

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

# Resuscitation Plus

journal homepage: [www.elsevier.com/locate/resuscitation-plus](http://www.elsevier.com/locate/resuscitation-plus)

## Review

# Strengthening trauma resuscitation education and training in low-resource settings: A call for global inclusion



Ileana Lulic<sup>a,\*</sup>, Carlos Mesquita<sup>b</sup>, Dinka Lulic<sup>c</sup>, Romeo Lages Simões<sup>d</sup>, Luís Ferreira<sup>b,e</sup>, Piotr Koleda<sup>f</sup>, Sérgio Baptista<sup>b,g</sup>, Henrique Alexandrino<sup>b,h,i</sup>, Thiago Rodrigues Calderan<sup>j</sup>, Vanessa Henriques Carvalho<sup>k</sup>, Vitor Favali Kruger<sup>j,l</sup>, Rodrigo Caselli Belem<sup>m</sup>, Fernando López-Mozos<sup>n</sup>, Carlos Yanez<sup>o</sup>, Jadranka Pavicic Saric<sup>a</sup>, Gustavo Pereira Fraga<sup>j</sup>

## Abstract

Trauma is a leading cause of preventable death worldwide, disproportionately affecting low-resource settings where access to specialized care is limited. Systemic barriers, including fragmented trauma networks and workforce shortages, contribute to poor outcomes. Strengthening trauma resuscitation through structured education and training is critical to improving survival and reducing disparities. However, traditional trauma training models often fail to address regional constraints, limiting their effectiveness. Brazil has developed a comprehensive trauma resuscitation education model by integrating public awareness campaigns, medical student-led initiatives, digital learning, simulation-based training, and telemedical support. A horizontal approach to trauma patient management, combined with hands-on immersive simulation training, has further enhanced this framework, emphasizing the team approach and non-technical skills essential for high-performance trauma care. This narrative review examines Brazil's trauma resuscitation training strategies and explores their potential to serve as a template for low-resource settings. By analyzing key educational components, we identify cost-effective solutions to strengthen trauma system capacity. To bridge disparities, trauma education must extend beyond well-resourced environments. Faculty development, sustainable mentorship, and access to technology-driven education are critical to equipping providers with the skills needed to manage complex trauma scenarios. Mobile simulation units and telemedicine platforms expand training to remote regions, while scalable digital platforms enable real-time collaboration. Despite these advancements, funding constraints, logistical barriers, and the need for culturally tailored education hinder widespread implementation. Embedding trauma education into national health policies and disaster response systems is essential to ensuring sustainable, high-quality trauma care worldwide.

**Keywords:** Trauma resuscitation, Education, Simulation-based training, Horizontal team approach, Multidisciplinary approach, Low-resource settings

## Introduction

Traumatic injuries are a leading cause of morbidity and mortality worldwide, with low-resource settings experiencing the greatest bur-

den.<sup>1</sup> Limited access to specialized trauma care, workforce shortages, and delays in prehospital and hospital-based interventions contribute to preventable deaths. The Utstein formula of survival provides a standardized framework for trauma care, integrating medical education, system performance, and adherence to evidence-based

\* Corresponding author at: Department of Anesthesiology, Intensive Care and Pain Medicine, Clinical Hospital Merkur, Zajceva 19, 10 000 Zagreb, Croatia.

E-mail addresses: [ileanalulic@gmail.com](mailto:ileanalulic@gmail.com) (I. Lulic), [mesquita.carlos@sapo.pt](mailto:mesquita.carlos@sapo.pt) (C. Mesquita), [dinka.lulic@gmail.com](mailto:dinka.lulic@gmail.com) (D. Lulic), [romeolages-simoes@gmail.com](mailto:romeolages-simoes@gmail.com) (R.L. Simões), [luisferreira82@hotmail.com](mailto:luisferreira82@hotmail.com) (L. Ferreira), [pkoleda@me.com](mailto:pkoleda@me.com) (P. Koleda), [sergiofariabatista@gmail.com](mailto:sergiofariabatista@gmail.com) (S. Baptista), [halexandrino123@gmail.com](mailto:halexandrino123@gmail.com) (H. Alexandrino), [calderan.thiago@gmail.com](mailto:calderan.thiago@gmail.com) (T.R. Calderan), [vanessah@unicamp.br](mailto:vanessah@unicamp.br) (V.H. Carvalho), [vitorfkruger@gmail.com](mailto:vitorfkruger@gmail.com) (V.F. Kruger), [rdcaselli@terra.com.br](mailto:rdcaselli@terra.com.br) (R.C. Belem), [ferlomo@gmail.com](mailto:ferlomo@gmail.com) (F. López-Mozos), [carlosybl@gmail.com](mailto:carlosybl@gmail.com) (C. Yanez), [jpavicic58@gmail.com](mailto:jpavicic58@gmail.com) (J.P. Saric), [fragagp2008@gmail.com](mailto:fragagp2008@gmail.com) (G.P. Fraga).

<https://doi.org/10.1016/j.resplu.2025.100935>

Received 21 January 2025; Received in revised form 16 March 2025; Accepted 17 March 2025

guidelines (Fig. 1).<sup>2</sup> However, its implementation remains challenging in low-resource settings, where infrastructure limitations and inconsistencies in trauma training programs hinder effective care delivery exacerbating survival disparities.<sup>3,4</sup> Structured quality improvement initiatives, such as protocol standardization, performance audits, and targeted skill development, enhance system efficiency and provider competency, forming the foundation for scalable trauma resuscitation strategies.<sup>5</sup> Integrating these initiatives with scenario-based simulation training and telemedicine strengthens trauma care capacity, empowers local communities, and fosters global collaboration in trauma education.<sup>6</sup>

This narrative review explores the transformation of trauma resuscitation in Brazil through evidence-based research, community engagement, digital innovations, and healthcare-led initiatives. It examines the implementation of a structured, hands-on trauma resuscitation training models, integrating training strategies tailored to low-resource settings to enhance multidisciplinary teamwork, non-technical skills, and system adaptability. By analyzing Brazil's experience, this study aims to identify cost-effective strategies for trauma education and training in low-resource settings and support the development of a globally inclusive trauma resuscitation training framework.

### Trauma systems in Brazil: Structure, challenges, and pathways to improvement

Brazil's trauma system operates within the universal healthcare framework of the Sistema Único de Saúde, which provides free healthcare to all citizens.<sup>7</sup> While 25% of the population has supplemental insurance and uses private sector services, they still have access to the public system. Trauma care follows a hierarchical referral model based on injury severity and facility capacity.<sup>8</sup> However, regional disparities significantly impact access to trauma services, particularly in rural and remote regions, where limited prehospital care, treatment delays, and a shortage of specialists may contribute to worse patient outcomes.<sup>9,10</sup> Table 1 outlines the structure of trauma care in Brazil.

Within this system, prehospital emergency medical services (EMS) play a critical role. The nationalized Serviço de Atendimento Móvel de Urgência provides basic and advanced life support units, supplemented by the fire brigade, Resgate 193, in some regions.<sup>11</sup> Additionally, Unidade de Pronto Atendimento emergency care units ensure continuous trauma care for medium-complexity cases. Table 2 summarizes the key features and operational roles of Brazilian EMS components, highlighting their contributions to prehospital trauma care.

Emergency departments serve as the frontline of hospital-based trauma care, utilizing structured triage systems such as the Manch-

ester Triage System and Simple Triage and Rapid Treatment to prioritize patients.<sup>12,13</sup> Despite these structured triage systems, systemic challenges continue to hinder efficient trauma resuscitation in Brazil.<sup>14,15</sup> Table 3 outlines the structural, operational, and socio-cultural factors influencing trauma care in low- and middle-income countries (LMICs), highlighting key areas for system improvements.

In the broader context of prehospital trauma care in LMICs, a global systematic review reported an average ambulance response time of 14 min and 25 s.<sup>16</sup> However, Brazilian data remain scarce, and response times likely vary due to disparities in EMS coverage, transport logistics, and system capacity. A Brazilian study assessing helicopter deployment in trauma care found that off-site landings requiring additional ground transport to the hospital resulted in transport times averaging five minutes longer than direct landings at trauma centers.<sup>17</sup>

Strengthening Brazil's trauma system requires equitable resource allocation, improved EMS-hospital integration, and specialized training to enhance trauma care delivery and reduce preventable mortality. Recent data from a Brazilian trauma center transformation project at Hospital de Base do Distrito Federal (HBDF) provide compelling evidence of system-wide improvements.<sup>18</sup> A series of targeted interventions, including standardized trauma protocols, faculty development, and structured training programs, resulted in a 49% reduction in trauma room mortality between 2018 and 2021.

### Closing the evidence gap: Advancing trauma resuscitation research in low-resource settings

Trauma resuscitation education and training are guided by an expanding body of medical evidence that informs clinical practice and strengthens trauma care systems.<sup>19</sup> Despite advancements, research on injury prevention, resuscitation strategies, and trauma system optimization remains severely underfunded, receiving only 6% of total research funding.<sup>20</sup> This funding disparity limits the development of targeted interventions and data-driven improvements in trauma care.<sup>21,22</sup> Addressing these gaps requires a coordinated approach that integrates system-wide evaluation, standardized protocols, and research.<sup>23</sup>

Models such as the United Kingdom's Major Trauma Networks and the Trauma Audit and Research Network demonstrate how continuous evaluation and evidence-based refinements can enhance trauma system efficiency.<sup>24</sup> In low-resource settings, where centralized trauma networks are often unavailable, progress depends on regional initiatives.<sup>25</sup> The Brazilian Trauma Society (SBAIT) has contributed to research on injury patterns, treatment approaches, and patient outcomes despite resource constraints.<sup>26,27</sup> A study

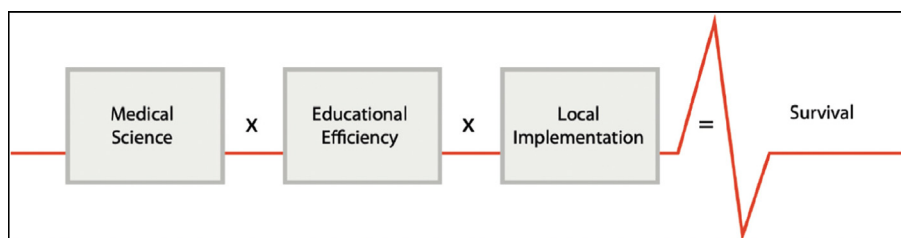


Fig. 1 – The Utstein formula for survival.

**Table 1 – Levels of trauma care in Brazil: distribution, services, and challenges.**

TRAUMA CARE LEVEL	LOCATION	SERVICES PROVIDED	CHALLENGES
1 LEVEL I TRAUMA CENTERS	Large urban hospitals	Continuous surgical, neurosurgical, and intensive care services	High patient volume and resource demand
2 LEVEL II & III TRAUMA CENTERS	Mid-sized cities	General emergency and surgical care, often lacking subspecialty coverage	Limited specialist availability and referral dependencies
3 EMERGENCY CARE UNITS	Various urban and semi-urban areas	Intermediate stabilization for trauma cases not requiring immediate hospital admission	Limited capacity for major trauma cases
4 GENERAL HOSPITALS	Smaller municipalities	Basic emergency care with limited trauma capacity, relies on referrals	Lack of trauma specialists, delayed referrals due to geographic constraints

**Table 2 – Key features and capabilities of emergency medical service components in Brazil.**

SERVICE COMPONENT	DESCRIPTION	KEY FEATURES AND CAPABILITIES
1 SERVIÇO DE ATENDIMENTO MÓVEL DE URGÊNCIA	Nationalised emergency medical service system operating under a centralized dispatch, prioritizing cases based on medical urgency	Established in 2003, operates regionally and provides free emergency care under Sistema Único de Saúde, ensuring nationwide coverage
2 BASIC LIFE SUPPORT UNITS	Staffed by paramedics and nurses, providing non-invasive stabilization and transport	Handles non-critical emergencies, lacks advanced airway management and drug administration capabilities, but ensures rapid transport
3 ADVANCED LIFE SUPPORT UNITS	Equipped with a physician, nurse, and intensive care resources, responding to severe trauma cases requiring on-scene interventions	Manages critical trauma, traumatic cardiac arrests, and complex medical emergencies, adhering to strict prehospital care protocols
4 FIRE BRIGADE EMERGENCY RESPONSE (RESGATE 193)	Provided by the fire department in some regions	Specialized in extrication and rescue operations, playing a key role in vehicle accidents and structural collapse

conducted in a Brazilian university teaching hospital demonstrated how implementing a trauma registry enhanced system evaluation, enabling the identification of critical improvement areas such as over-triage control and the development of specific management protocols.<sup>28</sup>

Despite their potential, trauma registries in low-resource settings remain underutilized due to lack of national coordination and fragmented integration.<sup>29,30</sup> Leveraging these data-driven tools beyond isolated hospital-based surveillance is essential for guiding system-wide improvements, optimizing resource allocation, and informing policy development.<sup>31,32</sup>

### **Evolving trauma education: Adapting training to low-resource settings**

Trauma resuscitation education initially relied on didactic instruction delivered by various trauma organizations.<sup>33</sup> Over time, training methodologies shifted toward hands-on, simulation-based learning, which has proven more effective in maintaining resuscitation skills, enhancing clinical readiness, and improving provider confidence.<sup>34</sup> This transition reflects a broader movement toward learner-centered approaches, emphasizing active engagement and internal motivation, key principles of adult learning.<sup>35</sup>

Logistical barriers to ongoing education, inconsistent mentorship opportunities, and limited access to advanced training facilities pose significant challenges in low-resource settings, making this transformation particularly critical. Traditional one-size-fits-all training models often fail to address local limitations, whereas decentralized, context-specific education frameworks have expanded access, improved skill retention, and strengthened patient outcomes.<sup>36</sup> Integrating flexible and cost-effective training strategies can better prepare providers for the complexities of real-world trauma care while ensuring sustained improvements in clinical performance and patient survival. The implementation of structured trauma education programs has been associated with measurable reductions in trauma-related mortality.<sup>37</sup> Although outcome data from Brazil's trauma education initiatives remain scarce, evidence from the HBDF trauma center transformation demonstrates that expanding multidisciplinary trauma education programs can significantly reduce mortality.<sup>18</sup>

### **Community-driven trauma education: Mobilizing public engagement**

Global trauma resuscitation education and training face significant challenges due to disparities in emergency response capacity, critical care accessibility, and rehabilitation infrastructure. To address these gaps, many regions have expanded trauma management efforts by actively involving public representatives in education and

**Table 3 – The structural, operational, and sociocultural factors influencing trauma care in low- and middle-income countries.**

BARRIER	DESCRIPTION	IMPACT ON TRAUMA CARE
1 <b>FINANCIAL LIMITATIONS</b>	Inadequate funding for trauma care, insufficient hospital budgets, and financial barriers limiting patient access to care	Restricts access to essential services, exacerbates inequalities in care, and limits investment in trauma system improvements
2 <b>HEALTHCARE FACILITY CAPACITY ISSUES</b>	Overcrowded emergency departments, insufficient intensive care unit beds, and lack of trauma-specific infrastructure, particularly in rural areas	Forces trauma patients into under-resourced facilities, increases wait times, and reduces availability of advanced interventions
3 <b>RESOURCE AND EQUIPMENT SHORTAGES</b>	Limited availability of trauma equipment, insufficient diagnostic tools, and inconsistent supply of essential medications	Compromises treatment quality, limits diagnostic accuracy, and increases mortality in severe trauma cases
4 <b>WORKFORCE SHORTAGES</b>	Shortage of trained trauma surgeons, emergency physicians, nurses, and paramedics, leading to gaps in coverage and expertise	Increases workload for available staff, leads to fatigue, and prolongs response times in emergency scenarios
5 <b>TRAINING DEFICIENCIES</b>	Lack of specialist trauma training, absence of structured education programs, and inadequate continuing professional development	Reduces provider competence, delays decision-making, and contributes to poor patient outcomes
6 <b>LACK OF STANDARDISED PROTOCOLS</b>	Absence of standardized triage systems, non-uniform treatment guidelines, and poor documentation practices	Leads to inefficient patient triage, delays resuscitation efforts, and contributes to system-wide inconsistencies
7 <b>TRANSPORT AND LOGISTICAL CONSTRAINTS</b>	Delays in prehospital response due to inadequate ambulance coverage, difficult terrain, and poor infrastructure	Extends prehospital transport times, reduces survival chances for critically injured patients, and delays definitive care
8 <b>SOCIOCULTURAL BARRIERS</b>	Cultural resistance to protocol implementation, hierarchical team dynamics, and reluctance to adopt quality improvement initiatives	Creates resistance to evidence-based practices, fosters inefficiencies in care delivery, and limits interdisciplinary collaboration
9 <b>LIMITED PUBLIC EDUCATION</b>	Low awareness of trauma prevention strategies, lack of public training in basic life support, and poor adherence to road safety measures	Increases trauma incidence, delays help-seeking behaviors, and contributes to preventable mortality

prevention initiatives.<sup>38</sup> However, a lack of definitive evidence regarding the most effective training strategies for non-clinical participants has resulted in program variations tailored to local system needs.

Between 2011 and 2020, the United Nations General Assembly launched the “Decade of Action for Road Safety”, aiming to reduce global road traffic fatalities.<sup>39</sup> Brazil ranked fifth in traffic and violence-related deaths, behind China, India, Russia, and the United States. Recognizing this public health crisis, Brazil developed a national action plan to mobilize policymakers, healthcare professionals, and community representatives in trauma prevention efforts. Brazil’s “Family Health Program” represents a large-scale community-based initiative with documented impact on injury-related mortality. An analysis of municipality-level data demonstrated a significant reduction in trauma-related deaths, particularly in impoverished regions.<sup>40</sup>

One of the most impactful community-driven initiatives is “Yellow May”, launched in 2014 by the National Observatory for Road Safety and SBAIT.<sup>41</sup> The campaign raises awareness of trauma-related deaths caused by road traffic accidents while mobilizing public representatives to identify priorities, promote trauma resuscitation education, and implement cost-efficient trauma systems. These trauma ambassadors foster collaboration between healthcare professionals and the public, improving survival outcomes. Since 2015, “Yellow May” has expanded through monthly events and community-led initiatives, growing to include 21 countries across five continents with

support from over 600 organizations. These efforts have significantly influenced trauma prevention strategies and reinforced the role of community participation in strengthening the trauma care continuum.

#### ***Future leaders in trauma care: Medical students as catalysts for change***

Trauma resuscitation education and training gained momentum in the early 1990s, with medical students playing a pivotal role in improving trauma quality indicators. Trauma academic leagues have introduced a parallel curriculum that enables medical students to engage in trauma education under expert mentorship.<sup>42</sup> These initiatives focused on four core objectives: expanding theoretical knowledge, integrating students into trauma resuscitation care, advancing trauma research, and assessing educational outcomes through structured trauma meetings and prevention programs. By bridging the gap between theoretical education and hands-on clinical experience, these efforts have strengthened trauma education and contributed to the development of evidence-based trauma resuscitation practices.

Established in 1992, the University of Campinas (Unicamp) Trauma League (UTL) became Brazil’s first trauma academic league and remains a leading model for trauma resuscitation education.<sup>43</sup> The UTL program follows a structured, three-phase selection process designed to ensure comprehensive faculty development and student engagement. Candidates first complete a three-day intensive workshop covering core trauma education principles. A written

assessment then evaluates knowledge retention, followed by an interview assessing motivation, communication skills, and commitment to the curriculum. As UTL marks its 30th anniversary, it continues to shape trauma education and mentorship across Brazil, demonstrating the impact of structured, time-sensitive training in preparing future trauma care professionals. These academic leagues not only cultivate technical expertise but also foster leadership, research engagement, and advocacy for trauma system improvements, reinforcing the role of medical students in driving change within trauma care systems.

### ***Global trauma education in the digital age: Innovations connecting experts worldwide***

Advanced educational technologies are revolutionizing trauma resuscitation education and training, fostering global collaboration and real-time knowledge exchange. These innovations enable cross-border learning opportunities, allowing trauma professionals to engage with multidisciplinary experts worldwide. However, their implementation requires careful navigation of privacy regulations, data security, and equitable access, particularly in low-resource settings.

One of the most impactful initiatives in digital trauma education is “Tele-Grand Rounds”, a platform that facilitates virtual case discussions among trauma specialists across institutions and countries.<sup>44</sup> The Ryder Trauma Center at the University of Miami, under the leadership of Dr. Antonio Martos, has pioneered weekly “Tele-Grand Rounds”, providing a structured forum where complex trauma cases are presented and analyzed by experts in real time. The Unicamp Division of Trauma Surgery actively participates in these sessions, leveraging this international network to enhance clinical expertise, refine training methods, and strengthen global trauma education partnerships. To date, 42 trauma centers, spanning academic, military, urban, community, and rural institutions, have integrated “Tele-Grand Rounds” into their trauma resuscitation programs.<sup>45</sup> As digital platforms continue to reshape medical education, initiatives like “Tele-Grand Rounds” play a critical role in democratizing trauma training, ensuring that expert insights reach providers in diverse and low-resource environments.

### ***Trauma education at the frontline: Strengthening healthcare professionals***

Trauma resuscitation spans the entire continuum of care, from the prehospital environment to in-hospital management, requiring seamless coordination among healthcare professionals. Its growing complexity demands not only technical proficiency but also a culture of competence, where trainees are evaluated on their ability to achieve an optimal learning curve in high-pressure situations.<sup>46</sup> While multiple specialties contribute to reducing morbidity and mortality, assembling skilled professionals alone does not create an effective trauma team. Advancing global trauma care, particularly in low-resource settings, requires structured, multi-professional training programs that emphasize non-technical skills such as communication, decision-making, and team dynamics.<sup>47</sup>

Technological advancements have revolutionized trauma resuscitation education, enabling realistic simulations with measurable clinical feedback.<sup>48</sup> Simulation-based training provides a safe, controlled environment for trauma teams to practice high-risk scenarios and enhance clinical decision-making without compromising patient safety. Post-simulation debriefing plays a critical role in refining performance, identifying gaps, and fostering behavioral changes that

improve team coordination and patient outcomes. Despite the widespread adoption of trauma simulation models, the comparative effectiveness of different approaches remains unclear, highlighting the need for further research to optimize training methodologies.

As low-resource settings work toward strengthening trauma education, a multi-professional, simulation-driven approach is essential for developing competency-based training frameworks that enhance teamwork and improve trauma outcomes.<sup>49</sup> Ensuring that healthcare professionals are equipped to navigate complex trauma scenarios will facilitate high-quality care delivery, regardless of resource constraints. Fig. 2 illustrates key milestones in Brazil’s trauma resuscitation education, highlighting structured initiatives that have expanded trauma care capacity.

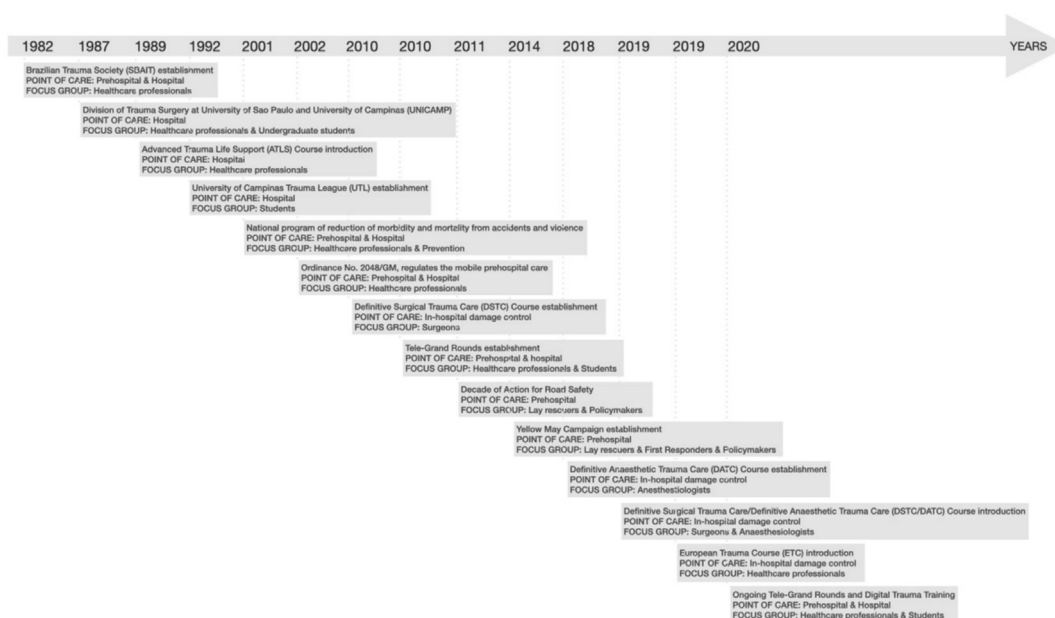
### **Advancing trauma resuscitation in Brazil: Implementing a modular, team-based approach**

Brazil has a longstanding tradition of trauma resuscitation education, with structured training programs evolving to reduce preventable errors that contribute to trauma-related fatalities. Miscommunication, procedural delays, and cognitive overload remain major contributors to system failures, with up to 48% of trauma-related deaths linked to these breakdowns in care.<sup>50</sup> To standardize trauma resuscitation and enhance patient safety, internationally recognized training models have been integrated into Brazil’s trauma education framework.

As a cornerstone of trauma training, the Advanced Trauma Life Support (ATLS) program has provided a structured approach to trauma resuscitation since its introduction in 1989. With over 100 courses conducted annually across 20 centers, ATLS equips healthcare providers with the skills to systematically assess, resuscitate, and prioritize trauma patients based on injury severity. By emphasizing protocol-driven decision-making and real-time critical interventions, the course enhances efficiency in high-pressure environments, ensuring coordinated trauma care and reducing preventable treatment delays.<sup>51</sup> Expanding ATLS training to nurses and non-physician providers has further strengthened interdisciplinary collaboration, improving trauma system coordination and bridging workforce gaps in low-resource settings.<sup>52</sup> Beyond its role in clinical competency, ATLS has been incorporated into structured skill retention programs, such as the “Individual Critical Task Lists” in military medical training, which track procedural proficiency and deployment readiness.<sup>53</sup> This adaptation highlights the course’s versatility across diverse healthcare settings, reinforcing its importance in environments with variable patient volumes and limited trauma specialists.

As Brazil’s trauma care landscape evolved, the need for specialized surgical and anesthetic trauma training led to the introduction of the Definitive Surgical Trauma Care (DSTC) and Definitive Anesthetic Trauma Care (DATC) courses, designed to enhance real-time collaboration between surgeons and anesthesiologists in high-acuity trauma settings.<sup>54</sup> Functioning as an integrated training model, these programs optimize intraoperative coordination, structured communication, and crisis resource management, ensuring a seamless surgical-anesthetic approach to trauma care.<sup>55</sup> Studies demonstrate that the DSTC-DATC model significantly improves intraoperative communication, closed-loop interaction, and structured team exchanges, reducing preventable errors and enhancing multidisciplinary trauma care efficiency.<sup>34</sup> The Brazilian experience





**Fig. 2 – Timeline of trauma resuscitation education in Brazil.**

with this approach reflects a progressive shift toward real-time, interdisciplinary trauma training, aligning with global advancements in trauma education while addressing workforce development gaps and system coordination challenges.

Building on Brazil's expanding trauma education framework, the European Trauma Course (ETC) was introduced through an international collaboration between the Lusitanian Association for Trauma and Emergency Surgery (Portugal) and the University of Campinas (Unicamp).<sup>47</sup> Designed to reinforce structured, team-based resuscitation, ETC employs an immersive, simulation-driven model that eliminates hierarchical barriers, fostering shared responsibility, structured communication, and seamless task coordination.<sup>56</sup> A defining feature of ETC is its emphasis on non-technical skills, including leadership, situational awareness, and crisis resource management, all reinforced through high-fidelity simulations and structured debriefing sessions. The low instructor-to-student ratio enhances individualized feedback, hands-on training, and faculty supervision, accelerating competency acquisition in a controlled learning environment.<sup>57</sup> To address Brazil's trauma care challenges, ETC has been adapted to regional needs while maintaining core learning objectives. A key modification includes the integration of emergency department nursing staff and senior medical students with trauma experience as apprentices, strengthening multidisciplinary collaboration.<sup>58</sup> Beyond routine trauma training, ETC played a critical role during Brazil's catastrophic floods in the greater Porto Alegre region, where its digital platform enabled remote trauma resuscitation training, ensuring continued education for healthcare providers amid disaster response efforts.<sup>59</sup> This demonstrates its scalability and flexibility, positioning it as an essential tool for both routine trauma education and emergency preparedness. As ETC expands across Latin America, its adaptable framework will be instrumental in scaling trauma resuscitation training, overcoming logistical barriers, and strengthening emergency response systems in low-resource healthcare settings.

## Conclusion

The Brazilian model highlights scalable, cost-effective strategies that can inform trauma training frameworks worldwide. The spectrum of implementations described offers resource-efficient, adaptable solutions that extend beyond low-resource settings, providing a template for improving trauma training and care.

## Previous presentation in conferences

This work hasn't been previously presented at national and international scientific meetings.

## Ethics

This manuscript didn't require Institutional Ethics Committee approval.

## CRedit authorship contribution statement

**Ileana Lulic:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Conceptualization. **Carlos Mesquita:** Writing – review & editing, Investigation, Conceptualization. **Dinka Lulic:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Conceptualization. **Romeo Lages Simões:** Writing – review & editing, Investigation. **Luís Ferreira:** Writing – review & editing, Investigation. **Piotr Koleda:** Writing – review & editing, Investigation. **Sérgio Baptista:** Writing – review & editing, Investigation, Conceptualization. **Henrique Alexandrino:** Writing – review & editing, Investigation.

**Thiago Rodrigues Calderan:** Writing – review & editing, Investigation. **Vanessa Henriques Carvalho:** Writing – review & editing, Investigation, Conceptualization. **Vitor Favali Kruger:** Writing – review & editing, Investigation, Conceptualization. **Rodrigo Caselli Belem:** Writing – review & editing, Investigation. **Fernando López-Mozos:** Writing – review & editing, Investigation. **Carlos Yanez:** Writing – review & editing, Investigation, Conceptualization. **Jadranka Pavicic Saric:** Writing – review & editing, Investigation. **Gustavo Pereira Fraga:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Investigation, Conceptualization.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Author details

<sup>a</sup>Department of Anesthesiology, Intensive Care and Pain Medicine, Clinical Hospital Merkur, Zajceva 19, 10 000 Zagreb, Croatia <sup>b</sup>Lusitanian Association for Trauma and Emergency Surgery, Rua Fernando Pessoa, 7-1° 3000-170 Santo António dos Olivais, Coimbra, Portugal <sup>c</sup>Immediate Medical Care Unit, Saint James Hospital, George Borg Olivier St, Sliema SLM 1807, Malta <sup>d</sup>School of Medicine, University Vale do Rio Doce, Federal University Juiz de Fora, Rua José Lourenço Kelmer s/n, Bairro São Pedro, CEP: 36036-900 Juiz de Fora, Minas Gerais, Brazil <sup>e</sup>Department of Surgery, Hospital Dr. Nélio Mendonça, Av. Luís de Camões 6180, São Martinho, 9000-177 Funchal, Portugal <sup>f</sup>Department of Emergency Medicine, Jan Mikulicz-Radecki University Teaching Hospital, 213 Borowska St, 50-566 Wrocław, Poland <sup>g</sup>Department of Anesthesiology, Médio Tejo Hospital Center, Av. Maria de Lourdes de Mello e Castro, 2300-625 Tomar, Portugal <sup>h</sup>Faculty of Medicine, University of Coimbra, Edifício da FMUC, R/C dto., 3004-504 Coimbra, Portugal <sup>i</sup>Department of Surgery, Coimbra University Hospital Center, Praceta Professor Mota Pinto, Celas 3004-561 Coimbra, Portugal <sup>j</sup>Division of Trauma Surgery, Department of Surgery, School of Medical Sciences, University of Campinas (Unicamp), R. Tessália Vieira de Camargo, 126 Cidade Universitária, Campinas - SP, 13083-887, Brazil <sup>k</sup>Department of Anesthesiology, University of Campinas, Campinas, Brazil R. Tessália Vieira de Camargo, 126 Cidade Universitária, Campinas SP 13083-887, Brazil <sup>l</sup>Division of Trauma Surgery, Vera Cruz Hospital, 495 Rua Onze de Agosto, Campinas, Brazil <sup>m</sup>Emergency Department, Federal District Hospital de Base, SMHS - Área Especial, Q. 101 - Asa Sul, Brasília - DF, 70330-150, Brazil <sup>n</sup>Department of Digestive and General Surgery, University Hospital Valencia, 106, Avinguda de Fernando Abril Martorell, E-46026 Valencia, Spain <sup>o</sup>Mediclinic Parkview Hospital, Umm Suqeim St, Arjan-Dubailand, Al Barsha South, Dubai, United Arab Emirates

## REFERENCES

- Gallaher J, An SJ, Kayange L, Davis D, Charles A. Tri-modal distribution of trauma deaths in a resource-limited setting: perception versus reality. *World J Surg* 2023;47:1650–6.
- Søreide E, Morrison L, Hillman K, et al. Utstein formula for survival collaborators. The formula for survival in resuscitation. *Resuscitation* 2013;84:1487–93.
- Semeraro F, Greif R, Böttiger BW, et al. Systems saving lives. *Resuscitation* 2021;2021(161):80–97.
- Brohi K, Gruen RL, Holcomb JB. Why are bleeding trauma patients still dying?. *Intensive Care Med* 2019;45:709–11.
- Moran CG, Lecky F, Bouamra O, et al. Changing the system - major trauma patients and their outcomes in the NHS (England) 2008-17. *EClinicalMedicine* 2018;2:3:13–21.
- Thies KC, Deakin CD, Lott C, et al. The European trauma course—trauma teaching goes European. *Resuscitation* 2014;85:19–20.
- Fraga GP, Quintas ML, Abib SC. Trauma and emergency: is the unified health system (SUS) the solution in Brazil?. *Rev Col Bras Cir* 2014;41:232–3.
- Padilla Rojas LG, López Cervantes RE, Pérez Atanasio JM, Sánchez MM, Gómez Acevedo JM, Kojima KE. Latin America trauma systems-Mexico and Brazil. *OTA Int* 2023;2:e020.
- Carreiro PR, Drumond DA, Starling SV, Moritz M, Ladeira RM. Implementation of a trauma registry in a Brazilian public hospital: the first 1,000 patients. *Rev Col Bras Cir* 2014;41:251–5.
- Patel A, Vissoci JRN, Hocker M, Molina E, Gil NM, Staton C. Qualitative evaluation of trauma delays in road traffic injury patients in Maringá, Brazil. *BMC Health Serv Res* 2017;17:804.
- Gonsaga RA, Brugnolli ID, Fraga GP. Comparison between two mobile pre-hospital care services for trauma patients. *World J Emerg Surg* 2012;7:S6.
- Zachariasse JM, Seiger N, Rood PP, et al. Validity of the manchester triage system in emergency care: a prospective observational study. *PLoS One* 2017;12:e0170811.
- Lin YK, Chen KC, Wang JH, Lai PF. Simple triage and rapid treatment protocol for emergency department mass casualty incident victim triage. *Am J Emerg Med* 2022;53:99–103.
- Lipsky AM, Karsteadt LL, Gausche-Hill M, et al. A comparison of rural versus urban trauma care. *J Emerg Trauma Shock* 2014;7:41–6.
- Kinder F, Mehmood S, Hodgson H, Giannoudis P, Howard A. Barriers to Trauma Care in South and Central America: a systematic review. *Eur J Orthop Surg Traumatol* 2022;32:1163–77.
- Bhattarai HK, Bhusal S, Barone-Adesi F, Hubloue I. Prehospital emergency care in low- and middle-income countries: a systematic review. *Prehosp Disaster Med* 2023;38:495–512.
- Bitencourt MR, Iora P, Dutra AC, et al. Helicopter transportation of brazilian trauma patients: a comparison of times to care. *Air Med J* 2021;40:259–63.
- Caselli-Belem R, Lins RD. Trauma centers: a transformation needed to save lives. *JAC Resus* 2024;1:86–8.
- Juffermans NP, Gözden T, Brohi K, et al. Transforming research to improve therapies for trauma in the twenty-first century. *Crit Care* 2024;28:45.
- Ralaidovy AH, Adam T, Boucher P. Resource allocation for BIOMEDICAL research: analysis of investments by major Funders. *Health Res Policy Syst* 2020;18:20.
- Efron PA, Brakenridge SC, Mohr AM, et al. The persistent inflammation, immunosuppression, and catabolism syndrome 10 years later. *J Trauma Acute Care Surg* 2023;95:790–9.
- Lotfalla A, Halm J, Schepers T, Giannakopoulos G. Health-related quality of life after severe trauma and available PROMS: an updated review (part I). *Eur J Trauma Emerg Surg* 2023;49:747–61.

23. McElroy L, Robinson L, Battle C, et al. Use of a modified Delphi process to develop research priorities in major trauma. *Eur J Trauma Emerg Surg* 2022;48:1453–61.
24. Beeharry MW, Moqem K. The London major trauma network system: a literature review. *Cureus* 2020;12:e12000.
25. Malta DC, Morais Neto OL, Cardoso LSM, et al. Road traffic injuries and deaths and the achievement of UN sustainable development goals in Brazil: results from the global burden of disease study, 1990 to 2019. *Rev Soc Bras Med Trop* 2022;55:e0261.
26. Fraga GP, Augusto de Andrade V, Schwingel R, Neto JP, Starling SV, Rizoli S. The scientific production in trauma of an emerging country. *World J Emerg Surg* 2012;7:S13.
27. Coimbra R, Fraga GP, Starling SV. World trauma congress: when dreams come true. *World J Emerg Surg* 2012;7:S1.
28. Parreira JG, de Campos T, Perlingeiro JA, et al. Implementation of the trauma registry as a tool for quality improvement in trauma care in a Brazilian hospital: the first 12 months. *Rev Col Bras Cir* 2015;42:265–72.
29. Boeck MA, Blair KJ, Foianini E, et al. Implementation of a hospital-based trauma registry in santa cruz de la sierra, bolivia: methodology, preliminary results, and lessons learned. *Panam J Trauma Crit Care Emerg Surg* 2015;5:101–12.
30. Lulic I, Lulic D, Nasr ZA, Saric PJ, Nasr AO. Refining the continuum of resuscitation medicine practice in the Middle East and North Africa region. *JAC Resusc* 2024;1:3–6.
31. Røislien J. Saving lives with statistics. *Scand J Trauma Resusc Emerg Med* 2024;32:79.
32. Detchou D, Jenkins A, Barrie U. The creation of a global neurotrauma registry. *Neurosurg Rev* 2024;47:569.
33. Danford 3rd JR, Reyes Jr F, Gurney JM, Smith JP, Stinner DJ. Optimizing advanced trauma life support (ATLS) to maximize readiness. *Mil Med* 2024;189:e2206–10.
34. Alexandrino H, Baptista S, Vale L, et al. Improving intraoperative communication in trauma: the educational effect of the joint DSTC™-DATC™ courses. *World J Surg* 2020;44:1856–62.
35. Bergmans E, Billington A, Thies KC. From tradition to innovation: a comparison of the traditional 4-step approach versus a blended learning modification for technical skills teaching. *Scand J Trauma Resusc Emerg Med* 2023;31:80.
36. Farquharson B, Cortegiani A, Lauridsen KG, Yeung J, Greif R, Nabecker S. Education implementation team task force of the international liaison committee on resuscitation ILCOR. Teaching team competencies within resuscitation training: a systematic review. *Resusc Plus* 2024;19:100687.
37. Petroze RT, Byiringiro JC, Ntakiyiruta G, et al. Can focused trauma education initiatives reduce mortality or improve resource utilization in a low-resource setting?. *World J Surg* 2015;3:926–33.
38. James A, Tran V-T, Gauss T, et al. Important issues to severe trauma survivors: a qualitative study. *Ann Surg* 2022;275:189–95.
39. Hyder AA, Paichadze N, Toroyan T, Peden MM. Monitoring the decade of action for global road safety 2011–2020: an update. *Glob Public Health* 2017;12:1492–505.
40. Rocha R, Soares RR. Evaluating the impact of community-based health interventions: evidence from Brazil's Family Health Program. *Health Econ* 2010;19(Suppl):126–58.
41. Fraga GP, Carreiro PR, de Souza HP, Scarpelini S. Yellow may: an active campaign to prevent road traffic injury. *Rev Col Bras Cir* 2015;42:200–1.
42. Simões RL, Dorigatti AE, Silveira HJV, Calderan TRA, Rizoli S, Fraga GP. Trauma leagues-a novel option to attract medical students to a surgical career. *World J Surg* 2018;42:549–56.
43. Simões RL, Bicudo AM, Passeri SMRR, Calderan TRA, Rizoli S, Fraga GP. Can trauma leagues contribute to better cognitive performance and technical skills of medical students? The experience of the Unicamp trauma league. *Eur J Trauma Emerg Surg* 2023;49:1909–16.
44. Marttos AC, Kuchkarian FM, Abreu-Reis P, Pereira BM, Collet-Silva FS, Fraga GP. Enhancing trauma education worldwide through telemedicine. *World J Emerg Surg* 2012;7:S4.
45. Marttos AC, Kuchkarian FM, Rojas DF, et al. Global connections: telemedicine as a tool to extend trauma education. *Panam J Trauma Crit Care Emerg Surg* 2013;2:62–6.
46. Boet S, Bould MD, Fung L, et al. Transfer of learning and patient outcome in simulated crisis resource management: a systematic review. *Can J Anaesth* 2014;61:571–82.
47. Bento A, Ferreira L, Yáñez Benítez C, et al. Worldwide snapshot of trauma team structure and training: an international survey. *Eur J Trauma Emerg Surg* 2023;49:1771–81.
48. Fung L, Boet S, Bould MD, et al. Impact of crisis resource management simulation-based training for interprofessional and interdisciplinary teams: a systematic review. *J Interprof Care* 2015;29:433–44.
49. Schnaubelt S, Garg R, Atiq H, et al. Cardiopulmonary resuscitation in low-resource settings: a statement by the international liaison committee on resuscitation, supported by the AFEM, EUSEM, IFEM, and IFRC. *Lancet Glob. Health* 2023;11:e1444–53.
50. Nikouline A, Quirion A, Jung JJ, Nolan B. Errors in adult trauma resuscitation: a systematic review. *CJEM* 2021;23:537–46.
51. van Olden GD, Meeuwis JD, Bolhuis HW, Boxma H, Goris RJ. Clinical impact of advanced trauma life support. *Am J Emerg Med* 2004;22:522–5.
52. Dunn JA, Wiley A, McFann K, et al. Building capacity for ATLS trauma education: role of nurse practitioners and physician assistants. *Trauma Surg Acute Care Open* 2024;9:e001195.
53. Danford 3rd JR, Reyes Jr F, Gurney JM, Smith JP, Stinner DJ. Optimizing advanced trauma life support (ATLS®) to maximize readiness. *Mil Med* 2024;189:e2206–10.
54. McLaughlin C, Barry W, Barin E, et al. Multidisciplinary simulation-based team training for trauma resuscitation: a scoping review. *J Surg Educ* 2019;76:1669–80.
55. Tan ECTH, Rijnhout TWH, Rensink M, Alken APB, Bleeker CP, Bowyer MW. Self-assessment of skills by surgeons and anesthesiologists after a trauma surgery masterclass. *World J Surg* 2020;44:124–33.
56. Lulic I, Alhemeiri S, Bin Sulaiman A, Jaafer AS, Lulic D, Mustafa M. Critical emergency medicine trauma team simulation training programmes as a pathway towards secure access to early vital function expertise: a crisis of faith?. *EJA* 2019;57S:238.
57. Thies KC, Bergmans E, Billington A, et al. The European trauma course: transforming systems through training. *Resusc Plus* 2024;18:100599.
58. Lulic I, AlHemeiri S, Qayed K, et al. A journey of 'trauma is easy - trauma teams are hard' pendulum: an innovative pathway of horizontal team approach to trauma patient management. *Resuscitation* 2018;130S:e28–e145.
59. Nasr AO, Lulic I, Mustafa MT, Tilsed J, Lulic D, Thies K. Bringing critical emergency medicine, resuscitation and trauma education and training back to armed rivalry-affected community: why the conflict in Sudan matters?. *Eur J Trauma Emerg Surg* 2023;49:2633–5.