


Management of non-compressible torso hemorrhage of the abdomen in civilian and military austere environments: a scoping review

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SUMMARY

Background Non-compressible abdominal hemorrhage (NCAH) is the leading cause of potentially preventable deaths in both civilian and military austere environments, and an improvement in mortality due to this problem has not been demonstrated during the past quarter century. Several innovations have been developed to control hemorrhage closer to the point of injury.

Objective This review assessed NCAH interventions in civilian and military settings, focusing on austere environments. It identified innovations, effectiveness, and knowledge gaps for future research.

Methodology The Joanna Briggs Institute for Evidence Synthesis methodology guided this scoping review to completion. Studies evaluating NCAH with human participants in civilian and military austere environments that were eligible for inclusion were limited to English language studies published between December 1990 and January 2023. The PCC (Participant, Concept, Context) framework was used for data synthesis.

Deductive and inductive thematic analyses were used to assess the literature that met inclusion criteria, identify patterns/themes to address the research questions and identify common themes within the literature. A stakeholder consultation was conducted to review and provide expert perspectives and opinions on the results of the deductive and inductive thematic analyses.

Results The literature search identified 868 articles; 26 articles met the inclusion criteria. Textual narrative analysis of the 26 articles resulted in the literature addressing four main categories: NCAH, penetrating abdominal trauma, resuscitative endovascular balloon occlusion of the aorta (REBOA), and ResQFoam. The deductive thematic analysis aimed to answer three research questions. Research question 1 addressed the effectiveness of REBOA, damage control resuscitation, and damage control surgery in managing NCAH in austere environments. No effectiveness studies were found on this topic. Research question 2 identified three knowledge gaps in NCAH management in austere environments. The analysis identified early hemorrhage control, prehospital provider decision-making ability, and REBOA implementation as knowledge gaps in NCAH. Research question 3 identified five innovations that may affect the management of NCAH in the future: transport of patients, advanced resuscitative care, expert consultation, REBOA implementation, and self-expanding foam implementation. The inductive thematic analysis resulted in four recurrent themes from the literature: prehospital care, decision-making, hemorrhage control,

and mortality in NCAH. During the stakeholders' consultation, the results of the deductive and inductive thematic analyses were reviewed and agreed on by the stakeholders. Special emphasis and discussion were given to prehospital management, expert opinions in the prehospital environment, decision-making in the prehospital environment, transport and resuscitation in the prehospital setting, REBOA, alternative discussion for research, and research gaps.

Conclusion NCAH is still a significant cause of preventable death in both military and civilian austere environments, even with ongoing research and interventions aimed at extending survival in such conditions. This scoping review has identified several potential concepts that could reduce the mortality associated with a preventable cause of death due to hemorrhage in austere environments.

INTRODUCTION

Rationale

Non-compressible abdominal hemorrhage (NCAH) is the leading cause of potentially preventable deaths in both civilian and military austere environments, and an improvement in mortality due to this problem has not been demonstrated during the past quarter century.¹⁻⁴ For further development of management strategies, it is essential to assess current and future innovations in prehospital management of NCAH in austere environments. A civilian and military austere environment is defined as 'Far-Forward in the environment where professional health care providers normally do not operate, and basic equipment and capabilities necessary for resuscitation are unavailable'.^{1,5}

Three innovations have been developed to manage NCAH in civilian and military austere environments: abdominal aortic junctional tourniquet (AAJT), resuscitative endovascular balloon occlusion of the aorta (REBOA), and ResQFoam.²⁻⁶⁻⁸ The AAJT and ResQFoam have proven well in efficacy trials; however, data on their effectiveness in civilian and military austere environments are lacking.⁶⁻⁸ REBOA is the most used innovation in managing NCAH, despite the lack of effectiveness studies in the current literature.²⁻⁹⁻¹⁰ A joint statement published by the American College of Surgeons Committee on Trauma and the American College of Emergency

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Physicians provides best practice implementation guidance for REBOA in the clinical setting.¹¹ To further advance the prehospital management of NCAH in civilian and military austere environments, it is essential to establish a body of knowledge for current and future innovations.

This scoping review aimed to review the effectiveness of innovations in prehospital management of NCAH in austere environments, to identify knowledge gaps for managing NCAH, and to identify potential future management strategies for managing NCAH in civilian and military austere environments.

METHODS

The methodology followed the previously published scoping review protocol for managing non-compressible torso hemorrhage in civilian and military austere environments.¹ The literature selected for this scoping review assessed the past and current conceptual management of NCAH in civilian and military austere environments.

The Joanna Briggs Institute for Evidence Synthesis methodology was followed for this scoping review.¹² Additionally, the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) extension for the Scoping Review checklist was used to improve the methodological and reporting quality.¹³

Eligibility criteria

Empirical studies that evaluated the effectiveness of the management of NCAH in civilian or military environments needed to include human participants, ages 18 years and older, male or female. All study designs were considered for inclusion. Only English-language articles were included in this scoping review.

Information sources

The search was conducted using PubMed, Scopus, and Cochrane Central Register of Controlled Trials. Additional literature was sought from citations in the selected literature and experts in the field of trauma surgery.

Additionally, articles and literature were sought referencing previous and current trauma surgery conferences from January 2010 to January 2023, as noted in [figure 1](#) for titles and abstracts referencing NCAH. To ensure the completeness of literature search, a gray literature review was conducted from internet queries, including Google Scholar and Science.gov. Other websites of interest are noted in [figure 1](#).

Search strategy

The search strategy for this scoping review was previously published as an appendix in the scoping review protocol.¹

Selection process

Three researchers screened 868 articles for inclusion. 776 articles were reviewed based on the title and abstract, and 312 went through full-text review. Finally, 26 articles were short-listed for data extraction and analysis. The PRISMA 2020 flow chart ([figure 2](#)) was reviewed and accepted by all authors of the scoping review.

Three researchers (DA, SH, ABM) reviewed all articles independently and systematically. Any disagreements were resolved through seeking a consensus. Two senior research advisors were consulted if needed.

The authors reviewed 26 articles, extracted data, and formed a presentation of results (online supplemental appendix A). Articles were categorized into four: NCAH, penetrating abdominal trauma, REBOA, and ResQFoam. The following items were collected from the 26 selected articles: study characteristics, publication year, research period, originating institution, country, purpose/aim, population, setting, sample size type of study, the main outcome, how the study outcome addressed the research question, context of civilian and military austere environments based on Holcomb's 2018 publication, management of NCAH, and healthcare disciplines involved.¹⁴ Two researchers (SH, ABM) reviewed the final product with minimal discussion. The article was then sent for review and approval by subject matter experts.

Data analysis

Textual narrative analysis was used to extract data from the 26 selected articles. Textual narrative analysis is grounded in the analysis of textual narrative synthesis. It groups studies into similar homogenous subgroups, highlighting diversity in study design and context. This helps identify gaps in the literature and evaluate evidence strength.¹⁵

To answer the three research questions, a deductive and inductive thematic analysis was performed. Thematic analysis, which includes deductive and inductive thematic analyses, is a qualitative research technique that aims to understand complex phenomena by identifying, analyzing, organizing, describing, and reporting the themes and patterns within a given data set.^{16,17} Deductive thematic analysis is researcher driven based on the analyst's interest in the area.¹⁸ Inductive thematic analysis involves coding data without attempting to fit it into a preconceived framework or the researcher's analytical preconditions. Both methods are reviewed iteratively, meaning that researchers can refine their analysis and gain a comprehensive understanding of the data set over time.¹⁸

Three researchers (DA, CP, BM) independently conducted deductive thematic analysis on selected articles. The author (DA) established coded statements under specific categories to answer each research question by reviewing each article line by line.

- ▶ What is known about the effectiveness of current innovations for managing NCAH in civilian and military austere environments?
- ▶ What are the existing knowledge gaps in the literature regarding managing NCAH in civilian and military austere environments?
- ▶ What future innovations may improve the management of NCAH in civilian and military austere environments?

Categories were developed via an iterative review of codes from selected articles, which provided foundational constructs for supporting each category under each research question. The final document provided support for answering each research question. Two researchers (CP, BM) approved it; any disagreement was resolved by two senior researchers (PvdW, PLM).

Three independent researchers (DA, SH, ABM) conducted an inductive thematic analysis of selected articles. The author collaborated with coauthors to ensure agreement on codes, categories, and themes. Any disagreements were resolved by two senior researchers (PvdW, PLM). The iterative review process resulted in four themes constructed from two codes. Two researchers (SH, ABM) provided their opinions and

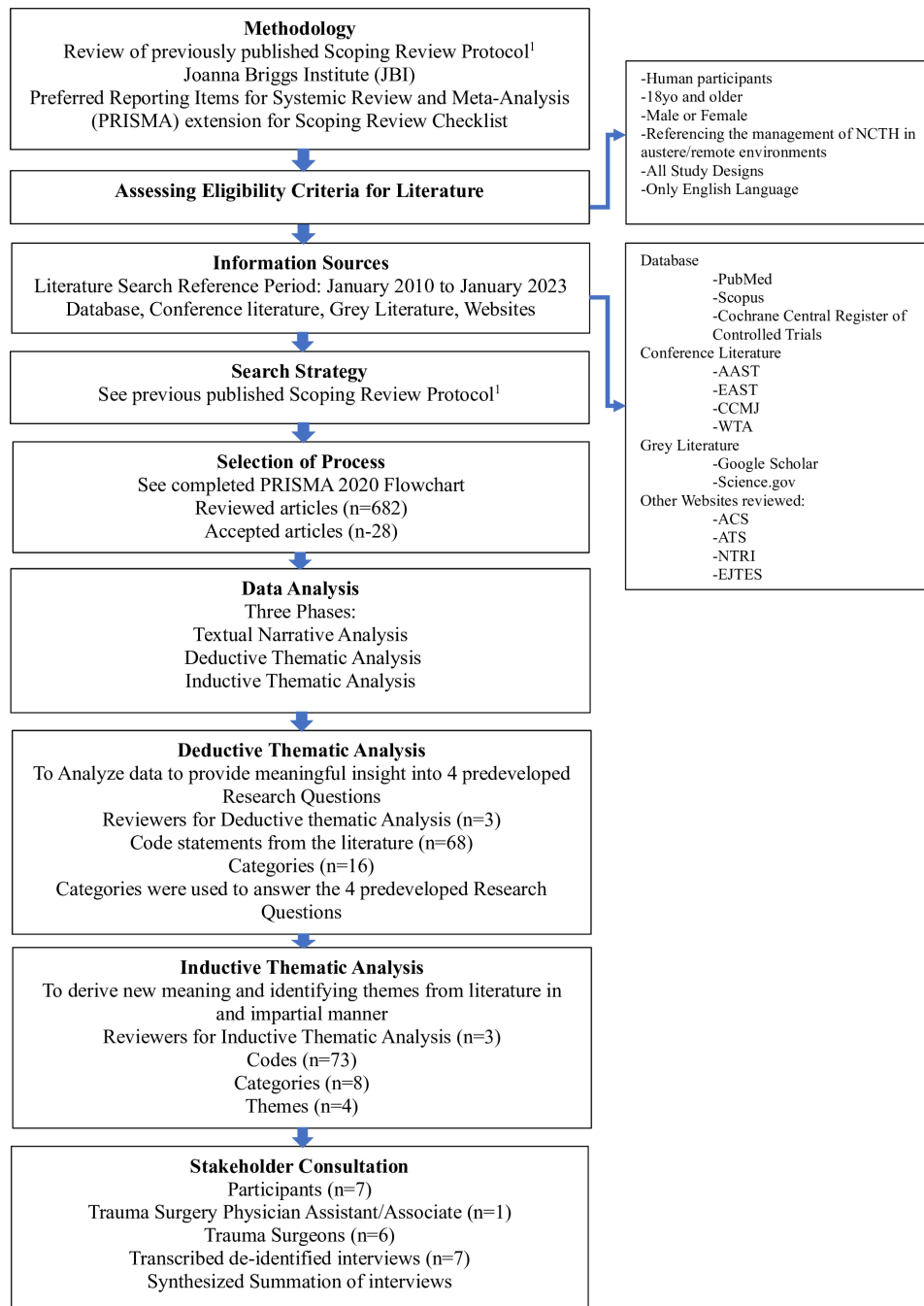


Figure 1 Graphic presentation of scoping review methodology. AAST, American Association for the Surgery of Trauma; ACS, American College of Surgeons; ATS, American Trauma Society; CCMJ, Critical Care Medical Journal; EAST, Eastern Association for the Surgery of Trauma; EJTES, European Society of Trauma and Emergency Surgery; NCTH, Non-compressible torso hemorrhage; NTRI, National Trauma Research Institute; WTA, Western Trauma Association. Adams *et al.*¹

concerns and resolved any issues with the author. The article was approved by two senior researchers (PLM, PvdW).

Stakeholder consultation

We conducted a stakeholder consultation to verify and synthesize the results of our analysis. The author interviewed seven participants, and the recorded interviews were transcribed and summarized into categories. Two researchers (DA, CM) provided feedback, and the final product was sent to two senior researchers (PLM, PvdW) for approval.

Study risk of bias assessment

A formal risk of bias assessment was not conducted as it did not fit the purpose of the scoping review.

RESULTS

Study selection

The flow chart of the selection of studies is presented in [figure 1](#).

Study characteristics

The articles addressed four main aspects of NCAH: (a) 15 articles addressed NCAH,¹⁹⁻³³ (b) 2 articles addressed

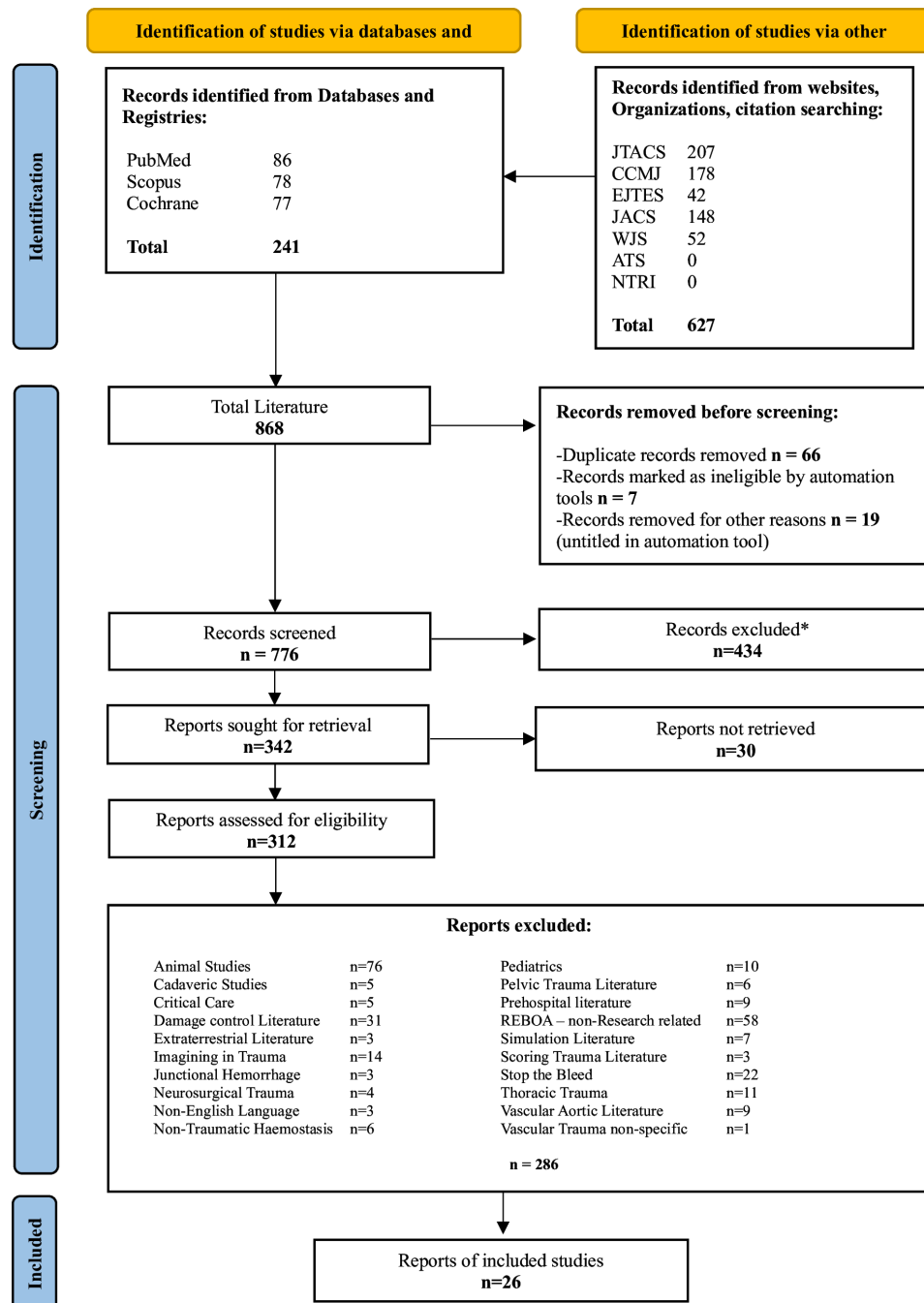


Figure 2 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram selection. *Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools. ATS, American Trauma Society; CCMJ, Critical Care Medicine Journal; EJTES, European Society of Trauma and Emergency Surgery; JACS, Journal of the American College of Surgeons; JTACS, Journal of Trauma and Acute Care Surgery; NTRI, National Trauma Research Institute; REBOA, resuscitative endovascular balloon occlusion of the aorta; WJS, World Journal of Surgery. From: Page *et al.*⁵³

penetrating abdominal trauma,^{34 35} (c) 8 articles addressed REBOA³⁶⁻⁴³ and (d) 1 article addressed ResQFoam.⁷

The articles included studies from seven countries: the USA contributed 17 articles,^{7 19-21 23 24 28-31 33-35 38 40 41 43} the UK,^{26 36} Netherlands,^{22 32} and Sweden^{37 42} contributed two articles each, and Canada,²⁷ Columbia,³⁹ and Switzerland²⁵ contributed one article each to this scoping review.

The included articles employed eight distinct methods. There were 11 retrospective review articles,^{19 20 25-28 30 33 35 40 42} 6 review articles,^{22-24 31 32 38} 4 observational studies,^{21 34 37 39} 1 lecture,²⁹

1 systematic review,³⁶ 1 autopsy,⁴¹ 1 case series,⁴³ and 1 commentary.⁷

The setting was categorized into three: civilian, military, and civilian-military. The military setting contributed to eight articles,^{7 19 23 26-30} the civilian-military contributed to nine articles,^{20 24 31 32 36-38 41 43} and the civilian articles contributed nine articles.^{21 22 25 33-35 39 40 42}

When assessing the different disciplines discussed throughout the 26 articles, prehospital providers were discussed or inferred in 22 articles, emergency medicine

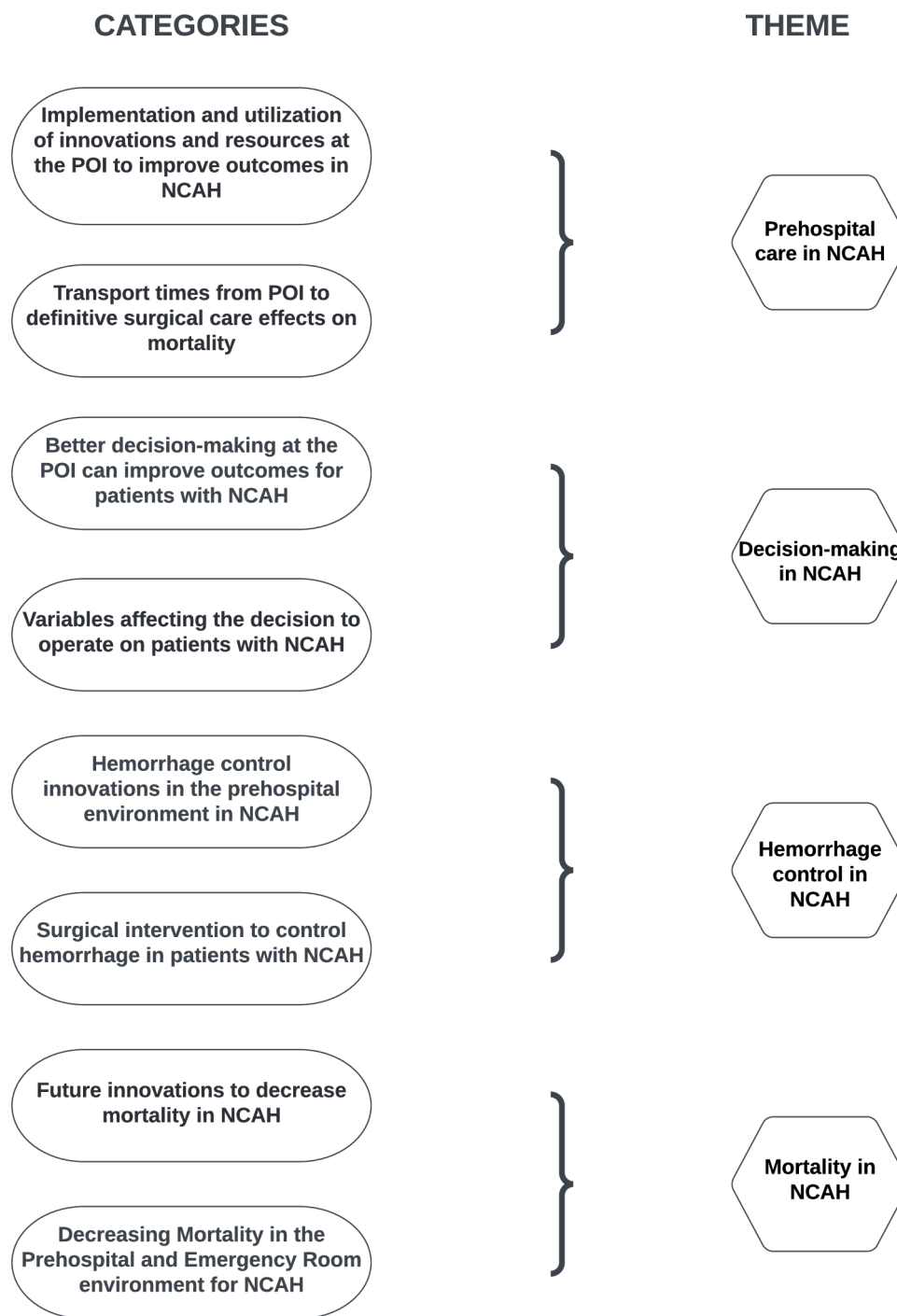


Figure 3 Thematic Analysis Categories and Themes. NCAH, non-compressible abdominal hemorrhage; POI, point of injury.

providers were discussed or implied in 21 articles, trauma surgeons were discussed or inferred in 19 articles, politicians, vascular surgeons, and interventional radiologists were discussed or inferred in one article each.

Deductive thematic analysis

What is the effectiveness of current innovations for managing NCAH in civilian and military austere environments?

The literature reviewed did not identify any effectiveness studies that directly evaluated REBOA, damage control resuscitation (DCR), and damage control surgery (DCS) in managing NCAH in austere environments. The scoping review did not find any

effectiveness studies of innovations or their implementation in real-world settings to improve mortality in patients with NCAH.

Early transportation for definitive management has been shown to improve mortality rates in patients with NCAH. Providing life-saving interventions to extend the window of survival in patients with NCAH in austere environments may further enhance their chances of survival with prolonged transport times.¹⁰ Medics transporting patients and effectively implementing hemorrhage control procedures have proven successful in sustaining life.⁴⁰⁻⁴⁴

Early recognition of indications for DCS, such as hemodynamically stable and unstable patients in penetrating trauma,

may potentially sustain life and improve mortality in patients with NCAH due to appropriate decision-making in the prehospital environment.^{30 31}

The sustainment of life begins at the point of injury; medical personnel must be supplied with the appropriate resources to sustain life.²⁰ Proper and early implementation of innovations, such as REBOA, DCR, and DCS, may sustain life at the point of injury if resourced appropriately.^{24 43–45}

Authors of several included articles argued that practical innovations such as REBOA could decrease mortality if implemented early in the management of NCAH.^{28 31 35 39 40 43} The proactive early use of REBOA in high-volume facilities has been shown to have better outcomes.⁴³ The prompt diagnosis of NCAH and early initiation of DCS in concurrence with DCR have improved outcomes in the management of NCAH in the clinical setting.^{35 46}

What are the existing knowledge gaps in the literature regarding managing NCAH in civilian and military austere environments?

The literature reviewed indicated three existing knowledge gaps in improving the survival of trauma patients with hemorrhaging in the prehospital trauma environment:

(1) Implementation of early hemorrhage control techniques and the prompt initiation of DCR in the prehospital setting can potentially improve mortality in patients with NCAH.^{30 32 33} However, interventions to control hemorrhage in NCAH are limited; therefore, early surgical interventions are needed.³² Providing prehospital medics with resources to manage NCAH and implement DCR may reduce mortality.^{23 27 35}

(2) The prompt transport of injured patients from the point of injury to a definitive surgical facility is essential to decreasing mortality in patients with NCAH. Prehospital provider decision-making ability to treat at the point of injury versus early transport to definitive care remains an existing knowledge gap.^{20 23 25}

(3) The implementation of REBOA in the prehospital trauma environment by skilled and qualified medical personnel is an existing knowledge gap.^{36–41 43 47} Implementing REBOA in advanced resuscitative care (ARC) may bridge the gap between prehospital and surgical hemorrhage control.^{4 11 35} Early identification of indications for the proactive implementation of REBOA is a knowledge gap.^{35 37 39 44} Other areas pending exploration in implementing REBOA in the prehospital trauma environment are the use of REBOA during transport, non-continuous versus continuous REBOA, and implementation of an algorithm in the proactive implementation of REBOA.^{37 38 41}

What future innovations may improve the management of NCAH in civilian and military austere environments?

Five innovations that may affect the management of NCAH in the future: transport of patients from the point of injury to definitive surgical care,^{19 21 25 27 33} ARC in the prehospital trauma environment,^{21 43} expert consultation in the prehospital trauma environment,²¹ implementation of REBOA in the prehospital environment,^{41 43} and the implementation of self-expanding foam in the prehospital setting.⁷ These future innovations may improve the mortality of patients with NCAH in austere environments.

Expert consultation at the point of injury may increase survival in patients with NCAH. Experts at the point of injury making proactive and decisive decisions for treatment versus transport can reduce time at the point of injury and shorten the time to definitive surgical intervention.^{19 21 25 27 33}

ARC in the prehospital environment could bridge the gap of future innovations from prehospital care to definitive surgical

hemorrhage control. Implementing fresh whole blood and freeze-dried plasma after or during feasible hemorrhage control as a part of ARC may improve mortality.^{21 43} Implementing REBOA and future innovations, such as self-expanding foam, may bridge the gaps of future innovations from prehospital care to definitive surgical hemorrhage control.^{20 41 43}

Inductive thematic analysis

Four overarching themes emerged from eight categories in the inductive thematic analysis. Figure 3 presents the resulting themes and corresponding codes.

The following explores each theme in more detail.

Prehospital care

Two codes contributed to this theme: the implementation and utilization of innovations and resources at the point of injury to improve outcomes in NCAH and transport times from the point of injury to definitive surgical care effects on mortality.

Implementation and utilization of innovations and resources at the point of injury to improve outcomes in NCAH evolved from discussions of the implementation of ARC in the prehospital environment.^{21–23 27 44} Moreover, the implementation of ARC ensures that non-surgeon providers can proactively implement more advanced hemostatic and resuscitative interventions at the point of injury to decrease the mortality of patients with NCAH.⁴³

Patient transport time of >30 minutes from austere environments in patients with high-grade torso injuries had higher mortality than patients with lower grade torso injuries.¹⁹ The literature supports discussions that shorter prehospital transport time, implementation of ARC, and shorter time for definitive surgical intervention can potentially improve mortality in patients with NCAH.^{7 21 25 29}

Decision-making

Decision-making in the management of NCAH emerged from two codes: better decision-making at the point of injury can improve outcomes in patients with NCAH and variables affecting the decision to operate on patients with NCAH.

Better decision-making at the point of injury can improve outcomes in patients with NCAH. The recognition and proactive intervention at the point of injury or while in transport can decrease mortality in patients with NCAH.^{7 21 22 25 35} The advantages of a proactive provider in the prehospital implementation of REBOA have resulted in positive outcomes. However, transporting a trauma patient with an inflated balloon from REBOA can potentially be catastrophic.^{40 41 43 47}

The variables affecting the decision to operate on patients with NCAH are the prompt recognition of indications for DCS, recognition in the prehospital environments of hemorrhage that may be amendable to REBOA, prompt diagnostic times, the time from door to hemostasis, and understanding that mortality is higher in institutions with a low volume of trauma cases.^{22 25 34 35 40 41}

Hemorrhage control

Two categories contributed to this theme: hemorrhage control innovations in the prehospital environment and surgical intervention to control hemorrhage in patients with NCAH.

Prehospital hemorrhage control innovations for NCAH are limited. Early hemorrhage control in the prehospital patient with NCAH may increase the patient's survival window during prolonged transport to definitive care.^{22 32 43 47} Innovations such

as DCR and REBOA have increased survivability in austere environments in patients with NCAH and may prolong survival in patients during prolonged transportation to definitive surgical facilities.^{22 29 32 38 41 43}

Despite multiple innovations for hemorrhage control in patients with NCAH, options for non-operative innovations are limited.³² Using interventions such as REBOA may support non-operative management if used proactively in conjunction with DCR.^{29 40 43 47} DCS remains the only means of controlling NCAH, provided the patient can be transported expeditiously with en route DCR.^{7 21 29 31}

Non-surgical and surgical interventions to control hemorrhage in patients with NCAH using DCR, DCS, and endovascular intervention remain the primary concepts in managing NCAH to decrease mortality.^{7 21 24 25} Rapid transport to a surgical facility capable of managing patients with NCAH will reduce mortality.^{7 21 40} Facilities that manage patients with NCAH often have lower complication rates than those that do not regularly manage patients with NCAH.⁴⁰

Mortality

Two codes contributed to this theme: future innovations to decrease mortality in NCAH and decrease mortality in the prehospital and emergency room environment in NCAH.

Prehospital hemorrhage control and resuscitation are essential to decreasing future mortality of patients with NCAH in austere environments. Innovations such as partial and continuous REBOA in the prehospital environment may allow patients with NCAH an opportunity to arrive at a definitive surgical facility for prompt, definitive surgical intervention.^{36 37 39 43} Additionally, implementing an algorithm may enhance the efficacy and effectiveness of partial and continuous REBOA in these environments.^{37 38} A second innovation, self-expanding intra-abdominal foam to control hemorrhage in patients with NCAH, may be an alternative innovation.^{7 39} The third and most important innovation is the implementation of fresh whole blood and potentially freeze-dried plasma.⁴³ Fresh whole blood is not new to DCR; however, its robust use in a prehospital environment by prehospital providers could change the paradigm of decreasing mortality in patients with NCAH.

Decreasing mortality in prehospital and emergency rooms was the second comprehensive discussion on mortality. Six variables can potentially decrease mortality in prehospital and emergency room patients: (1) improving prehospital care and implementing resources for DCR,^{22 28–30 33 43} (2) implementing hemorrhage control closer to the point of injury,^{22 30 40 43} (3) emergency rooms can decrease mortality rates by instituting hemorrhage control techniques/innovations in cases of failure to control hemorrhage at the point of injury,^{21 22 25 39–41 43} (4) shorter transport times from the point of injury to definitive surgical care,^{7 21 33} (5) reducing the time spent in the emergency department and providing rapid surgical intervention,^{25 40} and (6) ensuring rapid surgical interventions to control hemorrhage and continue DCR.^{7 21 25 29 31 40 43}

Stakeholder consultation summary

Five stakeholders (listed in online supplemental appendix B) agreed that the four themes identified through inductive thematic analysis, as well as the discussion of results from the deductive thematic analysis, were essential for managing NCAH. Analysis of the collected individual stakeholder interviews produced seven recurrent discussion patterns within the scoping review results: prehospital management, expert opinions in the prehospital environment, decision-making in the prehospital environment,

transport and resuscitation in the prehospital setting, REBOA, alternative discussion for research, and gaps in research.

Stakeholders discussed that the implementation of REBOA in the prehospital and in-hospital settings couples a steep learning curve with difficulty sustaining the skills needed for continued proficiency among trauma surgeons and prehospital providers. They also discussed that prolonged management at the point of injury delays care and potentially contributes to mortality and noted that rapid transport with en route ARC might lead to improved survival of a patient with NCAH versus prolonged on-scene management. Stakeholders emphasized that decision-making is essential in the prehospital environment. Good decision-making supporting early transport and en route management may lead to improved survival of patients with NCAH. Experts may improve prehospital care, but delayed transport harms outcomes due to limited resources.

Stakeholders discussed various topics not covered in the literature, such as the genetic component of trauma survival, improved door to cut times, and developing easy-to-adopt innovations. They emphasized the need for literature on prevention and effectiveness studies in managing NCAH. Lastly, stakeholders acknowledged the challenging comparison between wartime and civilian trauma.

DISCUSSION

This scoping review answered three research questions regarding the management of NCAH in civilian and military austere environments. Stakeholders agreed with the results and identified prevention and effectiveness studies as a need. The lack of effectiveness studies within the current trauma literature frustrates clinicians with the lack of external validity in research.^{48 49}

Research question 1: What is the effectiveness of current innovations for managing NCAH in civilian and military austere environments? Our review did not identify any effectiveness studies within the selected literature for this scoping review or within a secondary literature search to identify the beneficial effects of an intervention in real-world clinical settings.

Research question 2: What are the existing knowledge gaps in the literature regarding managing NCAH in civilian and military austere environments? Four recurring gaps were identified: implementing early hemorrhage control, providing medics with the necessary resources to manage patients in the prehospital environment, prompt transportation of the injured patient from the point of injury to a definitive treatment facility, and implementation of REBOA in the prehospital setting. These gaps in knowledge continue to reflect the lack of sponsorship in trauma research funding compared with the long list of non-trauma-related disease categories.⁴

Research question 3: What future innovations may improve the management of NCAH in civilian and military austere environments? Five future innovations have been identified for improving prehospital trauma care. These include transport from the point of injury to definitive surgical care, the use of ARC in the prehospital trauma environment, expert consultation in the prehospital setting, implementation of REBOA in the prehospital environment, and the use of self-expanding foam in the prehospital setting. Stakeholders emphasized the importance of allowing prehospital and in-hospital providers the ability to comprehensively understand the usage of any innovation/intervention in clinical practice before implementing it.

The inductive thematic analysis of the article's content revealed four themes: prehospital care, decision-making, hemorrhage control, and mortality in NCAH. Prehospital care in NCAH

literature identified the implementation of ARC innovations by the prehospital provider and prompt transport from the point of injury to definitive surgical facilities to decrease mortality in NCAH in austere environments. Stakeholders agreed that prompt transportation to a definitive care facility with en route ARC might be vital in decreasing mortality in patients with NCAH.

The second theme emphasizes the importance of decision-making in the prehospital environment in managing NCAH. A critical discussion in decision-making by prehospital providers evolves from three essential factors: initial exposure, repeated exposure, and comprehensive understanding, which leads to better decision-making. It was stressed that decision-making is different for every medical discipline. It is challenging to have a comprehensive understanding of any innovation with repeated exposure and the multitude of complications that go along with the repeated exposure to provide a comprehensive understanding. Stakeholders concurred that decision-making is critical in the prehospital environment. The decision to transport a patient to a definitive care facility while providing the benefits of alternative resuscitation strategies may be vital in decreasing mortality in patients with NCAH in austere environments.

Timely transportation with en route care is crucial in managing NCAH. This approach can significantly reduce mortality rates, as suggested by the literature. The importance of early transportation with en route care was emphasized by stakeholders during this scoping review, particularly in managing NCAH; this iterative discussion by stakeholders only highlights its importance.

The fourth theme, mortality in NCAH, is linked to prolonged prehospital care, transport, and time in the trauma bay. To reduce mortality, we must minimize time spent outside the operating room. Stakeholders noted that door to cut time is the only factor known to reduce mortality in NCAH.

This scoping review's results align with the existing literature. However, there has been minimal adoption of innovations to decrease the last preventable cause of death due to trauma.^{4 50–52} Future efforts should focus on financially supporting collaborative transdisciplinary trauma research, as recommended by the Coalition for National Trauma Research.^{50–52}

Our scoping review has several limitations. Despite our team's extensive search for literature that discusses the management of NCAH, we may have missed relevant literature that is not in English or available in alternative databases. Additionally, we faced challenges in finding general surgery physician assistants/associates to interview during the stakeholder consultation. Their perspectives and opinions on this matter would inform future research endeavors.

In conclusion, this scoping review reviewed the selected literature to provide insight into current and future research on the management of NCAH; answering three research questions, identifying current gaps in the literature, and assessing potential future innovations that may improve the mortality of NCAH in civilian and military austere environments. Continued research into this preventable cause of death due to injury will potentially reveal or support the development of innovations to reduce the mortality of NCAH.

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REFERENCES

- Adams D, McDonald PL, Sullo E, Merkle AB, Nunez T, Sarani B, Shackelford SA, Bowyer MW, van der Wees P. Management of non-compressible torso hemorrhage of the abdomen in civilian and military austere/remote environments: protocol for a scoping review. *Trauma Surg Acute Care Open* 2021;6:e000811.
- Adams D, Donald M, PA C. Management of non-Compressible torso hemorrhage of the abdomen in austere/remote environments by non-surgeon using Truncal hemorrhage control". (doctor of philosophy in Translational health sciences dissertations. paper 13). 2022 Available: https://hsr.c.himmelfarb.gwu.edu/smhs_crl_dissertations/13
- Morrison JJ. Noncompressible torso hemorrhage. *Crit Care Clin* 2017;33:37–54.
- Butler FK, Holcomb JB, Shackelford SA, Barbabella S, Bailey JA, Baker JB, Cap AP, Conklin CC, Cunningham CW, Davis MS, et al. Advanced resuscitative care in tactical combat casualty care: TCCC guidelines change 18-01. *J Spec Oper Med* 2018;18:37–55.
- Chang R, Fox EE, Greene TJ, Eastridge BJ, Gilani R, Chung KK, DeSantis SM, DuBose JJ, Tomasek JS, Fortuna GR, et al. Multicenter retrospective study of non-compressible torso hemorrhage: anatomic locations of bleeding and comparison of Endovascular versus open approach. *J Trauma Acute Care Surg* 2017;83:11–8.
- Castellini G, Gianola S, Biffi A, Porcu G, Fabbri A, Ruggieri MP, Coniglio C, Napoletano A, Coclite D, D'Angelo D, et al. Resuscitative endovascular balloon occlusion of the aorta (REBOA) in patients with major trauma and uncontrolled hemorrhagic shock: a systematic review with meta-analysis. *World J Emerg Surg* 2021;16:41.
- Chang JC, Holloway BC, Zamisch M, Hepburn MJ, Ling GSF. ResQFoam for the treatment of non-compressible hemorrhage on the front line. *Mil Med* 2015;180:932–3.

- 8 Smith S, White J, Wanis KN, Beckett A, McAlister VC, Hilsden R. The effectiveness of junctional tourniquets: a systematic review and meta-analysis. *J Trauma Acute Care Surg* 2019;86:532–9.
- 9 Wilson K, Rogers SO. Difficult decisions in trauma surgery. In: *Difficult Decisions in Trauma Surgery: An Evidence-Based Approach (Difficult Decisions in Surgery: An Evidence-Based Approach)*. 1st ed. Vol. 1. Springer, Cham. 2022:
- 10 Portney LG. Foundations of clinical research: applications to evidence-based practice (vol. 4TH edition). F. A. Davis Company, 2020.
- 11 Brenner M, Bulger EM, Perina DG, Henry S, Kang CS, Rotondo MF, Chang MC, Weireter LJ, Coburn M, Winchell RJ, et al. Joint statement from the American college of surgeons committee on trauma (ACS COT) and the American college of emergency physicians (ACEP) regarding the clinical use of resuscitative endovascular balloon occlusion of the aorta (REBOA). *Trauma Surg Acute Care Open* 2018;3:e000154.
- 12 Peters MD, Godfrey C, McInerney P, Munn Z, Tricco AC, Khalil H. Chapter 11: Scoping reviews. In: Aromataris E, Munn Z, eds. *JBI Manual for Evidence Synthesis*. 2020.
- 13 Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. PRISMA 2020 explanation and elaboration: updated guidance and Exemplars for reporting systematic reviews. *BMJ* 2021;372:n160.
- 14 Holcomb JB. Transport time and pre-operating room hemostatic interventions are important improving outcomes after severe truncal injury. *Crit Care Med* 2018;46:447–53.
- 15 Lucas PJ, Baird J, Arai L, Law C, Roberts HM. Worked examples of alternative methods for the synthesis of qualitative and quantitative research in systematic reviews. *BMC Med Res Methodol* 2007;7:4.
- 16 Nowell LS, Norris JM, White DE, Moules NJ. Thematic analysis: striving to meet the trustworthiness criteria. *Int J Qual Methods* 2017;16:1–13.
- 17 Kiger ME, Varpio L. Thematic analysis of qualitative data: AMEE guide no. 131. *Med Teach* 2020;42:846–54.
- 18 Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol* 2006;3:77–101.
- 19 Alarhayem AQ, Myers JG, Dent D, Liao L, Muir M, Mueller D, Nicholson S, Cestero R, Johnson MC, Stewart R, et al. Time is the enemy: mortality in trauma patients with hemorrhage from torso injury occurs long before the “golden hour”. *Am J Surg* 2016;212:1101–5.
- 20 Chang R, Fox EE, Greene TJ, Eastridge BJ, Gilani R, Chung KK, DeSantis SM, DuBose JJ, Tomasek JS, Fortuna GR, et al. Multicenter retrospective study of non-compressible torso hemorrhage: anatomic locations of bleeding and comparison of endovascular versus open approach. *J Trauma Acute Care Surg* 2017;83:11–8.
- 21 Duchesne J, Slaughter K, Puente I, Berne JD, Yorkgitis B, Mull J, Sperry J, Tessmer M, Costantini T, Berndtson AE, et al. Impact of time to surgery on mortality in hypotensive patients with noncompressible torso hemorrhage: an AAST multicenter, prospective study. *J Trauma Acute Care Surg* 2022;92:801–11.
- 22 Geeraedts LMG, Kaasjager HAH, van Vugt AB, Frölke JPM. Exsanguination in trauma: a review of diagnostics and treatment options. *Injury* 2009;40:11–20.
- 23 Kelly JF, Ritenour AE, McLaughlin DF, Bagg KA, Apodaca AN, Mallak CT, Pearse L, Lawnick MM, Champion HR, Wade CE, et al. Injury severity and causes of death from operation Iraqi freedom and operation enduring freedom: 2003–2004 versus 2006. *J TRAUMA* 2008;64:S21–6.
- 24 Kobayashi L, Coimbra R, Goes AMO Jr, Reva V, Santorelli J, Moore EE, Galante JM, Abu-Zidan F, Peitzman AB, Ordonez CA, et al. American Association for the surgery of trauma—world society of emergency surgery guidelines on diagnosis and management of abdominal vascular injuries. *J Trauma Acute Care Surg* 2020;89:1197–211.
- 25 Magyar CTJ, Bednarski P, Jakob DA, Schnüriger B, Swiss Trauma Registry. Severe penetrating trauma in Switzerland: first analysis of the Swiss trauma Registry (STR). *Eur J Trauma Emerg Surg* 2022;48:3837–46.
- 26 Morrison JJ, Stannard A, Rasmussen TE, Jansen JO, Tai NRM, Midwinter MJ. Injury pattern and mortality of noncompressible torso hemorrhage in UK combat casualties. *J Trauma Acute Care Surg* 2013;75:S263–8.
- 27 Pannell D, Brisebois R, Talbot M, Trotter V, Clement J, Garraway N, McAlister V, Tien HC. Causes of death in Canadian forces members deployed to Afghanistan and implications on tactical combat casualty care provision. *J TRAUMA* 2011;71:S401–7.
- 28 Patel S, Rasmussen TE, Gifford SM, Apodaca AN, Eastridge BJ, Blackburne LH. Interpreting comparative died of wounds rates as a quality benchmark of combat casualty care. *J Trauma Acute Care Surg* 2012;73:S60–3.
- 29 Schragger JJ, Branson RD, Johannigman JA. Lessons from the tip of the spear: medical advancements from Iraq and Afghanistan. *Respir CARE* 2012;57:1305–13.
- 30 Stannard A, Morrison JJ, Scott DJ, Ivatory RA, Ross JD, Rasmussen TE. The epidemiology of noncompressible torso hemorrhage in the wars in Iraq and Afghanistan. *J Trauma Acute Care Surg* 2013;74:830–4.
- 31 Waibel BH, Rotondo MF. Damage control in trauma and abdominal sepsis. *Crit Care Med* 2010;38:S421–30.
- 32 van Oostendorp SE, Tan E, Geeraedts LMG. Prehospital control of life-threatening truncal and junctional haemorrhage is the ultimate challenge in optimizing trauma care: a review of treatment options and their applicability in the civilian trauma setting. *Scand J Trauma Resusc Emerg Med* 2016;24:110.
- 33 Harvin JA, Maxim T, Inaba K, Martinez-Aguilar MA, King DR, Choudhry AJ. Mortality following emergent trauma laparotomy: a multicenter, retrospective study: mortality after emergent trauma laparotomy. *J Trauma Acute Care Surg* 2017;83:464–8.
- 34 Brown CV, Velmahos GC, Neville AL, Rhee P, Sangthong B, Demetriades D. “Hemodynamically “stable” patients with peritonitis after penetrating abdominal trauma”. *Arch Surg* 2005;140:767–72.
- 35 Johnson JW, Gracias VH, Schwab CW, Reilly PM, Kauder DR, Shapiro MB, Dabrowski GP, Rotondo MF. Evolution in damage control for exsanguinating penetrating abdominal injury. *J TRAUMA* 2001;51:261–9.
- 36 Morrison JJ, Galgon RE, Jansen JO, Cannon JW, Rasmussen TE, Eliason JL. A systematic review of the use of resuscitative endovascular balloon occlusion of the aorta in the management of hemorrhagic shock. *J Trauma Acute Care Surg* 2016;80:324–34.
- 37 Sadeghi M, Nilsson KF, Larzon T, Pirouzram A, Toivola A, Skoog P, Idoguchi K, Kon Y, Ishida T, Matsumura Y, et al. The use of aortic balloon occlusion in traumatic shock: first report from the ABO trauma registry. *Eur J Trauma Emerg Surg* 2018;44:491–501.
- 38 Biffi WL, Fox CJ, Moore EE. The role of REBOA in the control of exsanguinating torso hemorrhage. *J Trauma Acute Care Surg* 2015;78:1054–8.
- 39 García AF, Manzano-Nunez R, Orlas CP, Ruiz-Yucuma J, Londoño A, Salazar C, Melendez J, Sánchez ÁI, Puyana JC, Ordoñez CA. Association of resuscitative endovascular balloon occlusion of the aorta (REBOA) and mortality in penetrating trauma patients. *Eur J Trauma Emerg Surg* 2021;47:1779–85.
- 40 Gorman E, Nowak B, Klein M, Inaba K, Morrison J, Scalea T, Seamon M, Fox C, Moore L, Kauvar D, et al. High resuscitative endovascular balloon occlusion of the aorta procedural volume is associated with improved outcomes: an analysis of the AORTA registry. *J Trauma Acute Care Surg* 2021;91:781–9.
- 41 Henry R, Matsushima K, Henry RN, Wong V, Warriner Z, Strumwasser A, Foran CP, Inaba K, Rasmussen TE, Demetriades D. Who would have benefited from the prehospital use of resuscitative endovascular balloon occlusion of the aorta (REBOA)? an autopsy study. *J Am Coll Surg* 2019;229:383–8.
- 42 Mill V, Wellme E, Montán C. Trauma patients eligible for resuscitative endovascular balloon occlusion of the aorta (REBOA), a retrospective cohort study. *Eur J Trauma Emerg Surg* 2021;47:1773–8.
- 43 Northern DM, Manley JD, Lyon R, Farber D, Mitchell BJ, Filak KJ, Lundy J, DuBose JJ, Rasmussen TE, Holcomb JB. Recent advances in austere combat surgery: use of aortic balloon occlusion as well as blood challenges by special operations medical forces in recent combat operations. *J Trauma Acute Care Surg* 2018;85:S98–103.
- 44 Sims K, Montgomery HR, Dituro P, Kheirabadi BS, Butler FK. Management of external hemorrhage in tactical combat casualty care: the adjunctive use of xstamm compressed hemostatic sponges TCCC guidelines: change 15-03. *J Spec Oper Med* 2016;16:19–28.
- 45 Kragh JF, Murphy C, Dubick MA, Baer DG, Johnson J, Blackburne LH. New tourniquet device concepts for battlefield hemorrhage control. *US Army Med Dep J* 2011;38–48.
- 46 Rotondo MF, Schwab CW, McGonigal MD, Phillips GR, Fruchterman TM, Kauder DR, Latenser BA, Angood PA. Damage control: an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma* 1993;35:375–82.
- 47 Manley JD, Mitchell BJ, DuBose JJ, Rasmussen TE. A modern case series of resuscitative endovascular balloon occlusion of the aorta (REBOA) in an out-of-hospital, combat casualty care setting. *J Spec Oper Med* 2017;17:1–8.
- 48 Gartlehner G, Hansen RA, Nissman D, Lohr KN, Carey TS. Criteria for distinguishing effectiveness from efficacy trials in systematic reviews. *Technical Review Number 12* 2006.
- 49 Singal AG, Higgins PDR, Waljee AK. A primer on effectiveness and efficacy trials. *Clin Transl Gastroenterol* 2014;5:e45.
- 50 Coalition for national trauma research: IDENTIFY GAPS IN KNOWLEDGE. 2022. Available: <https://www.nattrauma.org/kt-tools/identify-gaps-knowledge/>
- 51 Price MA, A Kozar R, Bulger EM, Jurkovich GJ, Coalition for National Trauma Research Scientific Advisory Council. Building the future for national trauma research. *Trauma Surg Acute Care Open* 2020;5:e000421.
- 52 Hashmi ZG, Haut ER, Efron DT, Salim A, Cornwell EE, Haider AH. A target to achieve zero preventable trauma deaths through quality improvement. *JAMA Surg* 2018;153:686–9.
- 53 Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.