no association with hernia, decompressive craniectomy following EVT, or different types of intracranial hemorrhage, including ICH, sICH, or fatal ICH.

Furthermore, there was no association between the use of tirofiban and a low incidence of re-occlusion after EVT. On the other hand, tirofiban was linked to a lower risk of in-hospital mortality [18]. The study design and the number of patients in this study may have caused bias. Further studies are needed to confirm these results and improve the best treatment course that can benefit this patient population.

The main strength of this study is that it explicitly addresses cardioembolic stroke patients, which is the first review of different available treatment modalities for these patients. The primary limitation of our investigation is the small sample size of the included studies. More large-scale multicenter randomized controlled trials are necessary to validate these findings.

LIMITATIONS

This systematic review has several limitations that should be acknowledged. First, the included studies exhibited variability in study designs, sample sizes, and patient characteristics, which may have introduced heterogeneity in the results. The diversity in treatment protocols and outcome measures among different studies limits direct comparability and the generalizability of findings to broader populations.

Second, while RCTs were included in this review, some of the studies were observational, which may be subject to selection bias and confounding factors. The absence of uniform inclusion criteria across studies further complicates the interpretation of treatment efficacy and safety profiles.

Third, the small sample size in certain studies, particularly those evaluating specific anticoagulants and antiplatelet therapies, restricts the ability to draw definitive conclusions regarding their long-term safety and effectiveness. Larger multicenter trials with longer follow-up durations are needed to validate these findings.

Additionally, publication bias may have influenced the results, as studies reporting positive outcomes are more likely to be published, whereas negative or inconclusive findings may be underrepresented in the literature. The reliance on published data also limits access to unpublished clinical trial results, which may provide a more comprehensive understanding of treatment risks and benefits.

Lastly, the review primarily focuses on available studies up to May 2024, and emerging therapeutic advancements or novel interventions beyond this timeframe may not be captured. Continuous research and real-world data collection are necessary to further refine treatment strategies for cardiogenic cerebral embolism.

CONCLUSION

This systematic review highlights the safety profiles of current therapeutic strategies for CCE, a major cause of ischemic stroke with significant morbidity and mortality. Endovascular thrombectomy emerged as a highly effective intervention, particularly in severe cases, improving functional outcomes without increasing intracranial hemorrhage risk. Intravenous thrombolysis with alteplase demonstrated benefits in reducing 90-day mortality but carried an increased risk of sICH. DOACs such as apixaban and edoxaban exhibited a favorable safety profile, offering a viable alternative for long-term anticoagulation with minimal risk of hemorrhagic complications. Additionally, low-dose tirofiban showed potential in reducing in-hospital mortality without elevating bleeding risks.

Despite these promising findings, variability in study methodologies and sample sizes underscores the need for further large-scale RCTs to refine treatment guidelines. Future research should focus on optimizing therapeutic strategies to balance efficacy and safety, particularly in high-risk patient populations. Tailored approaches integrating patient-specific factors will be crucial in improving long-term outcomes for individuals with CCE.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Author Contributions

Study concept and design: MAA, SKSR. Acquisition of data: KKH, NH, AM. Analysis and interpretation of data: SM, MAA. Drafting of manuscript: OR. Critical revision of the manuscript for important intellectual content: MA, AA, MR, MAB, SHK. Administrative, technical, and material support: AHA, AIP. Study supervision: MAA, SKSR.

SUPPLEMENTARY DIGITAL CONTENT

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Supplementary Table 1. Database search strategy.

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Original Article

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Establishing a Swine Model of Acute Respiratory Distress Syndrome Secondary to Ischemia-Reperfusion Injury Following Acute Limb Ischemia

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Background: Acute Respiratory Distress Syndrome (ARDS) is a severe complication of ischemia-reperfusion injury (IRI), characterized by acute hypoxemic respiratory failure and high mortality. Acute limb ischemia (ALI) can trigger systemic inflammation leading to ARDS. This study introduces a swine model of ARDS secondary to ALI.
Methods: Two Yorkshire swine were used in this study. Animals were anesthetized and subjected to nine hours of hindlimb ischemia via arterial occlusion. The limb was then reperfused and animals monitored through physiological parameters, computed tomography imaging, lung ultrasounds and histology. Data was then analyzed using GraphPad Prism and Analyze software for statistical and imaging evaluation.
Results: Baseline measurements confirmed normal vasculature and stability, access was obtained and occlusion delivered. Following nine hours of hindlimb ischemia, reperfusion led to progressive respiratory decline, with worsening oxygenation, decline in the Horowitz index, elevated lactate and potassium levels, and imaging showing early signs of lung injury. Post-mortem analysis confirmed lung congestion, consistent with ARDS.
Conclusions: The study demonstrates a novel, easily performed, cost-effective and replicable swine model of ARDS using hindlimb IRI. This model mimics physiological and sterile conditions seen in a clinical setting and serves as a valuable tool for studying ARDS. It also allows for investigation of the systemic inflammatory cascade triggered by peripheral ischemia, mirroring human ARDS cases that occur with distal injuries. Future studies with larger sample sizes and extended critical care periods are recommended to validate the technique and enhance its relevance for experimental applications.

Keywords: *ARDS; ALI; Swine Model; Ischemia Reperfusion Injury*

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INTRODUCTION

Acute Respiratory distress syndrome (ARDS) is recognized as one of the most severe manifestations of organ dysfunction following ischemia-reperfusion injury (IRI) [1]. ARDS is defined as acute hypoxemic respiratory failure with bilateral pulmonary infiltrates on chest X-ray or computed tomography (CT) of a non-cardiac origin, and a Horowitz index (PaO_2/FiO_2; the ratio of partial pressure of oxygen in arterial blood to the fraction of inspiratory oxygen concentration) for lung function of less than 300 mmHg. The incidence of ARDS in the United States is estimated to be between 62.2 and 78.9 cases per 100,000, among which 75% is moderate or severe. The overall mortality was evaluated at 43% [2,3]. Although intensively investigated for years, the fundamental mechanisms contributing to ARDS have not been completely understood [3].

Acute limb ischemia (ALI) is defined as a sudden decrease in limb arterial perfusion that jeopardizes limb viability [4]. It is a common vascular emergency, with an incidence of 22–26 per 100,000 patients per year [5].

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One of the consequences of revascularization is IRI, defined as worsening of cellular dysfunction and death following restoration of the blood flow to previously ischemic tissues. The mechanism behind the phenomenon is mostly related to dysregulation of metabolic pathways during ischemia, accumulation of metabolites and generation of reactive oxygen species (ROS) with reintroduction of oxygen during reperfusion [6]. This is particularly important in large-scale combat operations, such as the war in Ukraine, where, due to loss of air supremacy, the tourniquet time is significantly prolonged [7]. More notably though, this process is not limited to the affected area (for instance, the limb), but may lead to extensive systemic insult with multiple organs, including ARDS [8]. Alongside its high mortality, ARDS is very costly to manage, as these patients require prolonged intensive care hospitalization, and there are limited therapeutic modalities available to combat this condition.

This has necessitated the creation of a reliable, reproducible and cost-effective animal model for further investigations and translational research to develop new therapies for ARDS. Commonly described animal models of ARDS were established by surfactant washout, oleic acid (OA) intravenous injection or lipopolysaccharide (LPS) injection. These, however, differ from the actual pathomechanism of lung insult [9]. A physiologically comparable model was implemented by inducing pulmonary ischemia by clamping the pulmonary artery, the bronchial artery, and the bronchus in the affected lung, but this model requires a rather complex and invasive surgical approach [1].

In the current work we propose a swine model of ARDS secondary to ALI. In this setting, in a time-dependent manner, the corresponding reperfusion injury releases a systemic burst of pro-inflammatory mediators and ROS, precipitating non-cardiogenic pulmonary edema. This approach offers a practical, physiological, less invasive and more accessible alternative to traditional ARDS models, which are often complex and costly. Facilitating this model in the medical field could enhance the understanding of ARDS mechanisms and allow preclinical studies of novel therapies with better translatability.

METHODS

Study Design and Overview

Before commencing the experimental protocol, approval from the Institutional Animal Care and Use committee was achieved. The animal facility is accredited by the American Association of Laboratory Animal Sciences.

Two female Yorkshire swine weighing between 47 kg and 52 kg were enrolled in the study. ARDS was induced using a three-phase process: animal preparation, hindlimb ischemia and reperfusion induced ARDS.

Animal Preparation

The animals were initially sedated with telazol (5 mg/kg) and xylazine (2 mg/kg) via intramuscular injection. The animals were transported to the laboratory where they were endotracheally intubated and general anesthesia was maintained using intravenous propofol. The animals were mechanically ventilated using a volume-controlled mode with a tidal volume of 8–12 ml/kg, FiO_2 60%, positive end-expiratory pressure (PEEP) at 5 cmH_2O and a respiratory rate titrated to maintain an end-tidal CO_2 between 30 and 40 mmHg. This is standard for large animal studies in our laboratory.

Ultrasound-guided percutaneous vascular access was obtained in the left common carotid artery (5 Fr) using a modified Seldinger technique. Intravenous catheters were inserted into bilateral ear veins for propofol administration and maintenance fluids. Under fluoroscopic guidance, the left carotid artery was upsized to a 12 Fr DrySeal Flex Introducer sheath (Gore, Flagstaff AZ) over a 260 cm 0.035″ Glidewire Advantage (Terumo, Tokyo, Japan). A 5 Fr Pigtail catheter (AngioDynamics, Latham, NY) was inserted into the 12 Fr DrySeal sheath, and angiography was performed with a power injector to appreciate the anatomy of the terminal aortic trifurcation. The same pigtail catheter was then used for serial digital subtraction angiography.

Induction of Hindlimb Ischemia

To achieve hindlimb ischemia, two 260 cm 0.035″ Glidewire Advantage (Terumo, Tokyo, Japan) were inserted through the DrySeal sheath and advanced into the left external iliac artery (EIA) and middle sacral artery (MSA). A 6 Fr, 135 cm, 8 mm × 40 mm Mustang balloon (Boston Scientific, Marlborough, MA) and a 5 Fr, 135 cm, 6 mm × 20 mm Mustang balloon (Boston Scientific) were advanced into the EIA and MSA, respectively. An Endoflator (Boston Scientific) was used to inflate each balloon under fluoroscopy until each artery was occluded. A repeat angiogram was performed to confirm occlusion. Total endovascular occlusion of the left lower extremity was maintained for nine hours without any intervention.

Reperfusion-Induced ARDS

At the end of the nine hours, the left lower extremity was revascularized by restoring native inflow by deflating the common iliac artery balloon and the left MSA balloon. Animals were then observed with continuous physiological monitoring and serial arterial blood gas (ABG) analysis was performed.

Data Collection

During the experiment, PaO_2 and FiO_2 measurements were obtained from ventilator settings and ABGs. A post-reperfusion CT scan of the thorax was acquired six

hours after the beginning of reperfusion, alongside an ultrasound of the lungs. Histology samples of the lungs were collected following euthanasia.

Data Analysis

GraphPad Prism v8.0 (GraphPad Software Inc, San Diego, CA, USA) was used for visual representation of data and statistical analysis. CT scans were analyzed with the Analyze software (Analyze Direct, Overland Park, KS, USA). Histology samples were stained with hematoxylin and eosin (H&E) and reviewed under microscope (Zeiss, Axiovert 135 TV, Germany).

Ethical Approval

All animal procedures were approved by the Institutional Animal Care and Use Committee (IACUC) at Mayo Clinic (Protocol Number: A00007153-23) and were conducted in accordance with institutional and national guidelines for the care and use of laboratory animals.

RESULTS

Two female Yorkshire Swine were enrolled in the study. Instrumentation was successfully performed. Baseline angiogram was obtained depicting normal swine vasculature (Figure 1*a*). Baseline ABG measurements were obtained, with a lactate of 1.8–2.1 mmol/L and potassium of 4.2–4.5 mmol/L. Baseline FiO_2 was 59%, blood pressure 130/80 mmHg, heart rate 100 bpm, SpO_2 99%, respiratory rate 16 and end-tidal CO_2 30 mmHg. The baseline Horowitz index was calculated to be 503.9 and 510 mmHg, for each animal, respectively. Subsequently, EIA and MSA balloon occlusion was achieved, and confirmed with angiogram images (Figure 1*b*,*c*).

During the nine-hour occlusion phase, no significant events occurred, and the animals remained hemodynamically stable. Upon reperfusion, blood flow was restored (Figure 1*d*). The lactate was 1.9–2.0 mmol/L, the potassium 4.8–4.9 mmol/L and the Horowitz index 340–349.5 mmHg.

During the reperfusion-induced ARDS phase, oxygen saturation decreased to 92%, necessitating ventilator adjustments, including increasing FiO_2 to 100%, transitioning to pressure-controlled ventilation, raising PEEP while maintaining a plateau pressure below 30 cmH_2O, and implementing an inverse inspiration-to-expiration ratio greater than 1:1.

After six hours of reperfusion, lung imaging including ultrasound and CT was obtained depicting B-lines and dense consolidations, respectively (Figures 2 and 3). Lactate was recorded at 4.9–6.4 mmol/L and potassium was 5.3–6.1 mmol/L. The Horowitz index was at 110 mmHg, indicating moderately severe lung injury. The graph depicting Horowitz index changes is illustrated below (Figure 4).

At the end of the study, the lungs were inspected and post-mortem lung tissue were obtained. The tissue was stained with H&E, which revealed diffuse alveolar damage, inflammatory infiltrate and edema, consistent with early ARDS (Figure 5).

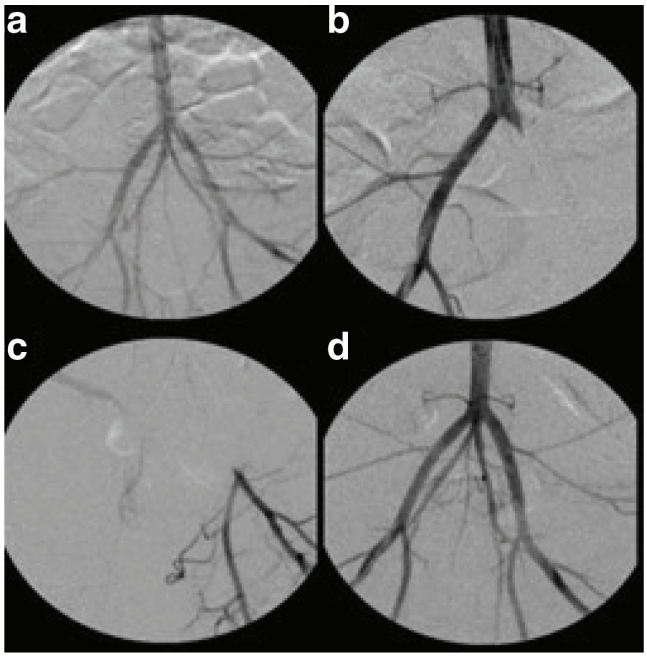

Figure 1 Representative digital subtraction angiography images: (**a**) baseline angiogram, (**b**) total balloon occlusion of the EIA and MSA, (**c**) tibial access confirmation and (**d**) post nine hours of occlusion.

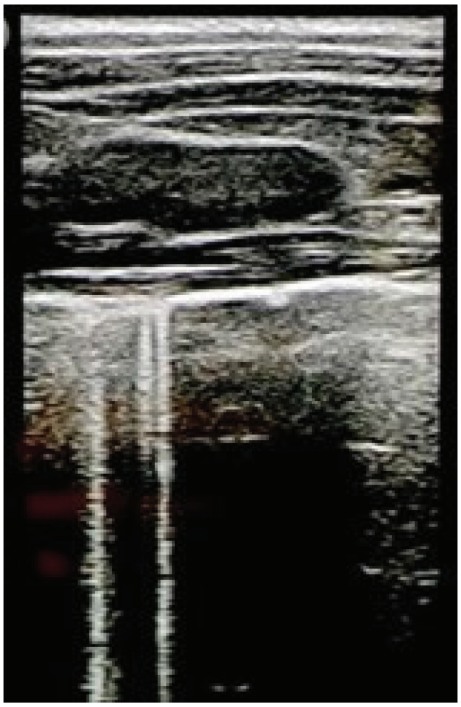

Figure 2 Lung ultrasound at the end of the study, depicting B-lines consistent with increased extravascular lung fluid.

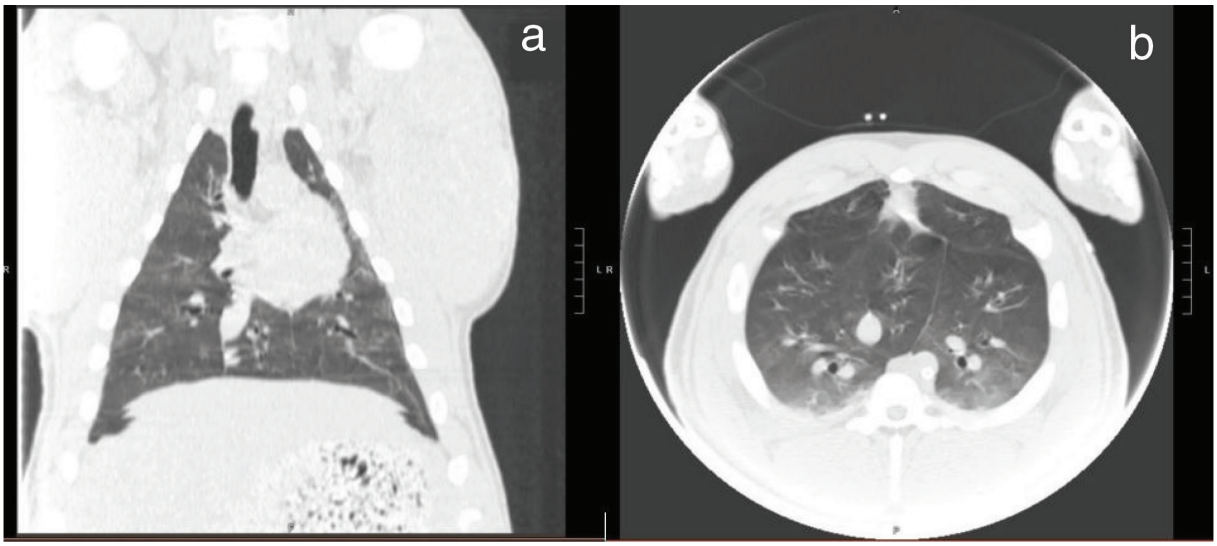

Figure 3 Chest computed tomography without contrast, axial plane (**a**) and coronal plane (**b**), at the end of the study, illustrating consolidation and ground-glass opacities, consistent with early ARDS.

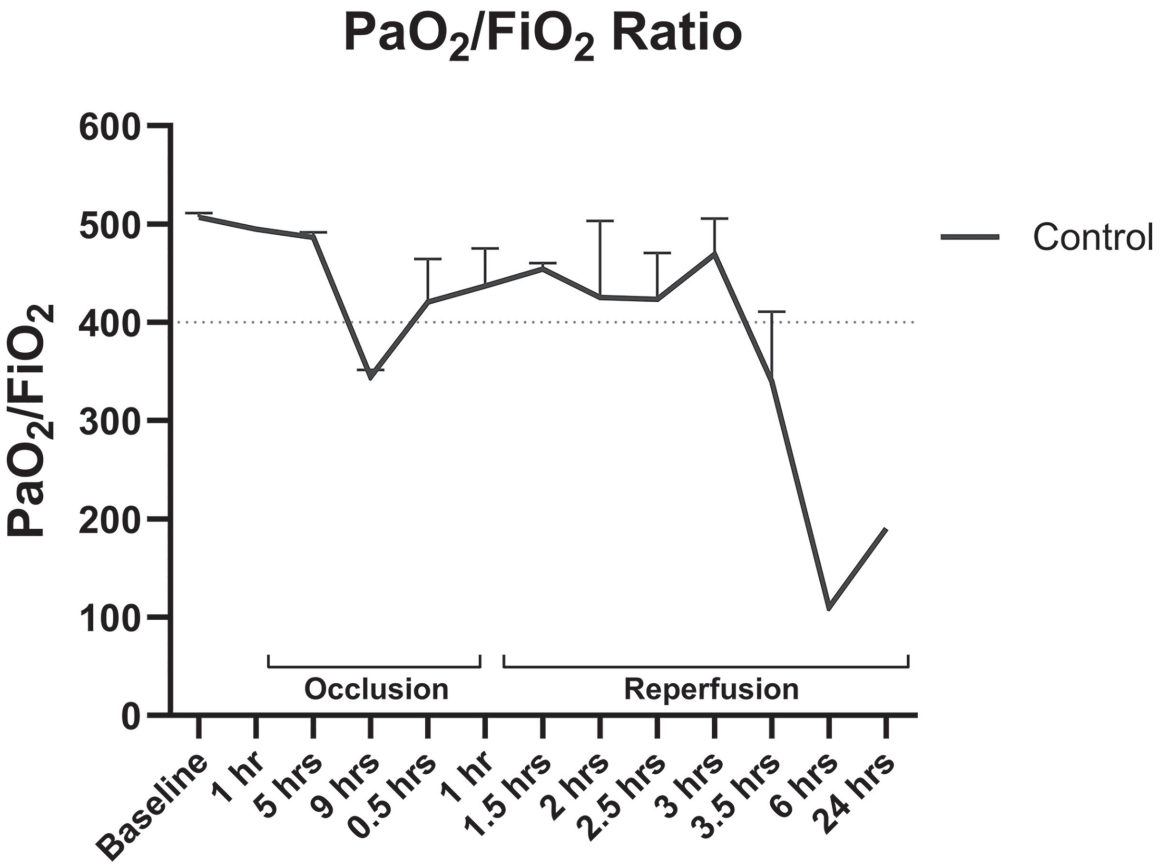

Figure 4 PaO_2/FiO_2 ratio in animals throughout the occlusion and reperfusion phases until euthanasia.

DISCUSSION

This study demonstrates a swine model of ARDS, implementing IRI by interrupting the blood supply to the hindlimb (Figure 6). This model has been shown to be easily performed, cost-effective and replicable. Furthermore, it serves as a valuable tool for studying ARDS, as it mimics physiological and sterile conditions, like those seen in a clinical setting. We have used a porcine model, as the anatomy, physiology, immune system and metabolism are more similar to humans compared to rodents, and the size allows for a broader spectrum of therapeutic testing [10].

Traditional animal ARDS models are important tools used by physicians and researchers to study the

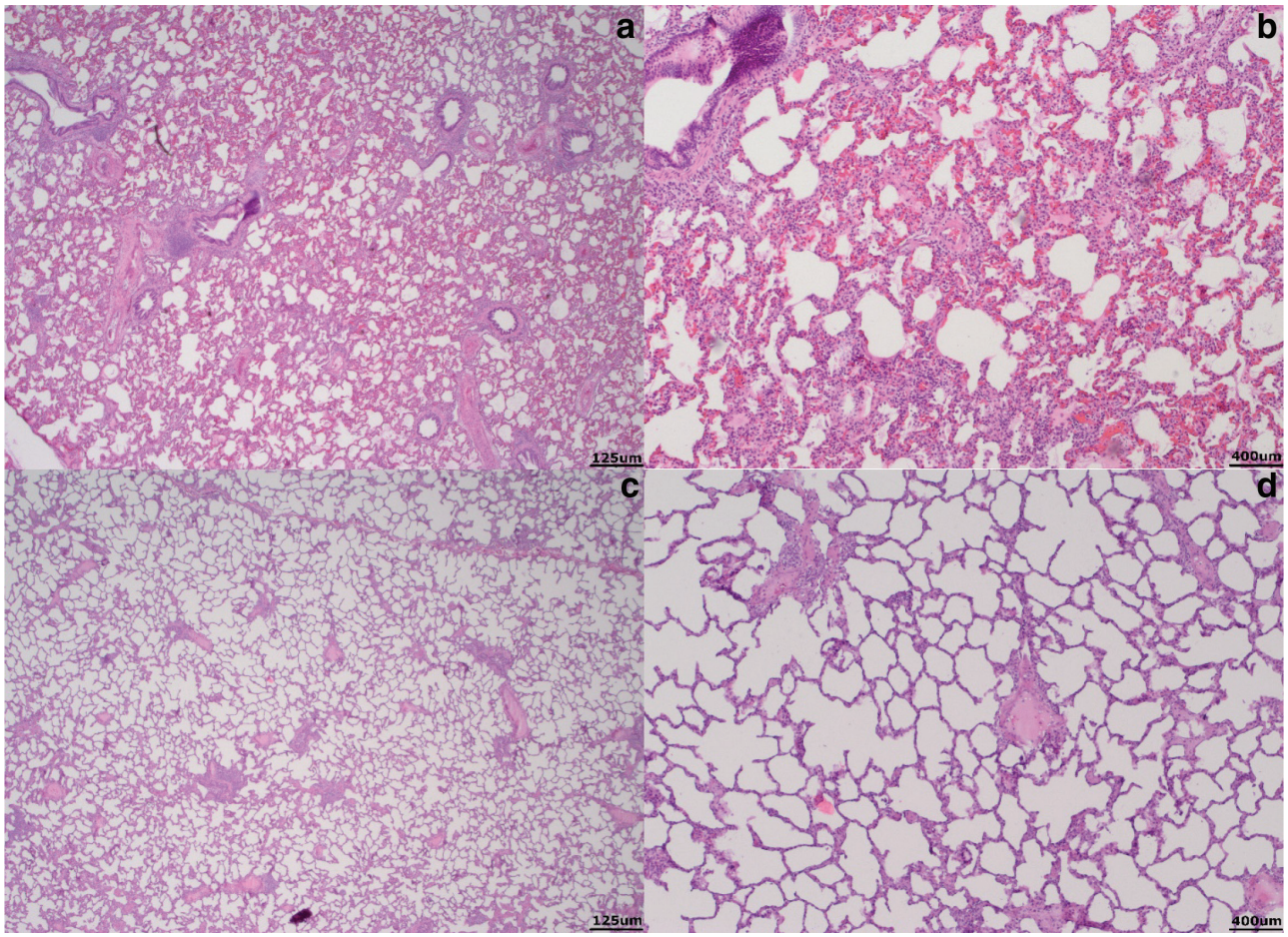

Figure 5 Histological sections of the lung stained with hemotoxylin and eosin ×12.5 magnification (**a**) and ×40 magnification (**b**) depicting pulmonary congestion and emphysema consistent with early ARDS, followed by ×12.5 magnification (**c**) and ×40 magnification (**d**) illustrating healthy lung tissue.

mechanisms and potential treatment options for this condition. While they provide valuable insights into the pathophysiological processes, none of them perfectly replicates all aspects of human ARDS [8]. The most used models are the lavage (LAV), OA and LPS models [6,9]. The LAV model, induced by repeatedly flushing the lungs with saline, primarily focuses on surfactant depletion and its consequences, including alveolar collapse [9]. This model is useful for studying the impact of different ventilation strategies and evaluating the potential therapies aimed at restoring surfactant friction. However, the LAV model does not inherently replicate the robust inflammatory response and permeability changes seen in ARDS [8,11]. In the OA model, OA is injected intravenously, leading to direct damage of the capillary endothelium and triggering the cascade of inflammatory response leading to ARDS. However, the main limitation lies in the distinct underlying cause, as ARDS very rarely results from fat embolism, the primary injury simulated in this model [8,12].

The third most popular model is created by injecting LPS, a component of bacterial cell walls and the aim is to replicate the pathophysiology of sepsis-induced ARDS, one of the most common ARDS etiologies [8,9]. LPS triggers a widespread inflammatory response, leading to lung injury, making this model valuable for exploring the inflammatory processes in ARDS and evaluating potential treatment targets. However, the LPS model often produces milder alveolar inflammation and permeability changes compared to those in ARDS. Additionally, the LPS model provides an incomplete representation of the effects of live bacteria, as it lacks direct cellular damage [8,9,13,14]. A slightly different approach was described where, instead of injecting LPS, mitochondrial damage-associated molecular patterns (DAMPs) were isolated and injected, replicating an inflammatory response comparable in severity to that seen in the LPS model [15]. It has also been shown that succinate, a marker of shock, global hypoxia and failure in energy production, can contribute to endotheliopathy in the gut, causing the release of LPS that further results in ARDS [16,17].

Pulmonary IRI models stimulate ARDS scenarios where lung injury arises from blood flow restoration after a period of oxygen deprivation, as seen in lung transplants or thoracoabdominal aortic surgery.

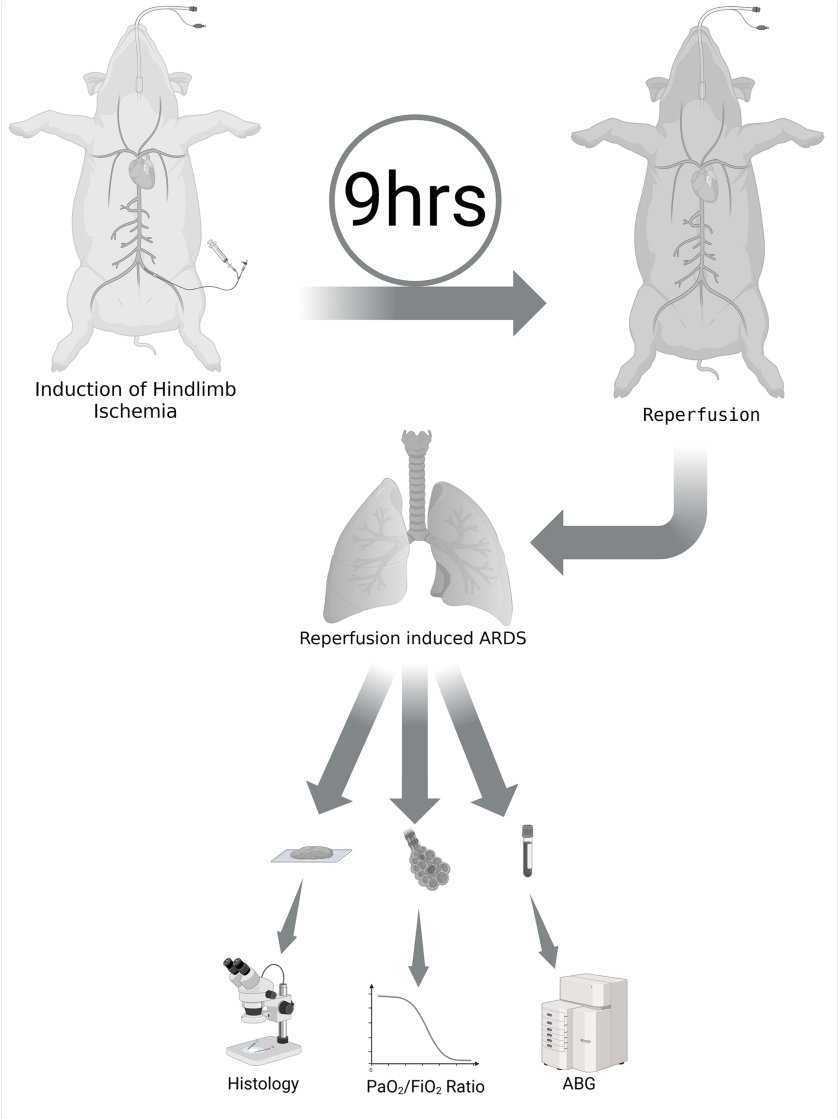

Figure 6 Experiment layout.

Pulmonary IRI involves clamping the pulmonary artery or the hilum of the lung for a defined period, followed by the restoration of blood flow. While this model helps examine injury mechanisms, it requires precise surgical skills and is time-consuming [6,18,19].

Our current approach, opting for an EIA and MSA occlusion IRI model over a pulmonary IRI model to induce ARDS, comes with unique advantages and disadvantages. Some of the former include the ability to investigate the systemic inflammatory cascade triggered by peripheral ischemia, mirroring human ARDS cases that occur with distal injuries. Because it mimics real-life pathophysiology, it might cause multi-system organ dysfunction from reperfusion injury in addition to ARDS, which contrasts with models that only target lung dysfunction [9]. Unlike pulmonary IRI, non-pulmonary IRI does not directly impair lung function, minimizing hypoxemia and hemodynamic instability within the lungs. This method offers a sterile approach, without the necessity of introducing systemic bacteria or DAMPs [15,20].

This model was designed with a focus on clinically relevant components, which is why the evaluation of biochemical markers was not included in the scope of this project. The animals presented symptoms typical of a lung injury, such as impaired gas exchange demonstrated by a dramatic decrease in the Horowitz index, but also confirmed with CT, ultrasound and histology. The sample size was limited to two animals, although the results remain promising. While combat-related trauma often involves polytrauma with extensive soft tissue and skeletal injuries, our model isolates IRI to establish a controlled platform for studying its direct role in ARDS pathogenesis. We do, however, acknowledge this limitation and see our model as complementary to more complex trauma models, providing foundational insights into isolated IRI contributions to ARDS. Further replication of this model in future experiments will help to validate the technique and enhance future experimental

use. Extending the duration of critical care periods will facilitate a more comprehensive progression of ARDS due to systemic reperfusion injury, providing greater insight into its pathophysiology and enhancing the model's relevance for future experimental applications.

Within the constraints of these limitations, this methodology for creating an ARDS model by inducing non-pulmonary IRI demonstrates promising results for further study. This model can be used in future studies to examine the pathophysiology and pathomechanism of ARDS.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Author Contributions

All authors have submitted substantially to the study, manuscript writing and editing.

Declaration of the Use of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work the authors used (Chat GPT, Open AI, San Francisco, California) to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Case Reports

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Aortic Graft Enteric Erosion Following EVAR: A Multidisciplinary Approach to Repair

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INTRODUCTION

Aortic graft infection is a rare but highly morbid complication of both open and endovascular aortic surgery, with reported incidence ranging from 0.05–5% [1]. With the increasing adoption of endovascular aneurysm repair (EVAR), aortic endograft infections are a more frequently encountered clinical challenge. An endograft infection may result from graft seeding during bacteremia from a separate infection, contiguous intraabdominal or retroperitoneal infection, or erosion into a hollow viscus. Endograft-enteric fistulas are a particularly challenging complication of EVAR. Management requires source control with explantation of the endograft, vascular, and enteric reconstruction. Presentations range from indolent chronic infection to septic shock in acute infection, to acute gastrointestinal hemorrhage from an aorto-enteric fistula. Surgical management of these cases requires complete explantation of the prosthetic material and vascular reconstruction, which may be performed *in situ* or in an extra-anatomic fashion. There are several options for *in situ* reconstruction, including antimicrobial-treated prosthetic (e.g. rifampin-soaked Dacron), reconstruction with autologous femoral vein as in neoaortoiliac system (NAIS) reconstruction, or reconstruction with cryopreserved aortic homograft. Extra-anatomic reconstruction involves ligation of the infrarenal aorta after prosthetic removal with axillo-bifemoral bypass.

Here, we describe a case of infrarenal aortic endograft erosion into the duodenum, treated with graft explantation, *in situ* reconstruction with cryopreserved aortic homograft, and resection of the third portion of the duodenum with reconstructive duodenojejunostomy.

CASE REPORT

A 61-year-old male with a history of ruptured infrarenal aortic aneurysm treated with EVAR five years prior was transferred to our hospital for a higher level of care, after presenting to an outside facility with abdominal pain, fever, and bacteremia. Initial blood cultures grew *Klebsiella pneumoniae* and *Streptococcus anginosus*. Imaging showed significant fat stranding around the endograft, which prompted evaluation with esophagogastroduodenoscopy. The study demonstrated visible endograft fabric and metallic struts eroding into the duodenum (Figure 1). Urgent transfer to our quaternary center was arranged.

His comorbidities included type 2 diabetes, hypertension, hyperlipidemia, coronary artery disease for which he had previously undergone coronary artery bypass, prior stroke without residual deficits, prior tobacco use, and peripheral arterial disease. His history was also notable for a left iliopsoas abscess three years prior to presentation, treated with incision, drainage, and a prolonged course of antibiotics. Follow-up with a vascular surgeon for further assessment of graft infection had been planned, but the patient was lost to follow-up.

He had not had any hematemesis or melena. He reported that ambulation was significantly limited by bilateral calf claudication, brought on by walking 20 feet.

On admission to the intensive care unit at our institution, he was febrile to 38.9°C and hemodynamically

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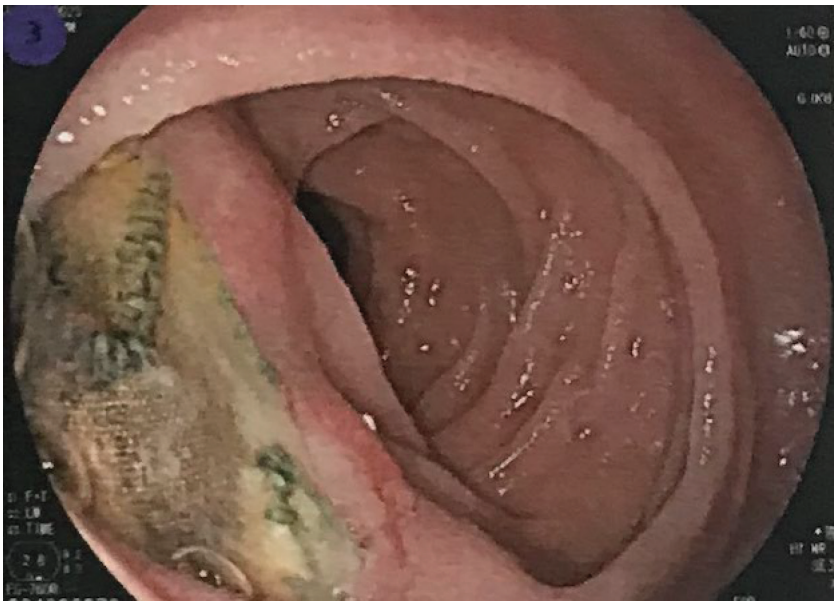


Figure 1 Preoperative esophagogastroduodenoscopy demonstrates extensive graft erosion into the third portion of the duodenum.

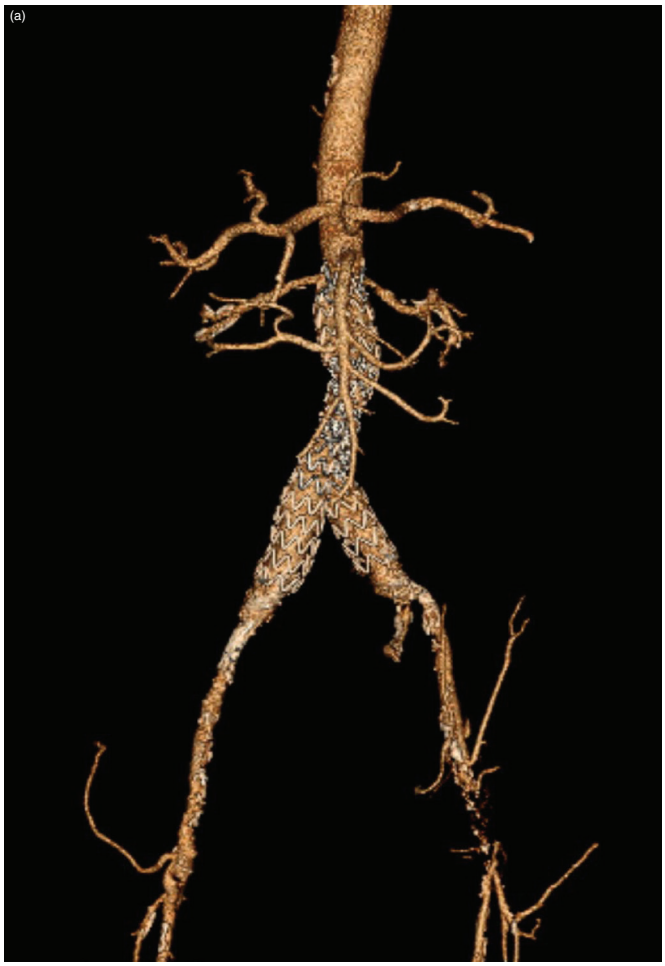
stable. Computed tomography angiogram (Figure 2) demonstrated the presence of an infrarenal aortobiiliac stent graft with suprarenal fixation struts. There was significant fat stranding and soft tissue thickening around the endograft. Imaging was also notable for occlusion of the left common femoral and right superficial femoral arteries. He was started on empiric broad-spectrum antibiotic coverage with piperacillin–tazobactam and vancomycin, total parenteral nutrition. A multidisciplinary surgical plan was developed for definitive surgical management consisting of graft excision, duodenal resection and reconstruction, and vascular reconstruction.

Surgically, he was explored through a midline laparotomy, and circumferential supraceliac aortic control was obtained. After mobilizing the small bowel, we identified the duodenum as densely adherent to the aorta, and it was carefully dissected free. This revealed a 5 cm aortic defect with exposed endograft at and below the flow divider (Figure 3). The defect in the duodenum was temporarily closed. We then clamped the supraceliac aorta and extended the defect in the anterior wall of the aorta cephalad, enough to expose the suprarenal fixation struts. These were divided with wire cutters, freeing the proximal portion of the endograft and leaving the suprarenal struts in the aorta. The supraceliac clamp was then moved to the suprarenal aorta. An appropriately sized cryopreserved aorta was brought onto the field and the proximal anastomosis was created in an end-to-end fashion to the infrarenal aorta using running 3-0 Prolene suture. At this point, the clamp was moved down onto the graft, restoring flow to the viscera and kidneys. The distal portion of the endograft was then removed from the iliac arteries and the aortic bifurcation was oversewn.

Due to the bilateral iliac occlusive disease, we elected to perform the distal anastomoses to the common femoral arteries. Both common femoral arteries were exposed. A left common femoral endarterectomy was performed given the extensive occlusive disease at this level. The external iliac arteries of the cryopreserved aortic homograft were anastomosed to cryopreserved superficial femoral artery homograft to gain the necessary length for femoral anastomoses. The limbs were tunneled to the groin incisions in the standard fashion, and anastomosed to the common femoral arteries in an end-to-side fashion with running 6-0 Prolene suture.

The previously oversewn duodenal perforation was resected with gastrointestinal anastomosis (GIA) staplers, leaving the distal third and proximal fourth portions of the duodenum as a blind end. The proximal jejunum was then freed from the ligament of Treitz and brought through the colonic mesentery. A generous Kocher maneuver was performed to further mobilize the duodenum so that the anastomosis would lie in the right upper quadrant. A side-to-side anastomosis was performed between the distal duodenum and proximal jejunum using a 60 mm GIA stapler. The enterotomy was closed with a running polydioxanone suture. A feeding nasojejunal tube and a decompressing nasogastric tube were placed. An omental flap was interposed between the vascular and enteric reconstructions.

Postoperatively, the patient had a slow return of bowel function, and nutrition was maintained with parenteral nutrition, transitioned to enteral nutrition as bowel function returned. His antibiotics were narrowed to ceftriaxone and doxycycline based on susceptibilities of the *Streptococcus anginosus* and *Klebsiella pneumoniae*, with plans for close follow-up with infectious



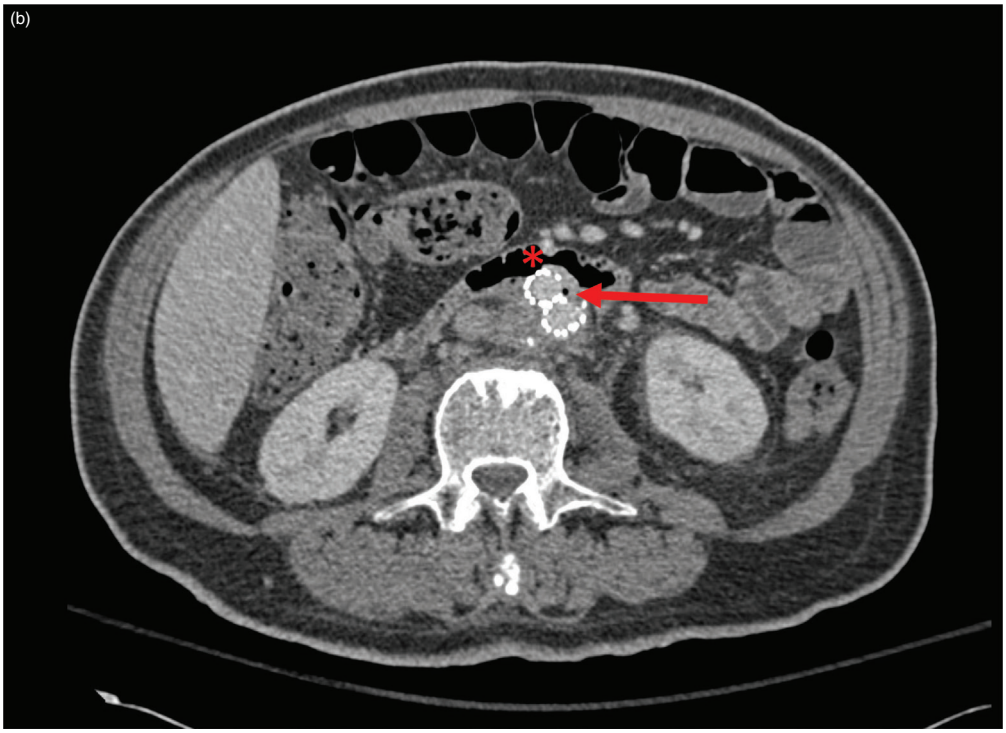


Figure 2 Preoperative imaging. **(a)** The configuration of the aorto-bi-iliac endograft with suprarenal fixation. **(b)** The duodenum (marked with *) coursing over the aorta immediately below the endograft flow divider. The arrow notes the focus of air within the aneurysm sac.

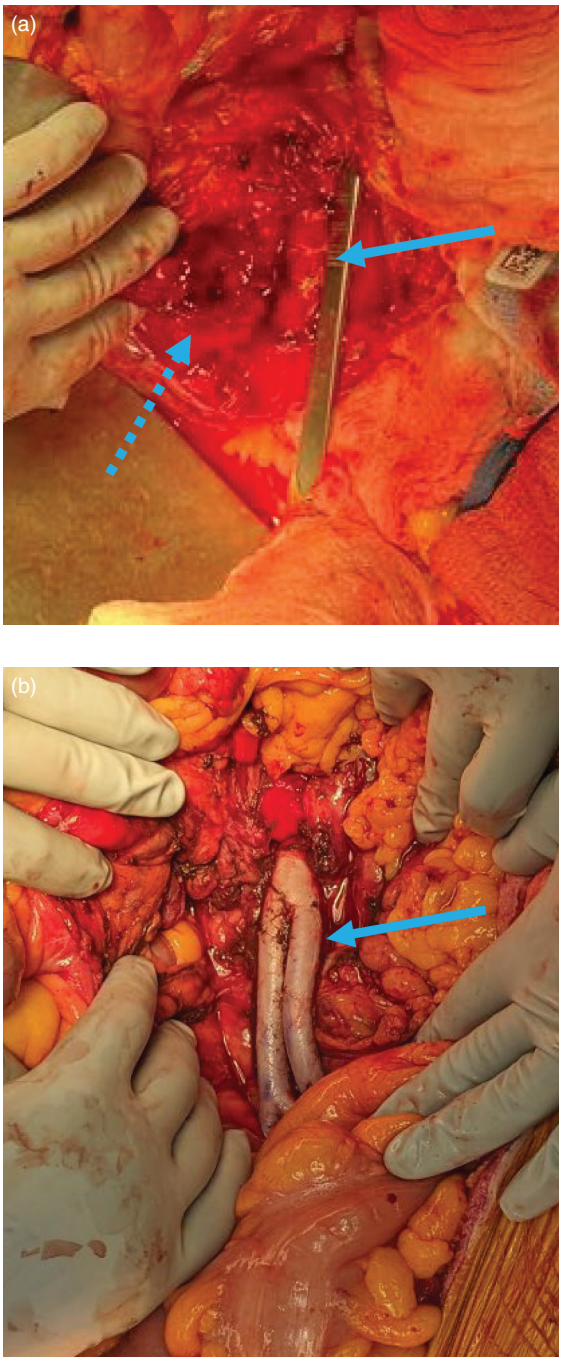


Figure 3 Operative findings. **(a)** The aortic defect with exposed endograft (solid arrow) after dividing the aortoduodenal fistula. The duodenal defect shown with a dashed arrow. **(b)** The completed vascular reconstruction (solid arrow). Photos oriented with the superior aspect of the field at the top of the photo.

disease specialists and indefinite antibiotics. He was discharged home on postoperative day 20.

Ethical Approval and Informed Consent

Ethical approval to report these cases was not required. Written informed consent was not required.

DISCUSSION

Graft-enteric erosion following endovascular aortic aneurysm repair represents a complex and challenging pathology that can have a mortality rate of up to 30–100% [1–3]. Definitive surgery requires open explantation of the stent graft, complex aortic revascularization, and gastrointestinal reconstruction. A multidisciplinary approach is optimal in the care of these complex patients.

Graft-related complications following open abdominal aortic repair have been well studied, with an approximate incidence of graft-enteric erosion/fistula estimated to be 0.4–1.6% [4,5]. Commonly, more than half of these complications involve the third and fourth portions of the duodenum due to its fixation in the retroperitoneum and proximity to the aorta [6]. A multi-institutional study from Italy found the incidence of aorto-enteric fistulas following EVAR to be 0.8%, with an incidence of 0.46% in patients with atherosclerotic aneurysmal disease, and 3.9% in patients with the development of a postoperative pseudoaneurysm [7]. The pathogenesis of graft-enteric erosion/fistula following EVAR is complex. Local/systemic infection, pulse-synchronous repetitive trauma between the graft and bowel, and endoleaks have been previously implicated [8]. In our patient, a history of localized infection from an iliopsoas abscess and repetitive pulse trauma likely led to his presentation.

In the setting of a graft-enteric erosion following EVAR, the goal of operative management are to prevent hemorrhage, control infection, maintain adequate distal perfusion, and recreate gastrointestinal continuity. The management of the bowel defect is based on the size of the defect as well as the quality of the surrounding intestinal walls [8]. Studies have reported that gastrointestinal leaks or other gastrointestinal complications increase the risk of postoperative mortality by up to three times [9]. If the defect is greater than one-third, concern for poor tissue quality, or if there is any risk of anastomotic tension, a resection and primary anastomosis or reconstruction are likely to be required. Despite the size of the defect in our patient, given the proximity to the second portion of the duodenum, we were able to resect the affected portions and reconstruct with a duodenaljejunal anastomosis. The placement of a distal jejunostomy tube should be considered, in addition to an omental flap between the vascular and gastrointestinal reconstructions [10,11].

Vascular reconstruction can be undertaken with a variety of options. Given the mechanical erosion of the stent graft, there is no definitive endovascular treatment option. Definitive management requires explanation of the entire graft, and reconstruction using any of a number of conduits and configurations: *in situ* aortic reconstruction with autogenous femoral vein, cryopreserved allograft, rifampin-soaked Dacron, or extra-anatomic bypass grafting, often with axillofemoral bypass with ringed polytetrafluoroethylene

[9,12]. There are a few important considerations in this regard – each strategy will have its own benefits and consequences with regard to the risk of re-infection, cross-clamp time, overall procedure time and longevity of the revascularization. With regard to anatomic versus extra-anatomic, for example, while a staged extra-anatomic bypass might induce the least physiologic stress, it would not be as durable as an aortobifemoral bypass [13]. However, an overly contaminated field might be best approached with an extra-anatomic approach.

With regard to conduit choice, there is no overarching consensus, and we recommend that the choice be made based on clinical and operative characteristics on a case-by-case basis. While autogenous femoral vein harvest may have decreased cost and has been theorized to have lower re-infection rates, this would likely add operative time and morbidity that could be avoided with cryopreserved graft if available, as described in a single institution retrospective study by Navelsteen et al. [14]. Additionally, studies such as this retrospective single-institution study by Tabiei et al. compared cryopreserved arterial allografts versus rifampin-soaked Dacron for the treatment of infected aortic and iliac grafts and found that while five-year mortality and five-year freedom from re-infection was similar, the Dacron group had lower freedom-from-reintervention rates (66.2% versus 92.5% at five years) [15]. Given graft availability and this patient's fitness for open surgery, we judged an *in situ* reconstruction with cryopreserved homograft would be optimal.

A multidisciplinary approach to the operative and perioperative management of this patient was critical. Trauma surgery, vascular surgery, surgical critical care, cardiac anesthesia, gastroenterology, and infectious diseases were all involved to optimally care for this patient.

CONCLUSION

Aortic graft infection and associated graft-enteric erosion represent a rare but highly morbid complication following open or endovascular repair of the aorta. Definitive treatment requires explantation and reconstruction of the viscera and vessels. The method of gastrointestinal and vascular reconstruction should be determined on a case-by-case basis, and the literature supports using a variety of different approaches. Importantly, a multidisciplinary approach to perioperative care and operative intervention is optimal.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.

(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Author Contributions

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Case Reports

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Endovascular Treatment of Blunt Aortic Trauma: First Colombian Case Series

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Background: Endovascular repair of the aorta has been established as the treatment of choice for patients with closed traumatic aortic injury, and its implementation has resulted in better clinical outcomes for patients. Our objective was to describe a case series of patients with closed traumatic aortic injury who received endovascular management.
Methods: We carried out a retrospective review of the experience accumulated over 5 years in a level IV center in Colombia of the management of closed traumatic aortic injury with endovascular treatment. We found four patients with different aortic injuries described as grade II or III. Endovascular management was performed during the first 48 hours after admission to the emergency room; hospital survival was 100%, and there was no record of complications after the procedure.
Conclusions: Endovascular repair is the treatment of choice for closed traumatic aortic injury, including scenarios of hemodynamic instability. This is the first case series published from Colombia.

Keywords: *Aortic Diseases; Aortic Rupture; Endovascular Aortic Repair*

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INTRODUCTION

Trauma and consequent closed aortic injury occur most frequently secondary to sudden deceleration mechanisms, usually in a motor vehicle accident [1]. It also happens in motorcycle, aircraft, automobile, and pedestrian collisions, in addition to crush injuries.

The diagnosis and comprehensive approach to this entity is of vital importance in clinical practice since it involves a high mortality rate. Some injuries are even fatal in the out-of-hospital setting, which highlights the priority of addressing these patients early.

The diagnosis is made with extension studies such as computed tomography angiography, which also allows us to classify the severity. In this regard, the Society for Vascular Surgery (SVS) and European Society for Vascular Surgery (ESVS) have classified aortic traumatic injury as follows [2,3]:

- Grade I of ESVS or grade I and II of SVS: Injury confined to the intima or vessel wall with normal external wall contour
- Grade II of ESVS or grade III of SVS: abnormal external wall contour or external wall disruption with contained hemorrhage (e.g., pseudoaneurysm)
- Grade III of ESVS or grade IV of SVS: complete wall transection with free rupture.

The possible treatment methods are as follows. Conservative treatment is intended for patients with grade I injuries of ESVS or grade I injuries and some stable grade II injuries of SVS, who can be closely monitored with tomographic images to

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establish lesion progression and intervene. Thoracic endovascular aortic repair (TEVAR) and open surgery are reserved for lesions classified as grades II to III of ESVS or III to IV of SVS [1,3]. Finally, the recommendation of the guidelines of the ESVS is for open surgical repair in selected patients with blunt aortic injury requiring intervention and those with an aortic anatomy unsuitable for a stent graft [3]. Regarding these therapeutic possibilities, since 2011 TEVAR has been recommended as the first-line treatment because it provides a greater chance of survival, and a lower probability of paraplegia, renal failure, transfusions, re-operation due to bleeding, cardiac complications, pneumonia, and hospital stay when compared to open surgery [4].

Despite the indication for TEVAR in closed aortic trauma, there is little evidence concerning the long-term prognosis of TEVAR, probably related to the diagnosis having low incidence. Some studies show a low mortality rate in patients with traumatic closed aortic injury managed with TEVAR (9%), compared to open surgical management (19%). This difference is greater when compared to patients who do not undergo surgical management (46%) [2].

In Colombia, a retrospective study evaluated endovascular versus open management of aortic injuries of non-traumatic origin, finding lower mortality, shorter surgical time, and shorter hospital stay for endovascular treatment [5]. The following describes the first case series on the use of TEVAR in aortic injury due to closed thoracic trauma in Colombia, which is the result of a review of five years of clinical records in a referral center in the city of Cali.

Ethical Approval and Informed Consent

This manuscript does not contain official information; the data presented is anonymous and has been reviewed and approved by the institution's ethics committee.

CASE SERIES

Case No 1

A 14-year-old male patient with polytrauma and hemodynamic instability secondary to a traffic accident as a pedestrian was admitted to a level II clinic. They in turn, rapidly referred the patient to a level IV emergency department in the same city, a few kilometers away from the reference center. This center had the capacity for endovascular and open surgical management of traumatic injuries.

He was diagnosed with a traumatic aortic injury grade II (described as a hematoma content of 19 mm) located at the exit of the left subclavian artery. Therefore, an endovascular repair with a femoral approach was performed (Table 1). No complications during the procedure were reported. A type c-tag 28 × 150 mm stent was used with subsequent arteriography showing the patency of the renal, celiac trunk, and superior mesenteric arteries (Table 2). The stent size was chosen with an oversizing of 30%.

During the peri- and postoperative period, he required vasopressor support with subsequent gradual withdrawal. Twenty days after hospitalization, he was transferred to another institution due to administrative agreements to continue management of other bone lesions.

Table 1 Summary of variables characterizing aortic trauma.

Variables	*Patient 1*	*Patient 2*	*Patient 3*	*Patient 4*
Age	14 years	29 years	27 years	18 years
Sex	Male	Male	Male	Male
Time of evolution	Unknown (not described)	24 hours	24 hours	1 hour
Referred	Yes	Yes	Yes	Yes
Time between admission to the emergency department and surgery	29 hours	7 hours	42 hours	19 hours
Associated trauma	Severe TBI, chest trauma, sternal fracture, left tibial spine fracture	ASIA A spinal cord trauma, blunt chest trauma, pulmonary contusion, femur fracture	Severe TBI, subdural hematoma, closed thoracoabdominal trauma, open femur and humerus fracture	Mild TBI, thoracoabdominal trauma, pelvic trauma, grade IV hepatic trauma
Location of injury	Descending thoracic aorta	Descending thoracic aorta	Descending thoracic aorta	Descending thoracic aorta
Mechanism of trauma	Unknown traffic accident (unknown kinematics)	Victim of a landslide	Motorcycle driver versus car	Motorcycle collision with a truck
Grade of injury (SVS scale)	II: 19 mm mural hematoma	II–III: mural hematoma and pseudoaneurysm.	II: mural hematoma	II: mural hematoma

TBI, Traumatic brain injury; ASIA, American Spinal Injury Association; SVS, Society of Vascular Surgery.

Table 2 Summary of the variables that characterize the intervention performed and the clinical outcomes measured.

Variables	*Patient 1*	*Patient 2*	*Patient 3*	*Patient 4*
Approach	Right femoral	Right femoral, right brachial	Right femoral, right brachial	Right femoral, left radial
Type of stent	Core tac thoracic 28 × 150 mm	Tag active control system 26 × 100 mm	Valiant thoracic 24 × 100 mm	Cook Medical Zenith 24 × 105 mm
Secondary complications	None	None	None	None
Days of stay	20 days	120 days	3 days	14 days
In-hospital mortality	No	No	No	No

Case No 2

A 29-year-old male patient, who presented with polytrauma due to crushing from a landslide, was admitted to the emergency service of a level II institution (in a city of 100,000 inhabitants and located 1 hour from the referral site by road), where tomographic studies were performed and a lesion of the thoracic aorta found. He was therefore referred to a level IV institution to consider endovascular management.

The lesion was described by radiology as a traumatic rupture of the thoracic aorta with pseudoaneurysm and hematoma in the wall due to blunt trauma (Table 1). A procedure was performed to insert a 26 × 100 mm stent graft using the femoral approach (Table 2).

Subsequent arteriography showed adequate patency of the renal, celiac trunk, and superior mesenteric arteries, without documenting immediate complications.

The patient was discharged from the institution in less than 24 hours to continue comprehensive in-hospital management.

Case No 3

A 27-year-old male patient was referred to a level II center in a small city (about 100,000 inhabitants) after a motorcycle accident, where management requirements were evaluated. He was then referred to a level IV center for endovascular treatment of a traumatic injury.

He had polytrauma with subsequent blunt trauma to the abdomen. In the emergency room of the level IV center, a mural hematoma in the descending aorta with traumatic dissection below the subclavian artery without active bleeding, classified as grade II (Table 1), was documented.

A femoral approach was performed for the passage of a Valiant thoracic 24 × 100 mm stent, without evidence of leakage in the control aortogram (Table 2). He presented with a satisfactory evolution and was discharged from the hospital after 3 days.

Case No 4

An 18-year-old male patient was referred to a level IV center (with capacity for endovascular and open management of traumatic injuries) after a motorcycle accident. He presented with a polytrauma, with closed chest and abdomen trauma, with a tomographic finding of a hepatic trauma, which was managed endovascularly.

An aortic dissection type lesion of grade II was confirmed on the descending aorta by computed tomography (Table 1). Therefore, an endovascular implantation of a thoracic 24 × 105 mm Cook Medical stent using a femoral approach was performed, without evidence of immediate complications and with verification of adequate perfusion to vital organs (Table 2). The patient completed inpatient management after 14 days for the resolution of other abdominal lesions.

DISCUSSION

Endovascular management of aortic injury due to closed thoracic trauma has evolved significantly in recent decades, gradually displacing open surgery as the follow up treatment. This change is largely due to lower mortality and morbidity associated with endovascular repair compared to open surgery. Specifically, fewer complications, such as paraplegia, renal failure, transfusion support, re-operation for bleeding, and shorter hospital stay have been reported [4]. The magnitude of the reduction of complications of stroke is 11.8% and of permanent spinal cord injury is 13.1%. The prevention of prolonged mechanical ventilation is reduced by 21.9% [6], compared to the reduction of mortality evaluated at 30 days, which is 22% lower [7]. These results are predominantly observed in patients with hemodynamic instability or multiple intra-abdominal injuries derived from trauma [2,8]. This is probably because a minimally invasive approach does not require the use of prolonged clamping of the aorta, added to the fact that surgical time is usually shorter. This decreases the probability of tissue ischemia and provides for a better recovery of the tissues, especially when the aortic injuries are high [9].

The indication for endovascular treatment is preferred in lesions classified as type II or III, i.e. when the damage is partial or involves the aortic wall, due to the risk of progression to rupture. It is also the recommended option for hemodynamically unstable patients, where a less invasive procedure results in better outcomes, including better survival [10].

However, endovascular repairs present certain technical challenges that require attention. For example, vascular access and the correct evaluation of the aortic anatomy are key for the precise placement of the stent. It is necessary to make an adequate selection of the size of the stent (since the aorta can vary in diameter according to the age and other conditions of the patient), in order to minimize the risk of displacement or endoleaks as complications associated with the procedure at an early stage.

For these reasons, it is necessary to transfer polytrauma patients to centers with multidisciplinary management capacity, which have trained surgical and endovascular teams.

The level IV center from which the presented case series was collected has a hybrid operating room for trauma cases and for cases where Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) is required. The center has health personnel trained to take tomographic studies (in the arterial and venous phases) as the first choice for analyzing vascular traumatic injuries, and the 24/7 availability of multiple specialties, such as emergency medicine, intensive care, interventional radiology, and vascular surgery, for the management of trauma.

Patient first-choice is key to the success of TEVAR use, and imaging studies such as tomography or magnetic resonance imaging are employed to identify and treat any short-term complications on time. However, the time in which such follow-up should be performed in the acute context has not been stipulated and protocolized, and it varies according to the clinical condition of the patients during their postoperative evolution.

Long-term follow-up is conducted in 1, 6, and 12 months, and from then on every year, usually with angiotomography [11]. In addition, the complications derived from the procedure itself must be taken into account. Some examples described are spinal cord ischemia, paraplegia, stroke, and acute renal injury, so clinical examination is important during the follow-up of patients so that it can guide the moment at which patients require imaging control in the short term.

For the cases presented, no follow-up records were found in the institution (because of the insurance system in which follow-up studies are directed to institutions where the patient has greater accessibility).

An attempt was made to follow-up with the patients by telephone, but it was only possible to communicate with the patient in case 1, where his family mentioned that an annual angiotomography study was performed for the first 3 years with no apparent record of complications.

Long-term results are still being evaluated, especially in young patients who may require new interventions due to factors such as aortic growth or stent wear, an aspect that could not be evaluated in our case series because we did not have a follow-up of the patients over time.

The case series described is the first case series reported in Colombia on endovascular management of closed traumatic aortic lesions. Although experiences of endovascular management with penetrating trauma [12] and closed chest trauma with a hybrid approach have been described previously [13], the present series shows how the implementation of endovascular management in these types of pathology (including in developing countries) results in favorable clinical outcomes. This is due to survival during in-hospital follow-up, with no record of complications and short hospital stays (except for cases due to lesions in other segments that require a longer time of in-hospital management).

CONCLUSION

Endovascular repair has been established as the treatment of choice for closed traumatic aortic injury, including scenarios of hemodynamic instability, due to its better results in terms of survival, reduced complications, and improved recovery time when compared to open surgical repair of the aorta.

This technique requires having endovascular intervention centers with experience in its use, as well as permanent availability of resources.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

All authors declare that they have no conflicts of interest.

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The authors declare that they have not received support in the form of grants, equipment, or drugs from public or private institutions.

Declaration of the Use of Generative AI and AI-assisted technologies in the writing process

The authors have not used artificial intelligence during the writing process of the paper. However, the authors admit to having tools to facilitate the translation of the manuscript from the Spanish language.

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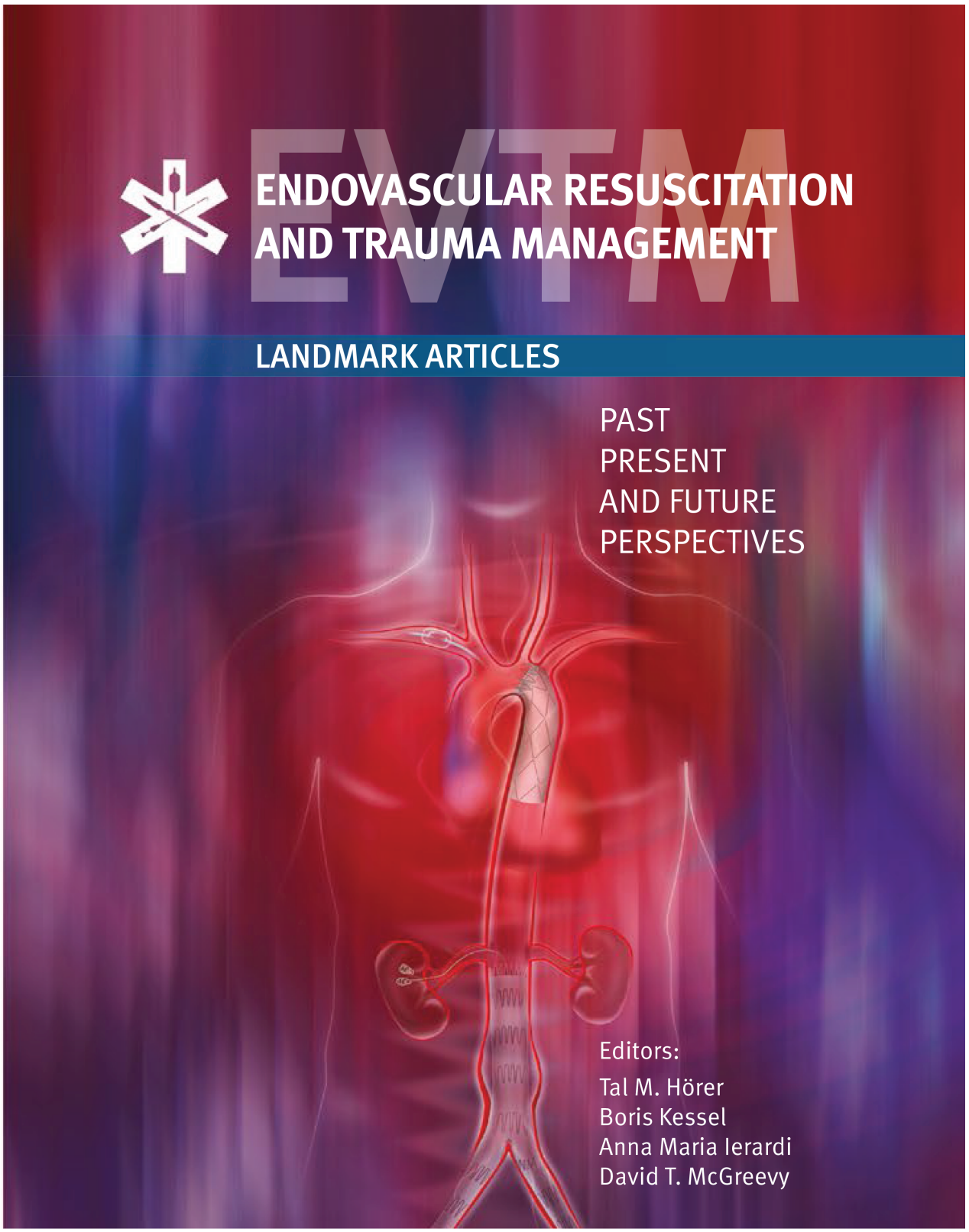
EVTM Landmark Articles



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Education

EndoVascular resuscitation and Trauma Management – Specialists in Training (EVTM-ST) is a group within the EVTM Society and EVTM Council who represent the interests of trainees, especially with regards to training, education, research and exchange programmes.

One of the main EVTM-ST events is the monthly multidisciplinary international case discussions on Zoom. An appreciated concept with focus on allowing the participating trainees to discuss a presented EVTM case, with only one consultant present for guidance. Participants are from all around the world, from various disciplines and with different levels of experience. We have great discussions, exchange of knowledge and hear about different local experiences that everyone can learn from.

If you are interested in joining the EVTM-ST case discussions,

please email: david.mcgreevy@regionorebrolan.se

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20250317

EndoVascular resuscitation bleeding and Trauma Management (EVTM)

Multidisciplinary Workshop

Örebro, Sweden 11–12th September 2025

Endovascular and hybrid solutions for the bleeding and resuscitation patient;

Aortic balloon occlusion (*REBOA*) usage, Vascular Access, Embolization, Imaging, Endografts, Endo-embolectomy, ECMO, SAAP and modern techniques in Resuscitation

EVTM instructors (preliminary)

Magnus Jonsson (Vascular, SE), Artai Pirouzram (Vascular, SE), Federico Coccolini (Surgery, IT), Paul Rees (Pre-hospital, UK), Jon Barret, (Pre-Hospital, UK) Frank Plani (Trauma, ZA), Hashem Hayek (Vascular, IL) , Pirkka Vikatmaa (Vascular FIN), TBA

Dept. of Cardiothoracic and Vascular Surgery, Dept. of General Surgery,
Dept. of Anesthesia and Intensive Care, Örebro University Hospital, Sweden

Local team: David McGreevy, Tal Hörer, Hozan Radhi, Nina Adolfson, Jonas Berlin, Johan Josefsson, Kristofer Nilsson, Emanuel Dogan

Target: Surgeons, Vascular, Trauma, IR, ED, Intensivists/ICU and Military with interest in trauma/bleeding/resuscitation, emergency & pre-hospital teams

Date: 11-12/9 2025 Place: Örebro University Hospital experimental Lab

Tal Hörer, Örebro University Hospital, tal.horer@regionorebrolan.se
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More info at www.jevtm.com/workshop and social media #EVTM

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DATE
20250317

Workshop Director: Dr. Tal Hörer MD, PhD, Associate Professor of Surgery

Workshop Secretary / Registration: Åsa Strandberg (asa.strandberg@regionorebrolan.se)

Cost (cover expenses only): 500€, 400€ for EVTM Society members, ESVS/SSVS members

Partners: Örebro University Hospital; TBA

The aim of this two days' workshop is to stimulate discussion, mutual learning and sharing of experiences while practicing EndoVascular resuscitation and Trauma Management (EVTM) using a multidisciplinary team approach. "No ego, just good science and cooperation" is the main motion of the event. It is built on an individual, professional level and we will together explore different methods for resuscitation, bleeding control and trauma management. Some methods used clinically world-wide while some are under developments and have been used in selected patients.

- Vascular access:
  - Different methods (blind, doppler, ultrasound, fluoroscopy and cut down)
  - Its use in hemodynamic unstable patients
- Aortic Balloon Occlusion (REBOA) basic and advanced methods and SAAP
- ECMO access
- Basic and advanced endograft and embolization methods
- Bleeding control methods
- Damage Control EVTM and Bailout methods
- Basic and advanced postoperative considerations
- Up-to-date research and clinical experience
- Knowledge of basic material and new technologies on the market
- Intensive training on live tissue
- ICU and ECMO aspects
- Basics for building an "EVTM service"
- Advanced experimental methods in resuscitation

The workshop is designed for experienced physicians but is individually tailored during the practical parts. Participants will get basic training and knowledge of REBOA placement as part of the EVTM concept. The workshop has been certificated by the EACCME and acknowledged by collaboration with societies like the European Society for Trauma and Acute Care Surgery, the European vascular society and others.

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Program at the animal lab training & research center, USÖ

Detailed schedule and program: TBA

Day 1 (Start lunch): Clinical and research data, guidelines and case presentations with discussions. Models.

Day 2 (whole day): Workshop on live tissue

Practical training points in the animal lab:

Every station is led by a highly experienced instructor with one-to-one training on live tissue as well as group scenario discussions. (Lunch and coffee will be served in the lab) Changing stations according to interest is encouraged. The team is a multidisciplinary one with vascular, IR, Trauma, Thorax, ICU and ED experts.

1. Material usage in bleeding patients, general considerations and management scenarios
2. Vascular Access
    - Basic principles/advanced methods
    - Cut down techniques
    - Endoshunts (and shunts)
    - Hybrid procedures stentgrafts and more
    - Puncture methods
    - Seldinger technique
    - The failing access - alternatives
    - Venous access and Ultrasound
3. Upgrading/introducers/guide wires
4. REBOA
    - Material and REBOA kit
    - Deflation and re-positioning
    - Intermittent/Partial inflation (MAP as target - iREBOA/pREBOA)
    - Ongoing bleeding practice
    - CPR procedures and pending arrest
5. ECMO practical use with tips and tricks (own station)
6. Endo-embolectomy
7. Embolization – from coils to fluid embolization, with hands on practice
8. Endografts for bleeders with practical use
9. Balloon in alternate locations (Iliac, Subclavian, Brachiocephalic trunk/Zone 1 neck)
10. Aortography and Angiography considerations (type, volume etc.)
11. Bailouts in endovascular and hybrid surgery
12. Open thorax and abdominal methods and hybrid solutions

"No ego, just good science and cooperation"

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Talks and discussions day 1: Start 12:00 with Lunch at the lab.

13:00 Welcome David McGreevy and Tal Hörer

13:15 EVTM general principles and examples

13:30 Vascular access- how to do basic and advanced Hashem H

13:45 The bleeding access- solutions Artai P

14:00 Access for resuscitation Paul R, Jon B

14:15 Use of REBOA in trauma and non trauma cases

14:30 Vascular trauma and iatrogenic injuries- possibilities and what should the team concentrate on (Surgeon, Anesthesia, ICU) Pirkka V

14:45 Coffee

15:00 Endovascular solutions for bleeding trauma/non trauma patients Magnus Jonsson

15:15 Traumatic pelvic bleeding- what, how and team work Federico C

15:30 Data- when to use REBOA and when not? My experience Frank P

15:45 Use of endovascular techniques in ruptured AA- data and what the TEAM should know

16:00 Femoral access bleeding- endovascular solutions? David McGreevy

16:15 Anesthesia and ICU aspects of bleeding patients in the endo era – Kristofer N and Emanuel D

16:30 Endo resuscitation- Endo thrombectomy taking over open embolektomi? Tal H

TBA

17:00-18:00 Clinical scenarios and group discussions on models

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Coming Meetings

AAST Annual Meeting, 10–13th September 2025, Boston, MA, USA
https://www.aast.org/annual-meeting/2025-annual-meeting

EVTM workshop dates, 11–12th September 2025
https://jevtm.com/evtm-news/

ESVS Annual Meeting, 23–26th September 2025, Turkey
https://esvs.org/events/annual-meeting/annual-meeting-2025/

VEITH Symposium, 18–22nd November 2025, New York, USA
https://www.veithsymposium.org/

More events on the www.jevtm.com website news...

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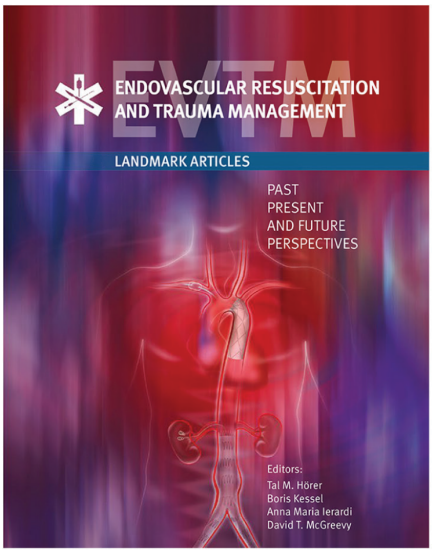

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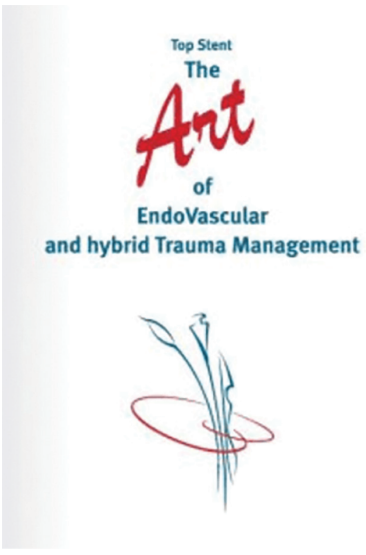

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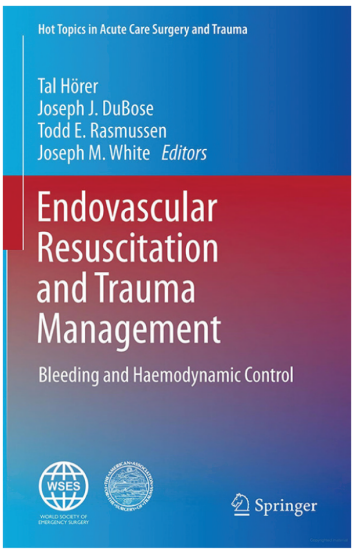

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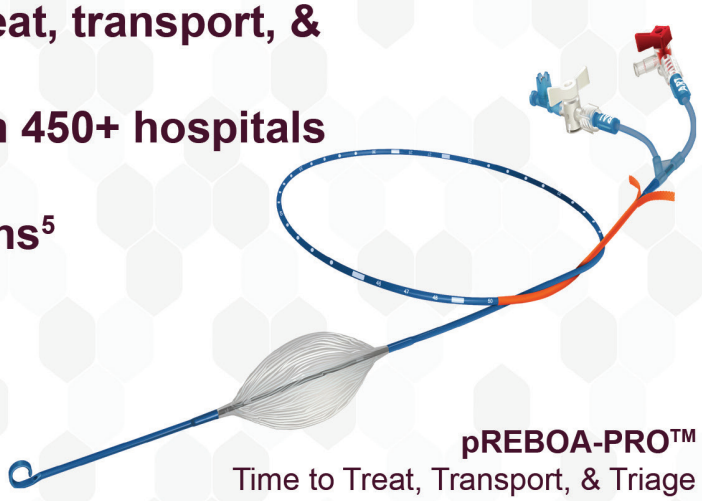
1. Centers of Excellence data. Internal data on file. Available upon request. 2. Ho et al., (2023) J Trauma Acute Care Surg. 3. Individual patient tolerance to occlusion may vary based on a variety of factors including age, health, status, injury pattern and severity, previous ischemic insult, etc. Surgical judgment is necessary when determining duration of occlusion for each patient. 4. Applies to all complete and partial REBOA uses. 5. Applies to all publications about complete and partial REBOA.



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