Applying military experience to the civilian environment: A bibliometric and thematic analysis of the published trauma and blood transfusion literature

Application de l'expérience militaire à l'environnement civil : une analyse bibliométrique et thématique de la littérature publiée sur les traumatismes et la transfusion sanguine

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Abstract

Background and Objectives: Trauma causes numerous injuries and deaths annually, and blood transfusion is crucial for treatment. We analysed publishing trends in trauma and blood transfusion literature providing insights into the history and current hotspots of this field.
Materials and Methods:
We collected trauma and blood transfusion-related research articles published in the past 20 years from the Web of Science Core Collection. We evaluated the volume of publications, journal names, and author information. Latent Dirichlet Allocation was applied to the extracted abstracts for analysis of research trends.
Results: The final analysis included 3,896 articles and reviews, with considerable growth in publication volume over the past 20 years. The main research areas included trauma treatment, limb injuries, and trauma-induced coagulopathy. The United States and the University of Texas System have emerged as predominant contributors in this field, with the Journal of Trauma and Acute Care Surgery being the principal source of publications.
Conclusion: The United States continues to contribute significantly to this field, with the integration of military battlefield experiences into civilian settings. Low titre group O whole blood and traumatic brain injury represent promising areas of future research.

Keywords: blood transfusion, traumatic, bibliometric analysis, Latent Dirichlet Allocation

Résumé

Contexte et objectifs : Les traumatismes sont à l'origine de nombreuses blessures et de nombreux décès chaque année, et la transfusion sanguine est capitale pour le traitement. Nous avons analysé les tendances de publication dans la littérature sur les traumatismes et la transfusion sanguine afin de fournir un aperçu de l'histoire et des points sensibles actuels dans ce domaine.
Matériels et méthodes :
Nous avons rassemblé des articles de recherche sur la traumatologie et la transfusion sanguine publiés au cours des 20 dernières années dans la Web of Science Core Collection. Nous avons évalué le volume des publications, les noms des revues et les informations sur les auteurs. L'allocation de Dirichlet latente a été appliquée aux résumés extraits pour l'analyse des tendances de la recherche.
Résultats : L'analyse finale a porté sur 3 896 articles et revues, avec une augmentation considérable du volume de publications au cours des 20 dernières années. Les principaux domaines de recherche incluaient le traitement des traumatismes, les lésions des membres et la coagulopathie induite par les traumatismes. Les États-Unis et le système de l'Université du Texas sont devenus les principaux contributeurs dans ce domaine, le Journal of Trauma and Acute Care Surgery étant la principale source de publications.
Conclusion : Les États-Unis continuent de contribuer de manière significative à ce domaine, avec l'intégration des expériences militaires du champ de bataille dans les environnements civils. Le sang total du groupe O à faible titre et les lésions cérébrales traumatiques représentent des domaines prometteurs pour la recherche future.

Mots-clés : transfusion sanguine, traumatisme, analyse bibliométrique, allocation de Dirichlet Latente.

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Introduction

Approximately 4.4 million people worldwide die from traumatic injuries each year, mainly caused by road traffic accidents, suicides, and conflicts [1]. Haemorrhage is a prevalent consequence of trauma, leading to insufficient tissue perfusion, acid-base

imbalances, depletion of coagulation factors, and inflammation - thereby emerging as the primary cause of death among trauma patients [2,3]. Blood transfusion is an essential facet of trauma treatment, effectively countering acute traumatic coagulopathy and trauma induced coagulopathy (TIC) [4]. As early as World War I, whole-blood transfusion was widely used in the treatment of casualties [5]. Today, the field of blood transfusion has become a vast professional discipline, covering areas such as blood donation, blood quality management, selection of blood transfusion schemes, and research on the side effects of transfusion [6-10]. With the continual rise in trauma injuries from road traffic accidents and local war conflicts, blood transfusion is projected to maintain its relevance as a critical direction of research [11].

Bibliometric analysis is an interdisciplinary research method that uses quantitative and qualitative methods to systematically analyse knowledge carriers and compare the contributions of different authors, institutions, and countries/regions to the field [12]. Latent Dirichlet Allocation (LDA) is a generative probabilistic model of topics that calculates a specific number of topics by considering the probability distribution of related terms and can be used to uncover latent topics in document collections [13]. These two methods have been widely applied in medicine, biology, and other research fields [12,14].

This study aims to conduct a comprehensive analysis of the advancements in transfusion technology within trauma research based on the Web of Science (WOS). Core Collection. We applied a bibliometric approach to identify research trends, hotspots, and major research teams and regions in trauma and transfusion research. Additionally, we used the LDA model to explore the evolution of research topics and predict potential future hotspots.

Methods

Data source and search strategies

In March 2023, we conducted a literature search of the WOS Core Collection online database to identify scientific literature related to the field of trauma and transfusion. The following search formula was used: TS = ((‘blood transfusion’) OR (‘Red blood cells’ AND ‘Transfusion’) OR (Platelet AND ‘Transfusion’) OR (‘Blood plasma’ AND ‘Transfusion’) OR (‘Whole blood’ AND ‘Transfusion’) OR (‘Pre-hospital transfusion’) OR (‘blood substitute’ AND ‘transfusion’) OR (‘frozen dry blood plasma’) OR (‘iPSC-derived platelets’) OR (‘platelet alloimmunization’) OR (‘Red blood cell’ AND alloimmunization) OR (‘plasma exchange’ AND ‘transfusion’) OR (‘Blood Component*’) OR (‘Blood Donation’) OR (‘Patient Blood Management’) OR (‘Therapeutic Apheresis’) OR (‘Transfusion Complications’) OR (Transfusion-Transmitted Diseases) OR (‘RBC storage lesion’) OR (‘Platelet storage lesion’) OR (‘Blood group system’ AND ‘transfusion’) OR (‘transfusion associated circulatory overload’) OR (‘transfusion associated lung injury’)) AND TS=(trauma* OR (‘war wound’) OR (‘first aid’)). The search parameters were restricted to the English language and a publication date range from January 1, 2003, to December 31, 2022. The search yielded a total of 4,088 articles (after duplicate removal). Upon exclusion of letters, editorial content, proceeding papers, book chapters, and other types of literature, a collection of 3,896 articles and review articles were obtained for further analysis.

Data collection and analysis

The search results were exported in the ‘Full Record and Cited References’ format and stored as plain text files. Python was used to extract all abstracts and the corresponding publication years from these text files, resulting in a total of 3,804 records that were subsequently saved in an Excel file.

The characteristics of all publications were analysed via WOS and Excel, and the data visualization was achieved using Vosviewer [15]. The optimal number of topics was determined to be 11 using the similarity method, and LDA topic modelling was applied to the extracted literature abstracts using Python’s gensim module, which yielded the keywords associated with each topic. These keywords were manually screened and divided into three themes. Lastly, a word cloud representing popular keywords from the past two decades was generated utilizing the word cloud tool in Python [16,17].

Results

Time-trend analysis of publications

An analysis of the progression in the number of publications and citations over time offers insight into the general evolution of this research field. There has been a consistent upward trend in related research in the past 20 years, rising from 48 publications in 2003 to 318 in 2022. As of March 2023, the

Table 1: Top 10 countries and regions with the highest number of publications in the past 20 years

Rank	Country/region	Count	Citations	H index	Institute	Count	Citations	H index
1	USA	2061	7514	123	University of Texas System	319	18750	66
2	England	344	16872	62	University of California System	209	18750	53
3	Germany	318	12374	55	University of Pittsburgh	186	6704	43
4	Canada	232	10789	53	United States Army	155	9177	49
5	Peoples Republic of China	210	2877	29	University of Colorado System	149	7001	47
6	Australia	180	4714	33	University of Washington	135	7062	40
7	France	158	4793	32	University System of Maryland	130	7948	43
8	Japan	107	3643	32	Harvard University	120	5412	36
9	Switzerland	104	1947	22	University of London	115	7139	39
10	Denmark	99	4754	37	University of Toronto	108	6497	38

total number of citations for related literature reached 118,184, with an average citation frequency of 30.31, and a collective H-index of 143.

Distribution of countries/regions and institutions

In the past 20 years, a total of 99 countries/regions have published research related to trauma transfusion. As shown in Table 1, with 2,061 published articles (52.90% of the total number of publications) over the past 20 years, the United States has made the most substantial contribution to this field. This count exceeds the sum of the publications in all other nations. Furthermore, these publications also hold the first position globally for citation count. Among the top ten institutions with the highest publication count, eight are based in the United States. The University of Texas, primarily the University of Texas Health Science Center Houston, leads with a total of 319 publications, marking it as the global leader in terms of research output in this field.

Collaboration between countries and institutions is prevalent in this field. As shown in Figure 1A, the United States and most developed European countries, such as England and Germany, are the most active regions in collaboration in this field, followed by Asian regions such as China and Japan. Cross-regional collaborations mainly occur between the countries within these regions, with lesser involvement of African and Central Asian countries in international cooperation. Figure 1B shows the evolution of institutional collaboration over time. It can be seen that the earliest research in the field was conducted at US military institutions, such as the Walter Reed Army Institute of Research and the Brooke Army Medical Center, while universities began to engage with trauma research after 2010.

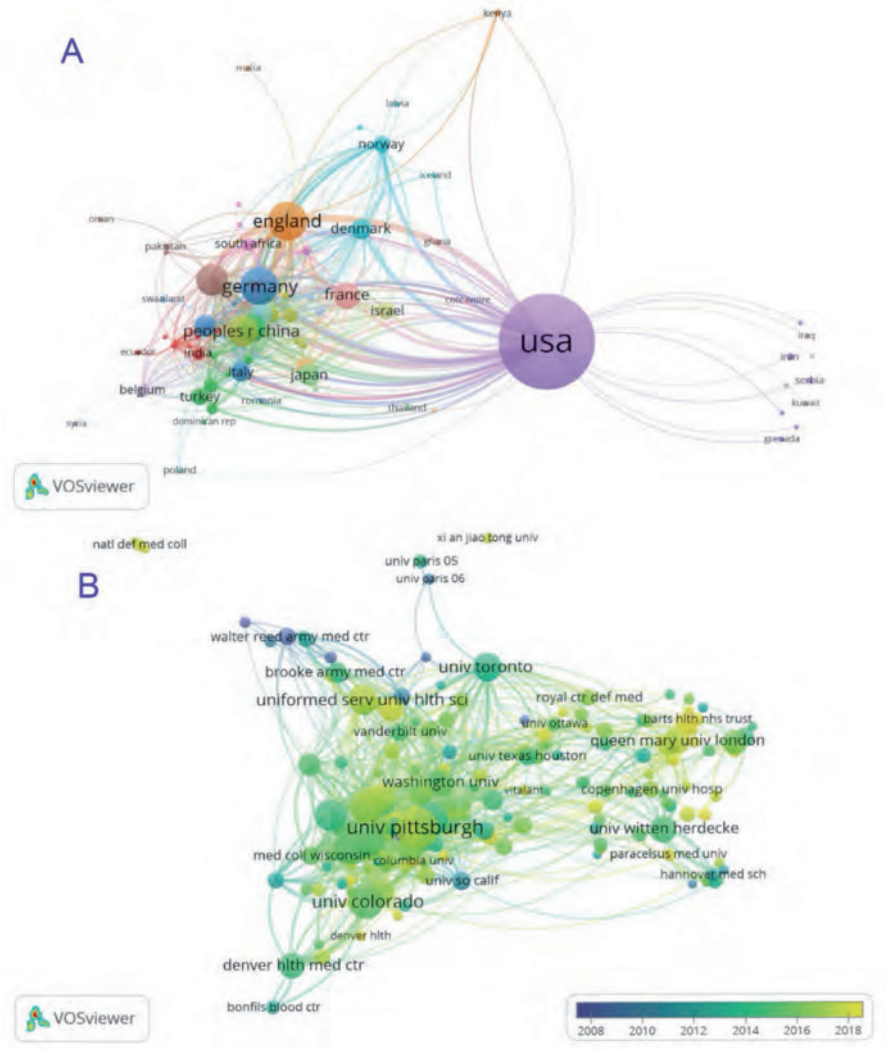

Figure 1

Analysis of journals and highly cited literature

The 3,896 retrieved articles were published in 718 journals. Table 2 shows the top 10 journals with the highest number of publications in the field of trauma and blood transfusion in the past 20 years. Over 20 years, the Journal Of Trauma And Acute Care Surgery had the greatest research productivity, contributing 341 articles to the collection. The journal with the highest number of citations is the Journal of Trauma Injury Infection and Critical Care, which also has the highest H-index.

As shown in Table 3, eight of the 10 articles with the most citations were contributions from research institutions based in the United States, while the remaining two were from England. The Journal of Trauma Injury Infection and Critical Care, which has the maximum total citations across all articles, was responsible for publishing 3 of

Table 2: Top 10 journals with the highest number of publications in the past 20 years

Rank	Productive Journals	Records	Citations	H index	IF (2023)	JCR
1	Journal of Trauma And Acute Care Surgery	341	8334	49	3.697	Q1/Q2
2	Transfusion	228	5528	43	3.337	Q3
3	Journal of Trauma Injury Infection And Critical Care	177	19368	72	1.722	Q2
4	Injury International Journal Of The Care of The Injured	126	3219	32	2.687	Q2/Q3
5	Shock	91	2681	30	3.533	Q1/Q2/Q3
6	Journal of Surgical Research	68	768	16	2.417	Q3
7	American Surgeon	64	846	16	1.002	Q4
8	Vox Sanguinis	61	1346	20	2.996	Q3
9	European Journal of Trauma And Emergency Surgery	50	247	9	2.374	Q1/Q3
10	Transfusion Medicine	48	767	17	2.057	Q3/Q4

Table 3: Top 10 most cited articles in the past 20 years

Rank	Title	Authors	Journal	Citations	Country	Year of Publication
1	Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant hemorrhage (CRASH-2): a randomised, placebo-controlled trial	Shakur, H; Roberts, I; Bautista, Raul; et al	Lancet	1801	ENGLAND	2010
2	Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma The PROPPR Randomized Clinical Trial	Holcomb, JB; Tilley, BC; Baraniuk, S; et al	Journal of The American Medical Association	1260	USA	2015
3	The ratio of blood products transfused affects mortality in patients receiving massive transfusions at a combat support hospital	Borgman, MA; Spinella, Philip C; Perkins, Jeremy G; et al.	Journal of Trauma-Injury Infection and Critical Care	1060	USA	2007
4	Impact of haemorrhage on trauma outcome: An overview of epidemiology, clinical presentations, and therapeutic considerations	Kauvar, DS; Lefering, Rolf; Wade, CE.	Journal of Trauma-Injury Infection and Critical Care	951	USA	2006
5	Early coagulopathy predicts mortality in trauma	MacLeod, JBA; Lynn, M; McKenney, MG; et al.	Journal Of Trauma-Injury Infection And Critical Care	848	USA	2003
6	Increased plasma and platelet to red blood cell ratios improves outcome in 466 massively transfused civilian trauma patients	Holcomb, JB; Wade, CE; Michalek, JE; et al.	Annals of Surgery	753	USA	2008
7	Red Blood Cell Transfusion: A Clinical Practice Guideline From the AABB	Carson, JL; Grossman, BJ; Kleinman, S; et al.	Annals of Internal Medicine	716	USA	2012
8	The importance of early treatment with tranexamic acid in bleeding trauma patients: an exploratory analysis of the CRASH-2 randomised controlled trial	Roberts, I; Shakur, H; Afolabi, A; et al.	Lancet	670	ENGLAND	2011
9	The Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) Study Comparative Effectiveness of a Time-Varying Treatment With Competing Risks	Holcomb, JB; del Junco, DJ; Rahbar, MH; et al.	JAMA Surgery	653	USA	2013
10	Efficacy of red blood cell transfusion in the critically ill: A systematic review of the literature	Marik, PE; Corwin, HL;	Critical Care Medicine	619	USA	2008

these top-cited articles. The single article with the highest citations was published in The Lancet.

Author analysis

A total of 15,421 authors were involved in research in this field, and 207 authors published more than 10 articles. Table 4 shows the top 10 authors with the highest number of publications in the field of trauma and blood transfusion in the past 20 years, they are all from the United States, and their published articles account for 13.3% of the total published articles. It is worth mentioning that among the top ten authors in this field, Holcomb. John R, Wade. Charles E, and Spinella. Philip C, although

Table 4: Top 10 authors with the highest number of publications in the past 20 years

Rank	Author	Count	Citations	H index	Affiliation
1	Holcomb, John B	176	15808	60	University of Texas
2	Wade, Charles E	97	10008	44	University of Texas
3	Moore, Ernest E	89	5916	43	University of Colorado
4	Spinella, Philip C	87	6914	44	University of Pittsburgh
5	Cap, Andrew P	81	2489	30	U.S. Army Institute of Surgical Research
6	Cotton, Bryan A	77	6142	37	University of Texas
7	Schreiber, Martin A	67	5409	33	Oregon Health & Sci University
8	Cohen, Mitchell J	66	5254	31	University of California
9	Hess, John R	61	5223	30	University of Washington
10	Inaba K	60	3512	26	University of Southern California

currently working in local research institutions, all have long-term work experience in the US military.

Analysis of the evolution of topics

We selected 3,804 articles with abstracts for further analysis of the evolution of topics. The abstracts from these articles were gathered and subjected to a topic analysis using the LDA model. After calculating text similarity, we found that the optimal classification effect and highest text similarity were achieved when the number of topics was 11. Subsequently, we identified the relevant keywords for these 11 topics using the LDA model. To facilitate our analysis, we classified the 11 topics into three distinct themes according to their keywords: research related to trauma treatment, limb injury, and TIC. These groupings are elaborated upon in Table 5.

Finally, we evaluated the evolution of keyword frequency across four distinct time frames (2003-2007, 2008-2012, 2013-2017, 2018-2022) for the three designated themes. We extracted the abstract content of the corresponding topics within each period and tallied the 25 words of the highest frequency. These were then visually represented as word clouds, as depicted in Figure 2. Despite the passage of time, the key areas of research within the three themes remained relatively stable. For instance, 'red blood cell' and 'ratio' were always the research hotspots in trauma treatment, as well as 'fracture' and 'score' in limb injury, and 'platelet' and 'coagulopathy' in TIC abnormalities. However, with the development of technology, some newly emerged keywords are attracting the attention of researchers, such as 'low titre group O whole blood' in the realm of trauma treatment, 'surgery' within limb injury, and 'traumatic brain injury' in TIC. These emerging keywords signal the potential future directions of this field.

Table 5: Topics covered by the three themes in the past 20 years

Themes and Topics			Key words
Theme 1: trauma treatment			
	Topic 1a (1)	haemostasis scheme	bleeding, coagulation, hypothermia, DIC (disseminated intravascular coagulation), guideline, management
	Topic 1b (2)	injury assessment	score, admission, ICU, predictor, severity, survival
	Topic 1c (3)	means of blood transfusion	FFP (fresh frozen plasma), PRBC (packed red blood cells), ratio, LTOWB (low titre group O whole blood), RBC (red blood cell), plasma
	Topic 1d (7)	battlefield rescue	prehospital, combat, military, medical, amputation, Afghanistan
Theme 2: limb injury			
	Topic 2a (5)	pelvic injury	pelvic, systolic, fracture, TAE (Therapeutic arterial embolization), shock, RTS(revised trauma score)
	Topic 2b (6)	lower limb injury	hip, fracture, knee, arthroplasty, thromboembolic, acetabular
	Topic 2c (10)	craniocerebral injury	TBI (traumatic brain injury), brain, cerebral, trial, traumatic, Cochrane
	Topic 2d (11)	abdominal injury	MTP(Massive transfusion protocol), abdominal, liver, spleen, renal, blunt
Theme 3: TIC			
	Topic 3a (4)	coagulation mechanism	platelet, storage, RBC (red blood cell), inflammatory, coagulation, haemolysis
	Topic 3b (8)	coagulation monitoring	fibrinogen, TEG (Hertert thromboelastography), clot, ROTEM (Rotational thromboelastometry), coagulation, APTT (activated partial thromboplastin time)
	Topic 3c (9)	anticoagulant therapy	antiplatelet, hematoma, aspirin, anticoagulant, clopidogrel, VTE (venous thromboembolism)

Discussion

General trends in research

Our study selected 3,896 articles on trauma and blood transfusion which were published between 2003 and 2022 in the WOS database, and analysed research trends and hotspots within this field. The findings indicate a steady yearly increase in the number of publications, signalling a growing interest and promising potential for development in trauma and blood transfusion research.

Research into trauma and transfusion initially stemmed from military requirements. Due to the continuous military operations of the US armed forces and to safeguard its military personnel, the US has emerged as the most prolific contributor to research in this field. The number of US publications exceeds the combined total of all other countries, with the US engaging in collaborative research with the majority of nations conducting related studies. Despite a gradual decline in localized conflicts worldwide since the beginning of the 21st century, related research has not decreased accordingly. Trauma and blood transfusion research is playing an increasingly important role in civilian contexts, and the technology developed in military settings continues to

Figure 2

bear significant value in non-war contexts.

The 10 most published authors in this field all come from the US, including Holcomb John B., Wade Charles E., Spinella Philip C., and Cap Andrew P., who have all served in the US military. Their research mostly revolves around casualties in past military operations of the US military, emphasizing the enormous value of this field in the military domain. They jointly participated in the study 'Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma The PROPPR Randomized Clinical Trial'. This research later became the standard guideline for transfusion [18]. As these authors transitioned from active military service, their research focus in recent years has shifted towards non-war fields. They have been instrumental in advancing the application of trauma and transfusion techniques within non-military contexts.

Time-trend analysis of published articles shows that US military institutions such as the Walter Reed Research Institute and the Army Surgical Research Institute were the first to conduct related research. However, around 2010, with the retirement of military researchers such as John B. Holcomb and Philip C. Spinella, and their joining of universities such as the University of Texas, universities began to transform into the primary research institutions in this field. This also confirms the transition of trauma and transfusion techniques to civilian scenarios. However, not all are good news regarding such a transition. Although the US Department of Defense is still the third-largest institution funding related research, ranking only behind the Department of Health and Human Services and the National Institutes of Health, the reduction of military investment has raised some concerns about the future development of this field of research [19].

Among the 10 most cited articles, two are from Shakur et al., the only non-US research group. The article by Shakur et al. titled 'Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomized, placebo-controlled trial' is the most cited article in the field. This research highlights the application value of tranexamic acid in the field of trauma and blood transfusion, as it can effectively stop bleeding and reduce the blood transfusion demands of patients to a certain extent [20]. These findings were published in The Lancet, the journal with the highest impact factor among the source journals of the top 10 most cited articles.

Evolution of research hotspots and frontiers

Using the LDA model, we identified three principal themes within the domain of trauma and blood transfusion research and divided the relevant articles by time. Word clouds were generated to illustrate the evolution of key research areas within each theme.

Trauma treatment-related research represents the most pursued direction within the trauma and blood transfusion field. Research hotspots in this area clearly demonstrate the application of battlefield-derived findings in civilian contexts, which often have the highest citation frequency. With the advent of whole-blood separation technology, component transfusion has emerged as the predominant method of blood transfusion. While blood separation technology offers numerous advantages, the determination of the ratio between plasma, platelets, and red blood cells remains a persistent challenge. The conventional approach of transfusion treatment, advocating a 1:1:1 ratio of red blood cells, plasma, and platelets in component transfusion therapy, was promoted by the US military and documented in the *Damage Control Resuscitation Clinical Practice Guidelines* [21]. Moreover, 'LTOWB' (low titre group O whole blood) therapy, another development from the US military, involves the utilization of unseparated blood drawn from donors with 'low' IgM and/or IgG anti-A and anti-B, which can be stored or administered fresh (within 8-24 hours) [22]. This protocol, initially applied during the Korean War, rapidly gained popularity due to its convenience, rapidity, and reduced adverse reactions. However, with the rise of component blood transfusion and concerns regarding disease transmission, the use of type O whole blood was largely confined to military scenarios [23]. In 2014 Strandenes et al. proposed that LTOWB should be the first choice for emergency transfusion when ABO-compatible transfusion safety cannot be guaranteed, sparking debates on its potential application within civilian contexts [24]. Yazer et al. issued the first report on LTOWB application in civilian patients in 2018, suggesting that the clinical outcomes for patients receiving LTOWB were comparable to those receiving traditional component transfusion [25]. Some studies, however, suggest that LTOWB may offer greater benefits to patients [26,27]. It is reported that 40% of level I trauma centres in the US have initiated the use of LTOWB, indicating its substantial potential for wider application [28]. However, there are many differences between military context and civilian environment, which bring uncertainty to the LTOWB. Thus, the effectiveness of LTOWB remains to be observed.

In trauma combined with limb injuries, 'fracture' and 'score' have always been the research hotspots, with 'pelvic fracture' being the most common type of fracture involved. This is because the pelvis is anatomically related to many vascular structures, such as the common iliac artery, inferior gluteal artery, and rectal artery [29]. The severity of pelvic fractures, particularly haemodynamically unstable fractures, is closely related to haematoma and haemorrhagic shock, and bleeding has become the main cause of death in pelvic fractures [30]. Research has demonstrated that rotationally and vertically unstable fractures require more blood transfusions than other pelvic fracture types [31,32]. Therefore, the accurate categorization of pelvic fractures and the implementation of individualized transfusion strategies are of great significance for effective treatment, which requires further investigation. In recent years, the importance of 'surgery' has been progressively increasing in this domain, indicating the transition of trauma and blood transfusion research, particularly transfusion management, into an integral component of the surgical process. These studies are obviously difficult to conduct in military environments with fewer patients and poorer conditions. However, the development of these studies in civilian settings, will enhance trauma and blood transfusion treatment within military settings, thereby improving casualty care capabilities on the battlefield.

The phenomenon of coagulation disorders in trauma patients has long been recognized, leading to the proposal of the concept of TIC. TIC constitutes a distinct coagulopathy affecting trauma patients, which can be further classified into early and late TIC. Characterized by the inability to stop bleeding efficiently, early TIC (typically occurring within 6 hours post-injury) could lead to uncontrolled bleeding and prolonged shock. Conversely, late TIC (usually occurring >24 hours post-injury) is characterised by a hypercoagulable state that may result in excessive macro- and mi-